Report

The atmosphere of our Earth, of planets of our solar system and of exoplanets

Author(s):
Brüesch, Peter

Publication Date:
2016

Permanent Link:
https://doi.org/10.3929/ethz-a-010580544

The Atmosphere of our Earth, of Planets of our solar System and of Exoplanets

Peter Brüesch

There are more things in Heaven and Earth, Horatio, than are dreamed of in your Philosophy.

from «Hamlet»

by William Shakespeare

(1564 – 1616)

CONTENTS

Each Chapter contains an Appendix with complementary information.

A

Preface

My first Book has been dedicated to the subject of «WATER: Its Significance in Science, in Nature and Culture, in World Religions and in the Universe».

According to the old Greek Philosophers, everything consists of the four basic elements: Air, Water, Earth and Fire. This second Book is dedicated to the element «Air» or more generally to the «Atmosphere». Similar to water, air is indispensable for all human beeings. Water and air in the first place make life on our Planet possible.

In contrast to liquid and solid water (ice), the air of our Earth is invisible. The air layer of our planet is extremely thin compared with the radius of the Earth. Our Atmosphere consists of several gases. Without these gases we would be burned by the intensive heat of the Sun during the days, and during the nights we would freeze because of the very low temperatures.

Although we need air constantly for breathing, we take it for granted. As a consequence, average people are hardly interested about the properties and quality of air. Only if the air is strongly contaminated (by thick smog, by carbone dioxide (CO_2) etc. or by bad odour), the alarm bells are ringing. Clean air and clean water are indispensable for our life.

Several implications associated with «Global Warming» have been discussed in my first Book dedicated to «WATER» and are therefore not repeated in the present work.

I found it necessary to embed each of the different topics into the associated larger context. Only in this way is it possible to generate a well-rounded and meaningful representation.

My last and tenth Chapter contains a survey about the properties and atmospheres of the Planets of our solar system as well as of Planets outside the solar system – the so-called extrasolar Planets or Exoplanets.

With a view exceptions, the Book is written deliberately simple and should be easily comprehensible. Each Chapter contains a large list of References for complementary and more detailed information.

Peter Brüesch January 2016

B

Acknowledgements

My deep thanks go to the following friends and collegues:

I would like to thank the late Dr. Walter Schneider for many years of support: During a large period of time he sent me highly relevant information from Journals and Books about the present topics.

During many discussions with Mister Peter Etter, I learned a lot about Insects and I am indepted for his highly illustrating demonstration and explanations of his very interesting butterfly collection (Chapter 4, Section 4.2.2). In addition I would like to thank him for his information concerning the smallest insect of the world, the «Dicopomorpha Echmepterygis» (Chapter 4, Sect. 4.2.2, p. 127).

In addition, I would like to thank Dr. Dieter Kuse for his suggestion to include a discussion about «Polar Lights» and the «Kennely-Heaviside Layer» (Chapter 8, Sections 8.2 and 8.3).

I am also indepted to Professor Dr. Straumann for his information concerning relevant Literature about «Exoplanets» (Chapter 10, Sections 10.3 and 10.4).

Many thanks to Reto Stephan Grimm for providing me with interesting Literature concerning the present «Brake of Climate Change» as well as for information about «Exoplanets».

I am very thankful to Mister Kirkor Arsik for his valuable help related to Data handling and PC support.

Furthermore, I thank my daughters Elisabeth Schraner – Brüesch and Christine Brüesch for Books about Exoplanets from which I have learned a lot about the Atmosphere of Extrasolar Planets. Many thanks also to my granddaughter Angéline Da Silva for helping me correcting a few Chapters of my text.

Last but not least I would like to thank my dear wife for her interest and valuable suggestions as well as for her support and never ending patience during the elaboration of this work.

Peter Brüesch

C

Peter Brüesch : Scientific Career

1934	Born in Schuls (Scuol) – Graubünden – Switzerland
1948 – 1954	Academic high school in Chur, Switzerland
1954– 1960	Study of Experimental Physics at the ETHZ in Zürich
1960 – 1965	PhD at the Laboratory of „Physical Chemistry“ at the ETHZ
1965 – 1967	Postdoctoral Fellowship at the Chemistry Department , Oregon State University, USA
1967 – 2002	Scientific collaborator and Project Leader at the ABB Research Center – Switzerland Studies of „Solid State Physics“ , resulting in 72 publications in refereed Journals
1975	Nominated «Assistant Lecturer» at the Physics Department of the EPFL in Lausanne Lectures about «Phonons: Theory and Experients»
1987	Nominated „Professeur Titulaire“ at the Physics Department of the EPFL Lectures about «Phonons» and «The Physics of Water and Aequeous Solutions»
1982 – 1986	Author of a 3- Volume Book about the «Physics of Phonons» -Springer Series in Solid State Physics
1998 – 2000	Consultant at the ABB Research Center in the field of «Water Technology and Aqueous Solutions»
2000 – 2011	Studies and Research on „Water and Aequeous Solutions and its role in Nature“ - Since 1997: Lectures about „Solid State Physics“ and about „**Water**“ at the EPFL in Lausanne - 2002 – 2001**:** Elaboration of a comprehensive work about „Water“ : This formed the basis of the following extended Work in German and English: **„Wasser : Seine Bedeutung in der Wissenschaft, in der Natur und Kultur, in den Weltreligionen und im Universum“** **„Water : Its Significance in Science, in Nature and Culture, in World Religions and in the Universe“**
2011 - 2015:	«The Atmosphere of our Earth, of the Planets of our Solar Sysrem and of Exoplanets»

E-Mail : p.brueesch@bluewin.ch

D

General References

R.0.1 The Greek four classical elements

a) Classical elements
http://en.wikipedia/org/wiki/Classical_ele,emts
b) Elemental: The Four Elements
From Ancient Greek Science and Philosophy to Ancient Sites Poetry
http://www.webwinds.com/myth/elemental.htm

R.0.2 Vier_Elemente_Lehre
http://de.wikipedia.org/wiki/Vier:Elemente_Lehre

R.0.3 Feuer, Wasser, Erde, Luft
Horst Rademacher, Erwin Lausch, Dagmar Röhrlich, Wiebke Rögener
Wiley-VCH Verlag GmbH & Co. KGaA
1. Auflage (12. Mai 2003); ISBN-10: 3527404473

R.0.4 WATER: Its Significance in Science, in Nature and Culture,
in World Religions and in the Universe
Brüesch, Peter
Home – ETH E-Collection
e-Collection.ethbib.ethz.ch

R.0.5 Die Atmosphäre der Erde» (Eine Einführung in die Meteorologie)
Helmut Kraus
Verlag: Springer Berlin (2004); ISBN: 978-3-540-20656-9

R.0.6 Air: Our Planet's Ailing Atmosphere
Hans Tammemagi
Oxford University Press, April 2009; ISBN-10: 0195430077

E

R.0.7 An Introduction to Atmospheric Physics
David G. Andrews
Second Edition published 2010
Cambridge University Press ; ISBN 978-0-521-87220-1

R.0.8 Fundamentals of Atmospheric Physics
Murry L. Salby
Elsevier Science 1996
ISBN 0126151601, 9780126151602

R.0.9 Atmosphärenphysik
Niklaus Kämpfer: Institut für angewandte Physik, Univ. Bern
[PDF] Atmosphärenphysik; Frühlingssemester 2011
www.iapmw.unibe.ch/teaching/.../FS.../AT-phys_FS13_Kapitel1_2.pdf

R.0.10 Die Entdeckung der Stratosphäre – ein Ereignis der
Berliner Wissenschaftsgeschichte
Karl-Heinz Bernhardt
Sitzungsberichte der Leibniz – Sozietät 12 (1996) 4, pp 91 – 96
www.leibnizsozietaet.de/wp-content/uploads/2012/10/07_bernhardt_kh.pdf

R.0.11 Physik unserer Umwelt: Die Atmosphäre
buch.de; Erschienen bei Springer
3. überarbeitete und aktualisierte Auflage, 06-2000
Walter Roedel
ISBN-10: 3-540-67180-3 ; ISBN-13 : 978-3-540-671800-0

R.0.12 Thermal Physics of the Atmosphere
Maarten H.P. Ambaum
ISBN: 978-0-470-74515-1
John Wijey & Sons , April 2010

F

R.0.13 Lectures in Atmospheric Physics , 2010
Björn-Martin Sinnhuber
University of Bremen - Master of Environmental Physics
www.iup.uni-bremen.de(.../lecture.../AtmosphericPhysics-09_01.pdf

R.0.14 Atmospheric Physics
[PDF] Lecture Notes - Assoc. Prof. Dr. Aysegül Yilmaz (2006)
Canakkale Onsekiz Mart University
www.nu.edu.sa/userfiles/semohammad/atmosphere.pdf

R.0.15 Wetter & Klima
Vorhersagen – Wetterphänomene – Klimaänderung – Meteorologie
DORLYNG KINDERSIAY – DK

G

Contents

H

I

J

M

N

O

P

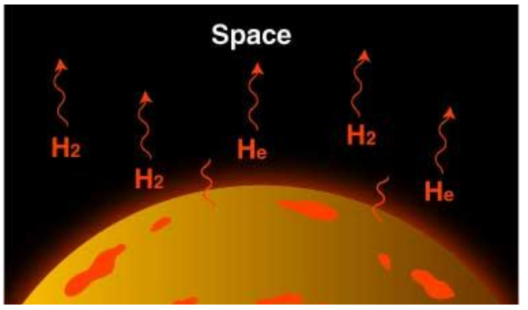
1. P r o l o g u e

The Atmosphere and the Air of our Planet

1

1.1 Formation of the Earth's Atmosphere

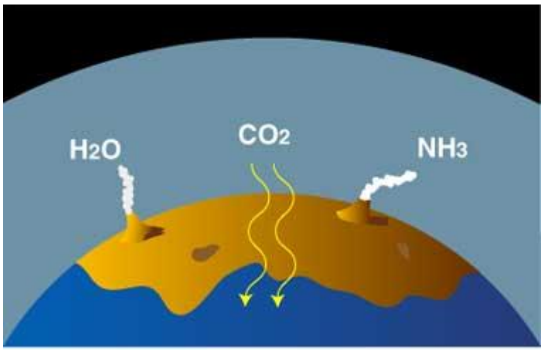
The Atmosphere in its primitive state



Our Earth has been formed about 4.5 Milliards of years ago. Already the early Earth had an Atmosphere consisting of (H_2) and Helium (He), as well as on small concentrations of Methane (CH_4), Ammonia (NH_3) and of some Rare Gases (the Figure shows only H_2 and He). Because of the small gravitational force and due to the fast rotation of the Earth, these molecules have been attracted only weakly to the Earth and many molecules have been lost into Space. The loss of the early Atmosphere was also due to the heat producing gravitational contraction of the Earth, the decay of heat-creating radio-nucleids as well as to the impacts of Meteorites and Asteroides. Because of the high temperature which has further been increased by nuclear fusion in the Sun, as well as due to the extremely intense solar winds, the last remnants of the atmosphere have been removed.

2

Atmosphere of the young Earth



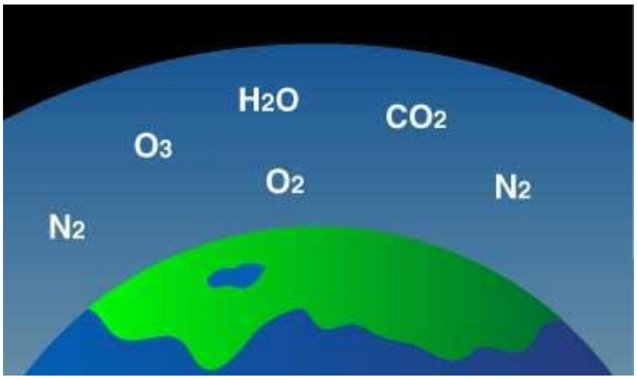
The young Earth: Water vapor (H_2O), Carbon dioxide (CO_2) and Ammonia (NH_3) has been released by active volcanoes. CO_2 was dissolved in sea water. Simple bacteria have been created with the help of sunlight and CO_2. and as a byproduct, molecular oxygen (O_2) was formed.

This second Atmosphere originated from the Earth itself. At that time, a very large number of volcaneous existed, much more than in the present time. This volcanism was a consequence of the formation of a crust of the Earth. From the volcaneous, the following gases have been ejected:

a) Water vapor (H_2O - molecules)
b) Carbon dioxide (CO_2) → dissoved in sea water
c) Ammonia (NH_3) from the volcaneous into the Atmosphere

3

Present Atmosphere of the Earth



Present Earth: Plants and animals developed together in equilibrium. Plants are breathing carbon dioxide (CO_2) and exhale oxygen (O_2) (see Photosynthesis, Chapterl 6).

In the Oceans, al large quantity of CO_2 is dissolved. During a large period of time, simple bacteria have been developed. These bacteria are living from CO_2 and sunlight. As a byproduct, these bacteria generated oxygen (O_2). This led to an enrichement of O_2 and a corresponding decrease of the CO_2 concentration in the Atmosphere. At the same time, Ammonia (NH_3) was decomposed by sunlight, whereby molecular nitrogen (N_2) and molecular hyddrgen (H_2) has been formed. The light H_2 – molecules ascended to the highest layers of our atmosphere and eventually diffused out into the free space of the Universe.

4

1.2 Atmosphere and Air

Atmosphere

The Atmosphere of the Earth is a gaseous layer which surrounds our Planet. These gases are attracted by the gravitational force of the Earth. The Atmosphere protects life on our Planet by absorbing the UV- radiation of the Sun, by protecting the Earth's surface from overheating (natural Greenhouse effct), and by reducing extreme temperature changes between days and nights.

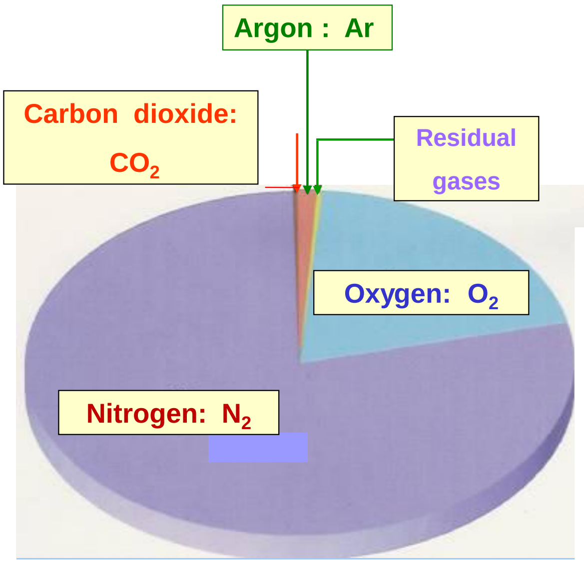
The Atmosphere has different layers which can be distinguished by their different temperatures and compositions. The Atmosphere has a mass of about 5.15 x 10^{18} kg, and about three quarters of this mass is present within the first 11 km from the surface of the Earth (p. 10). With increasing altitude, the density of the Atmosphere decreases continuously (p. 1-A-3-1) but there is no definite boundary between the Atmosphere and outer space. The Kàrmán line, at 100 km, is often regarded as the boundary between Atmosphere and outer space.

Air

Air is the name given to the Atmosphere used in breathing and photosynthesis. Dry air contains roughly (by volume) 78.09 % nitrogen, 20.95 % oxygen, 0.93 % argon, 0.039 % carbon dioxide, and small amounts of other gases (s. p. 6). Natural air also contains a variable amount of water vapor, on average around 1 %.
While the air content and atmospheric pressure vary at different layers, air suitable for the survival of terrestrial plants and terrestrial animals is currently only known to be found in Earth's Troposphere (pp 7,9,10). In addition, air can also produced in artificial atmospheres.

5

Composition of the dry (water-free) Atmosphere [in Vol. % and in parts per million (ppm)]



N_2 : 78.084 % (780 840 ppm)

O_2 : 20.946 % (209 460 ppm)

Ar : 0.934 % (9 340 ppm)

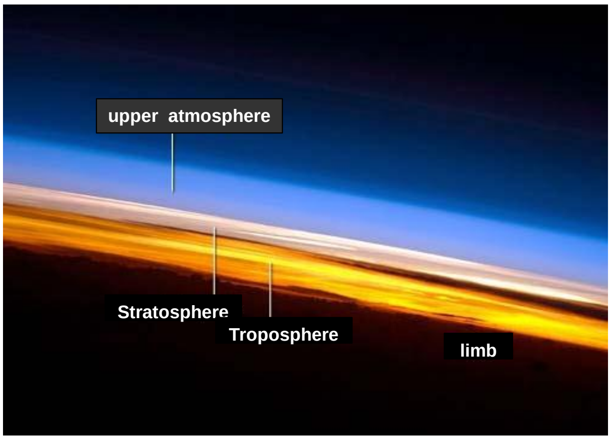
CO_2 : 0.036 % (360 ppm)

Residual gases:
Methane (CH_4) : 1.5 ppm
Nitrogen-oxide (Laughing gas): N_2O
Nobel gases, H_2

(Composition of the Troposphere: s. p. 16)

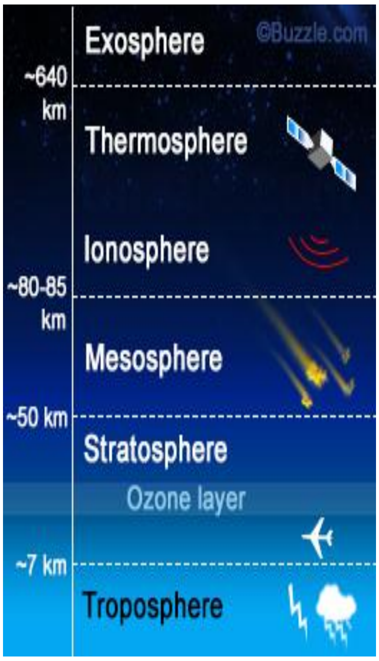
6

Layers of the Atmosphere



Spectacular view of Earth's Atmosphere

A brilliant sequence of colors in the image denotes each of the layers of Earth's Atmosphere, which are visible here because the picture was taken why the «International Space Station» had an edge-on view (Kantenansicht), or limb, view on the Earth. From this vantage point (Blickwinkel), the Earth's curvature can also be made out.



The 6 layers of the Atmosphere

7

All the Air on Earth

All the Air on Earth:
Sphere with a radius of R ≈ 1000 km

At techn. Normal Conditions:
(20 ºC, 1 atm) this corresponds to a mass of about 5.2 * 10^{18} kg.

At normal pressure, the height of the total Atmosphere would only be 7.8 km.

→ The Air layer is very thin:
Troposphere + Stratosphere together: only about 50 km

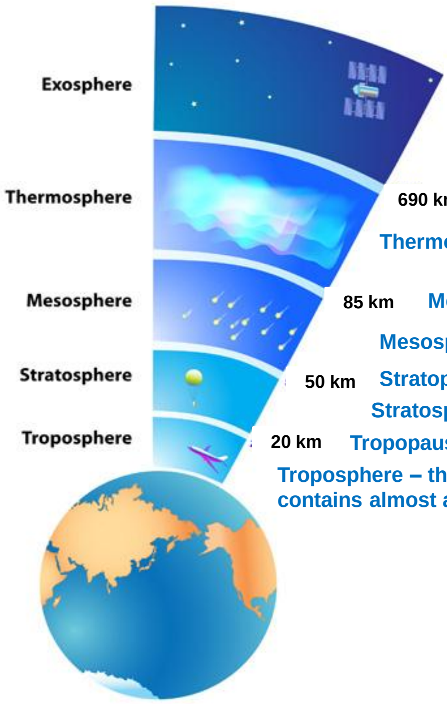
Air layer = protection layer:
stores the heat radiated from the Earth in the Infrared.
→ Pullover effect !

Without the air layer, the global temperature would be about – 15 to – 18 ºC !

→ No liquid water on our Planet: only Ice !

8

1.3 The Layers of our Atmosphere



Exosphere – outermost layer of the atmosphere

Thermopause – boundary: Thermosphere/Exosphere

Thermosphere – extremely small concentration of molecules

Mesopause- boundary: Mesosphere /Thermosphere

Mesosphere - burn out of most meteos

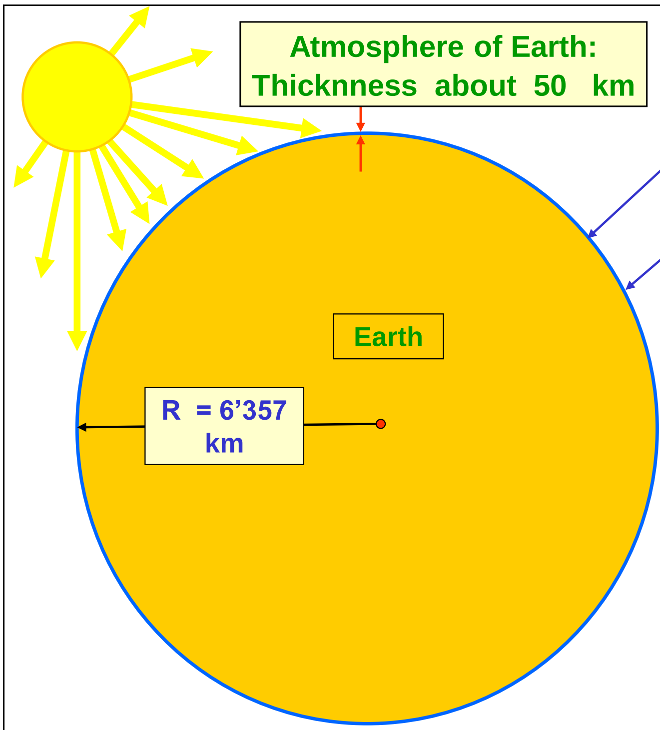
Stratopause – boundary: Stratosphere / Mesosphere

Stratosphere - contains the ozone layer

Tropopause – boundary: Troposphere /Stratosphere

Troposphere – the layer closest to the Earth's surface:
contains almost all of the air - wheather zone

9



- Troposphere: 0 to about 11 km altitude;
- Stratosphere: 11 to about 50 km altitude;
- Mesosphere

Very thin protective layer ! Contains more than 99 % of the mass of terrestrial Atmosphere.

Protective layer stores the heat radiated from the Earth – Radiation in the Infrared → Pullover !

Without protective layer, the global temperature would be – 15 to – 18 ^{0}C

In this case, liquid water would not exist on Earth !

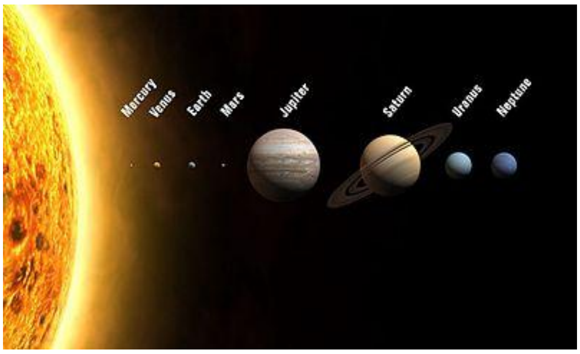
10

1.4 Atmospheres of other Planets

While Chapters 1 to 9 are dedicated to the Atmosphere of our Earth, Chapter 10 will contain a discussion of the Atmospheres of Planets of our Solar System as well as of Atmospheres of Exoplanets, i.e. of Planets outside our Solar System.

The Universe contains approximately 100 to 200 billions of Galaxies, and each Galaxy, such as our Milky Way Galaxy, contains again 100 to 200 billions of Stars and many of these Stars are orbited by many Planets.

The structure and Atmospheres of the Planets of our solar system are known to a great extent. Therefore, today and in future, Exoplanets in our Milky-Way Galaxy are studied extensively. The studies are dedicated to the search of Earth-like Planets in which life or even intelligent live exists. In other words: Scientists are trying to find a «Second Earth».



Our solar system

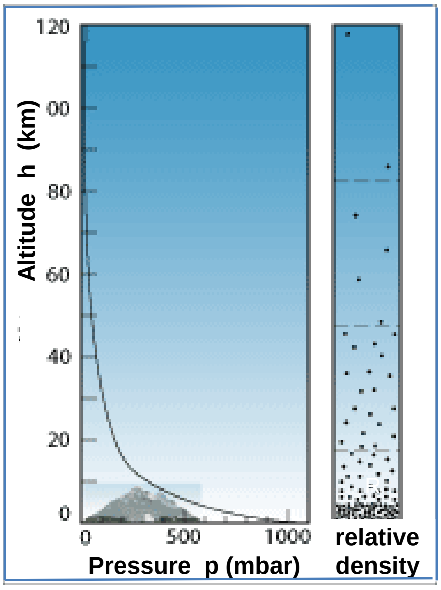
The Milky-Way Galaxy

11

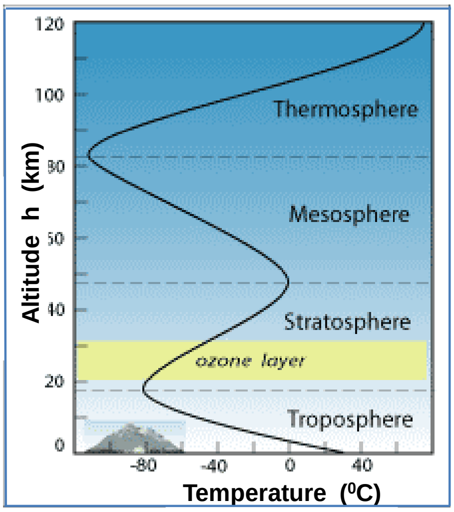
Appendix – Chapter 1

A-1-0

Pressure, relative Density and Temperature as a function of altitude



h(p) according to barometric height formula



Note the complex temperature variation as a function of altitude

1-A-3-1

References: Chapter 1

R-1-0

References : Prologue

1.1 Formation of Earth's Atmosphere, Asterorides, Meteorites, Comets - Solar Wind

R.1.1.1 p. 2: [PDF] TODAY – Asteroids, Meteorites, Comets …
www.astro.umd.edu/~miller/ASTR100/class13.pdf

R.1.1.2 p. 2: ASZEROID WATCH
Asteroids, Comets, Meteorites
http://www.jpl.nasa.gov/asteroidswatch/asteroids_comets.cfm

R.1.1.3 p. 2: Was ist der Unterschied zwischen einem Asteroiden , Kometen und Meteoriten ?
http://www.astronews.com/frage&antworten/1frage1783.html

R.1.1.4 p. 2: The Solar Wind
http://solarscience.msfc.nasa.gov/SolarWind.shtml

R.1.1.5 p. 2: Sonnenwind
www.http://de.wikipedia.org.wiki/Sonnenlicht

R.1.1.6 pp 2 – 4: How did the Earth's Atmosphere form ?
http://scijinks.nasa.gov/atmosphere-formation

R.1.1.7 pp. 2 – 4: Erdatmosphäre
http://www.reinis-welten,de/weltgeschichte.dieerde/erdatmosphaere/index.html

R.1.1.8 pp 2 – 4: History of the Earth
http://en.wikipedia.org/wiki/Histoty_of_the_Earth

R-1-1

1.2 Atmosphere and Air

R.1.2.1 p. 5: Atmosphere of Earth
www.http://en.wikipedia.org/wiki/Atmosphere_of_Earth

R.1.2.2 p. 6 : «Origin of the Earth's Atmosphere»
http://www.ux1.eiu/~cfjps/1400/atmos_origin.html
Figure textsL P . Brüesch

R.1.2.3 p. 7: Levels of the Atmosphere

a) Left hand picture: ISS crew captures spectacular view of Earth's Atmosphere
http://www.instantfundas.com/2010/06/iss-crew.captures-spectacular-view-of.html
b) Right hand picture Layers of the Earth's Atmosphere
http://www.buzzle.com/articless/layers-of-the-earths-atmosphere.html

R.1.2.4 p. 8: All the Air on the Earth

a) All the water and air on earth gathering into spheres and compared to the Earth
http://boingboing.net/2008/03/11/all.the-water-and_air.htm
b) Next Nature
http://www.nextnature.net/2008/03/all-the-water-and-air-on-eaeth/
c) Wasser und Luft der Erde : Alle Luft der Erde
Adam Nieman:
http://www.adamniemann,co,uk/vos/index.htnl

R-1-2

1.3 The Layers of our Atmosphere

R.1.3.1 p. 9: Layers of the Atmosphere
http://ete.cet.edu/edu/?/volcanoes/layers/

R.1.3.2 p. 10: Comparision of Air-layer thickness with Earth's Radius
Figure and Text from P. Brüesch with information from different Literature sources

1.4 Atmospheres of other Planets

R.1.4.1 p. 11: Atmosphären des Sonnensystems und Exoplaneten

a) Planetary system
http://en.wikipedia.otg/wiki/PPlanetary_system
Left hand picture: Our solar system
b) Solar System
http://en.wikipeia/org/wik/Soalr:System
c) Sonnensystem
http://de.wikipedia/wiki/Sonnensystem

R.1.4.2 a) Milky-Way
http://en/wikipedia.org/wiki/Mylky_Way
b) Right hand picture: The Milky-Way Galaxy
in: http://www-simone-bahia.de/astronomie/milchsreasse.html

Appendix

1.A.3.1 Pressure, Composition and Temperature of Earth^s Atmosphere
Earth's Atmosphere_ Composition and Structure
- www.visionlearning.com/.../library/Earth-Science/
[contains all 3 Figures: Pressure p(h) / relative Density ρ(h) and Temperature T(h)]
Left hand Figure: p(h) corresponding to simple narometric height formula, (strongly idealized)
Right hand Figure: p(h) corresponds to realixtic pressure variation
- Pressure and density of the Atmosphere as a function of altitude
s. p. 54, Chapter 2

R-1-3

2. Physics and Chemistry of the Atmosphere

12

2.1 Overview and Content

13

Content of Chapter 2

In this Chapter a survey about the physical and chemical properties of air and the global Atmosphere is given.

In Section 2.2 we discuss the most important molecules and atoms of the dry Atmosphere: molecular nitrogen (N_2), oxygen (O_2), ozone (O_3), atomic Argon (Ar) as well as very small amounts of trace gases, for example Carbon dioxide (CO_2).

The most important properties of the Troposphere are discussed in Section 2.3: General properties, water vapor, clouds, winds and barometric height formula.

Section 2.4 is dedicated to the Stratosphere: General properties, temperature profile as well as properties and function of ozone.

In Section 2.5 we are concerned with the Mesosphere: General characteristics, temperature profile and CO_2 – concentration .

In Section 2.6 the most important properties of the Thermosphere are discussed: H_2 - molecules and He – atoms – radiation temperature.

In Section 2.7 we discuss the outermost layer, the so-called Exosphere. In the Exosphere the concentration of the particles is negligibly small and the particles are almost completely ionized. The radiation temperature changes strongly between day and night.

14

2.2 Average Composition of the dry Atmosphere

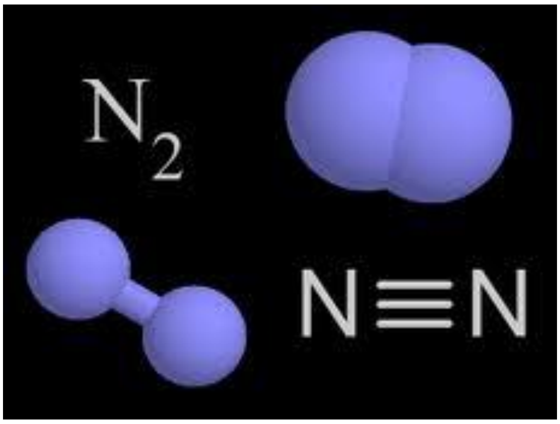
15

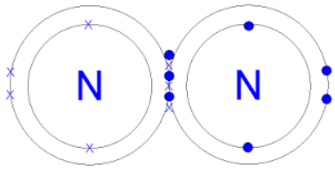
Average composition of dry Air in the Troposphere (s. A-2-1)

Principle constituents	Volume (%)	Volume (ppm	Masse (%)
Nitrogen (N_2)	78.084	780’840	75.518
Oxygen (O_2)	20.942	209’420	23.135
Argon (Ar)	0.934	9’340	1.287
Sub - total	99.960 %	999’600 ppm	99.940 %
Trace gases			
Carbon dioxide (CO_2)	$380.00*10^{-4}$	380	$580.000*10^{-4}$
Neon (Ne)	$18.18*10^{-4}$	18.18	$12.670*10^{-4}$
Helium (He)	$5.24*10^{-4}$	5.240	$0.720*10^{-4}$
Methane (CH_4)	$1.76*10^{-4}$	1.760	$0.970*10^{-4}$
Krypton (Kr)	$1.14*10^{-4}$	1.140	$3.300*10^{-4}$
Xenon (Xe)	$0.09*10^{-4}$	0.087	$0.400*10^{-4}$
Hydrogen (H_2)	~ $0.50*10^{-4}$	~ 0.5	~ $0.036*10^{-4}$
Nitrous oxide (N_2O)	$0.31*10^{-4}$	0.317	$0.480*10^{-4}$
Carbon monoxide (CO)	~ $0.2*10^{-4}$	~0.2	~ $0.100*10^{-4}$
Sub - total	~ 0.040 %	~ 400 ppm	~ 0.060 %

16

The Nitrogen molecule N_2





In a triple bond, 2 atoms share 3 pairs of electrons (6 electrons).

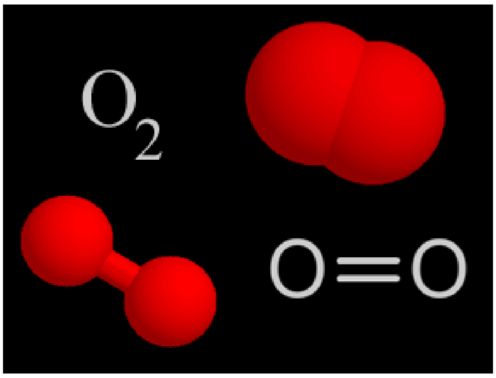
Elemental gaseous nitrogen is present only in the form of diatomic molecules. (molecular nitrogen); its molecular formula is N_2. Molecular nitrogen is the principal constituent in air. Air contains 78 Volume % of nitrogen gas.

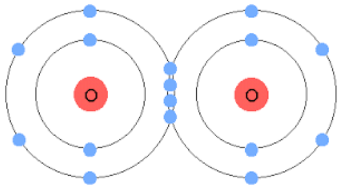
Molecular nitrogen is a colourless, odourless and tasteless gas.

The two N atoms of the N_2 molecule are bound by a stable triple bond (see Figure), and the molecule is very inert, i.e. it does hardly participate in chemical reactions. The associated high dissociation energy for the reaction $N_2 \rightarrow N + N$ is 942 kJ/mol (1 mol of nitrogen gas contains $6.023 \cdot 10^{23}$ N_2 molecules).

17

The oxygen molecule O_2





In a double bond, 2 atoms share 2 pairs of electrons (4 electrons).

Elemental oxygen is a chemical compound containig two oxygen atoms, i.e. its molecular formula is O_2. The two O- atoms of O_2 are bound by a stable covalent double bond.

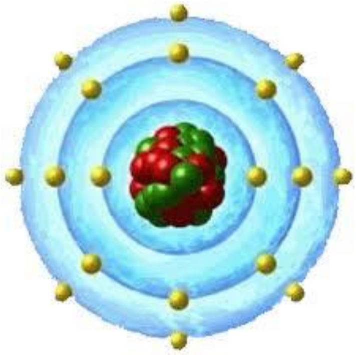
Molecular oxygen is a colourless and odourless gas. Air contains abot 20.9% O_2 and about 78% N_2.

Nearly all living beings need oxygen for breathing.

In contrast to nitrogen, oxygen is a highly reactive gas. But because of the chemical inactivity of nitrogen, N_2 does usually not react with O_2 in the atmosphere; reactions are only possible in very special cases, for instance in the case of a lightning.

18

The Argon atom Ar



Left-hand: A schematic representation of the shell of the Argon– atom

Right-hand: Argon atom with nucleus and shell; Atomic weight = 40

Concentration in Air: 0.9340 %; corresponds to 934 ml per 100 litres of Air.

Argon is the third most abondend element in Earth's Atmosphere (s. p. 16). The reason for the high abundance of Ar is due to the fact, that Ar results by the decay of ^{40}K, the abundance of which is 2.6% in the Earth's crust. It then has been transported into the Atmosphere by volcanic activities.

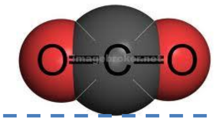
Decay reaction: $^{40}K_{19} \rightarrow {}^{40}Ar_{18}$ + 1 positron; half-life time = 11.93 Gyr ($^{40}Ar_{18}$: mass number of Ar = 40, proton number Z = 18; positron = antiparticle of the elektron); (1 Gyr = 1 Giga-year = 10^9 years).

19

Trace gases in the Air - 1 (s. p.16)

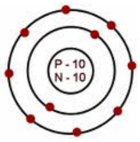
Molecule / Atom

CO_2



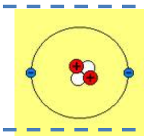
- Density at STP: 1.98 kg/m^3 ; in Air: 380 ppm (s. p. 16)
- Linear moleculel → non-polar , i.e. Dipol moment = 0
- C = O double bonds
- Relative high solubility in H_2O (1700 mg/L at NC)

Ne



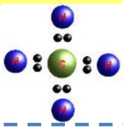
- Noble gas with 8 electrons in the outermost shell
- 2 electrons in the inner shell → a total of 10 electrons
- Number of protons (P) = number of neutrons (N) = 10
- Neon (Ne) is colourless and odourless
- Escapes from the Atmosphere into free space

He



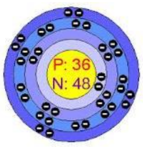
- Nobel gas with 2 electrons in the outermost shell
- Number of protons (P) = number of neutrons (N) = 2
- Helium (He) is colourless and odorless and nontoxic
- Escapes from the Atmosphere into free space

Methane: CH_4



- The nucleus of C has 6 protons and 6 neutrons
- The carbon atom C has 2 electrons in the inner shell and 4 electrons in the outer shell.
- In CH_4 there are 4 covalent C-H bonds.

Krypton Kr

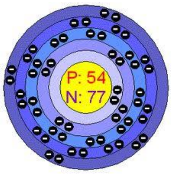


- Krypton is a Nobel gas with P = 36 and N = 48
- the 1. shell contains 2 electrons
- the 2. shell contains 8 electrons
- the 3. shell contains 18 electrons
- the 4. shell containst 8 electrons
- Total : 36 electrons

20

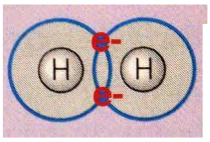
Trace gases in the Air (s. p. 16)

Xenon (Xe)



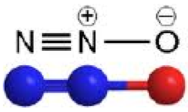
- colourless, odourless and inert noble gas;
- atomic number Z = 54; neutrons: N = 77; A = Z + N = 131;
- density ρ = 5.8982 kg/m^3 at 273.15 K and 1 atm = 1013 hPa; Xenon is heavier than air;
- in Air: about 0.09 ppm

H_2



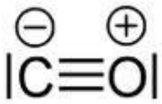
- two protons and 2 electrons
- covalent bond
- diatomic gas
- in Atmosphere: very small concentration (s. p. 16)

N_2O



- Nitrous oxide: colourless gas (laughing gas)
- laughing gas: respiration can cause euphory
- N_2O is a greenhous gas (6% are anthropogenic)
- N_2O contributes to the depletion of the O_3 layer (s. p. 22)

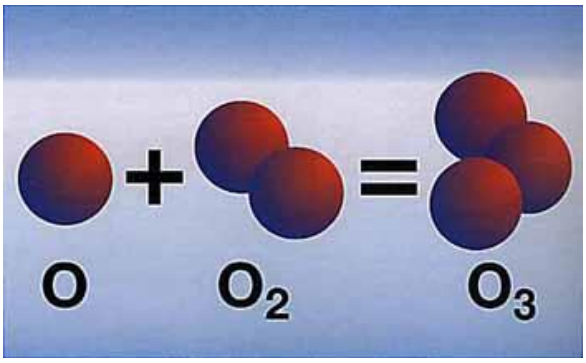
CO



- CO : colourless, odourless and tasteless
- very poisonous → dangereous for breathing
- CO is combustible
- doubling of the CO- concentration since pre-industrial times
- increase of troposheric CO
- contribution to glpbal warming

21

Ozone: Formation and Properties



Ozone (O_3) is formed from the dioxide O_2 and a oxygen atom O. The oxygen atom O is formed from O_3 by the action of ultraviolet light (UV) but also by atmospheric electrical discharges. O_3 is present in low concentrations troughout the Earth's atmosphere. In total, ozone makes up only 0.6 ppm of the atmosphere.

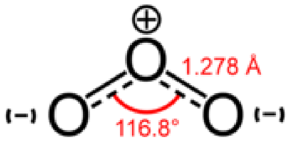
Ozone is a pale blue gas with a distinctively pungent smell. It is an allotrope of oxygen O_2. The term allotrope refers to one or more forms of an elemetary substance. The allotropes of oxygen are O, O_2 and O_3.

Ozone is not a very stable molecule: it decomposes in a short time into normal oxygen. This instability is due to its high reactivity and agressivity with other compounds.

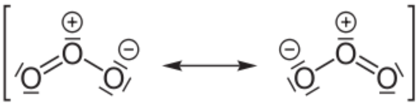
22

Some properties of the Ozone molecule

The molecular structure of the polar molecule is bent and the dipole moment is 0.5337 D. The O-O distance is 127.8 pm (= 1.278 Å = 0.1278 nm). The angle between the 3 oxygen atoms is 116.8°.
[1 D = 1 Debye = $3.338 \cdot 10^{-30}$ Cm (1 C = 1 Coulomb)]



The actual structure of the ozone molecule is the «average» of two resonance structures. This means that the bonding can be expressed as a resonance hybbrid with a single bond on one side and a double bond on the other, producing an average bond order of 1.5 for each side.



Resonance structure of the ozone molecule

Formation: $3\ O_2 \rightarrow 2\ O_3$; $\Delta H = +286$ kJ

In the atmosphere, O_3 is produced by the following three mechanisms:

a) Dissociation of O_2–molecules into O- atoms by solar UV-radiation. The O- atoms recombine with O_2- molecules to form O_3- molecules in the Stratosphere.
b) Low level ozone (i.e. close to Earth's surface) is produced by reaction of nitrous oxides (i.e. NO_2) with O_2 under the influence of UV radiation.
c) From thunderstorms: The electric current existing between clouds and Earth's surface from lightnings can produce O_3.

23

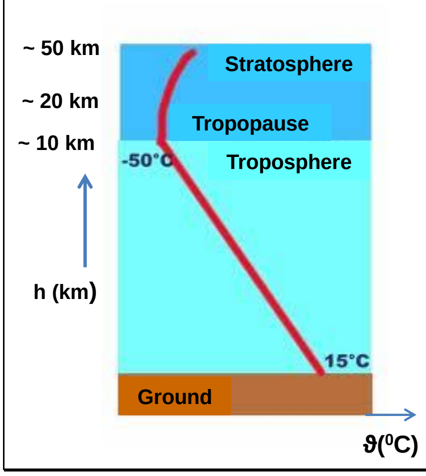
2.3 The Troposphere

24

2.3.1 General Properties - 1

The Troposphere is the layer of our Atmosphere which is closest to the Earth (s. pp 9 and 11). It contains the air around us, from the ground up to the highest clouds.

The thickness of the Troposphere is about 10 km at the Poles, and about 18 km at the Aequator. The Troposphere contains about 90% of the total air. Since a large part of the weather takes place in this layer, the Troposphere is also called the weather layer. The reason it is warmer at the surface is simple: The air is warmed up by heat given off by the Earth.



The farther away from the surface the air moves, the less heat there is to be absorbed. The temperature of the atmosphere at h = 10 km is about - 50 °C. (In the Figure, the scale of h is non-linear).

From 10 to 20 km the temperature of the atmosphere is stable. This region is called the Tropopause. The Stratosphere extends from 20 to about 50 km. In this region, the air actually warms with height! Ozon is concentrated in this part of the Atmosphere and it absorbs ultrviolet (UV) light from the Sun. More light is absorbed at higher altitudes compared to the lower stratosphere, so the temperature increases again.

25

General Properties - 2

The Troposphere is warmed up only to a small extent by solar radiation. The large part of warming originates from the surface of the Earth. For this reason, the temperature of the air decreases by about 6.5 ^{0}C per km height. This decrease is known as the vertical atmospheric temperature gradient. In dry-adiabatic areas (cloud-free areas of the sky) it amounts to about 1 ^{0}C per 100 m, while in humid areas of the atmosphere (areas covered by clouds and fog) this decrease is about 0.6 ^{0}C per 100 m. In the Tropopause (s. pp 9 and 26), the temperature is about -75 ^{0}C at the Equator and about - 45 ^{0}C at the Poles.

An Inversion layer is a layer in which the atmospheric temperature is inverted, i.e. its change is deviated from the normal pattern. A very stable inversion is formed at the Tropopause and is explaind by the fact, that for an altitude between 10 and 15 km the concentration of ozone starts to increase slowly. Ozone (O_3) is a very strong UV-absorber of the Sun light. This causes a temperature increase, oposit to the general trend of the temperature decrease with increasing altitude (s. Figure at p. 25).

The chemical composition of the dry Troposphere (N_2, O_2, Ar, .., s. p. 16) is essentially steady. But this is not the case for water vapour and clouds. The water content of the Troposphere depends usually very strongly on the location and altitude (s. Chapter 3).

Pressure and density of the atmosphere are largest at sea level and decrease strongly with increasing altitude (s. p. 54). In a first approximation the decrease of pressure with increasing altitude can be described by the barometric height formula (s. pp 27 – 29).

It should be noted that nearly the whole weather activity of our Planet takes place in the Troposphere.

Barometric height formula - 1

The barometric height formula describes the vertical distrubution of the (gas-) particles in the Earth's atmosphere, i.e. the relation hetween the air pressure p and altitude h. The result is a vertical pressure-gradient, but due the wheather dynamics present in the lower atmosphere, the function p(h) of the barometric height formula is only a first approximation of the actual more complicated situation.

The air pressure at sea level is 1 bar = 10^5 Pascal = 10^5 Pa = 10^3 hPa; 1 hPa = 100 Pa. In the simplest approximation it can be assumed, that the air pressure at sea level and 0 ^{0}C decreses by Δp = - 1 hPa per Δh = 8 m height: $\Delta p / \Delta h$ = - 1 hPa/ 8 m = - 12.5 Pa / m. This pressure corresponds to about 1 ‰ of the pressure p(0) = 10^3 hPa at sea level.

In the <u>isothermal barometric height formula</u>, the temperature T is assumed to be constant, independent on altitude h (isothermal atmosphere). Let h_0 and $h > h_0$ be two altitudes above sea level and $p(h_0)$ and p(h) the corresponding presures. In this case, the barometric height formula reads:

$$p(h) = p(h_0) * \exp(- \Delta h / h_S) ; \qquad \text{where the height difference is} \qquad (1)$$

$$\Delta h = h - h_0 ; \text{ (at sea level } h_0 = 0). \quad h_s \text{ is the so-called } \underline{\text{scale height}}: h_S = R*T / M*g \qquad (2)$$

R is the universal gas constant (R = 8.314 J/(mol K)) and M = 28.9644*10^{-3} kg/mol is the molar mass of air. For 300 K (27 ^{o}C). h_S = 8779 m, for T= 288 K (~ 15 ^{0}C), h_S = 8437 m und for T = 273 K (0 ^{o}C), h_S = 7989 m. For the Troposphere, h < 12 and hence g(h) ≈ g(0).
The density ρ is obtained from the ideal gas law pV = RT und ρ = M/V and one obtains

$$\rho(h) = \rho(h_0) * \exp(-\Delta h / h_s) . \qquad (3)$$

Barometric height formula - 2

Atmosphere with linear temperature debendence

For the derivation of the formulae 1 tp 3 it has been assumed that the temperature T is independent on alitude h. However, the Figures at p. 1-A-3-1 and p. 25 show, that in the Troposphere the temperature decreases with increasin altitude. [For the time beeing we disregared inversions, i.e. possible temperature increases with increasing altidutes]. In a first approximation we assume a linear dependence for T(h), namely

$$T(h) = T(h_0) - a*(h - h_0) \; ; \qquad (4)$$

where a is a positive constant. By substituting eq. (4) into the basic barometric equation, namely dp/p = - [M g/R*T(h)], integration over the height h gives the following result (s. Ref. R.2.3.18):

$$p(h) = p(h_0) * [1 - (a\,\Delta h/T(h_0)]^{(Mg / R\,a)} \quad \text{where} \quad \Delta h = h - h_0 \qquad (5)$$

For the density ρ(h) it follows:

$$\rho(h) = \rho(h_0) * [1 - (a\,\Delta h/T(h_0)]^{(Mg / R\,a) - 1} \qquad (6)$$

Note that in eq. (6) the exponent is reduced by 1. It is easy to show that a combiniation of eqs. (4), (5) and (6) gives the following relation between densities and pressures:

$$\rho(h) = \rho(h_0)* [T(h_0)/T(h)]*[p)h)/p(h_0)] \qquad (7)$$

Barometric height formula - 3

Measurements of the temperature profile in the Troposphere show, that the assumption of a linear temperature decrease is in general a good approximation, even if in some cases distinct deviations are observed, for instance if inversion layers are present (*).

The principle reason for the temperature decrease with increasing altitude is the warming of the lower air layers as a consequence of the heating of the Earth's surface, while the upper air layers are radiating heat into space. In the average over all weather conditions, the temperature gradiant is 0.65 K per 100 m, and from eq. (4) the temperature decrease is equal to a = ΔT/Δh = 0.65 K/100 m = 0.0065 K/m. [Remember that these numbers are valid for the Troposhere only]. In the Stratosphere, the temperature decreases distinctly slower. In most cases, it even increases again with increasing height. This is due to the absorption of UV-radiation by the ozone layer (s. pp 9, 1-A-3-1, 37 - 42).
For a temperature gradient of a = 0.0065 K/m, the value of the exponent M*T/R*a in eq. (5), p. 28 is 5.255, i.e. one obtains

$$p(h) = p(h_0)* [1 - 0.0065*\Delta h / T(h_0)]^{5.255} \qquad (8)$$

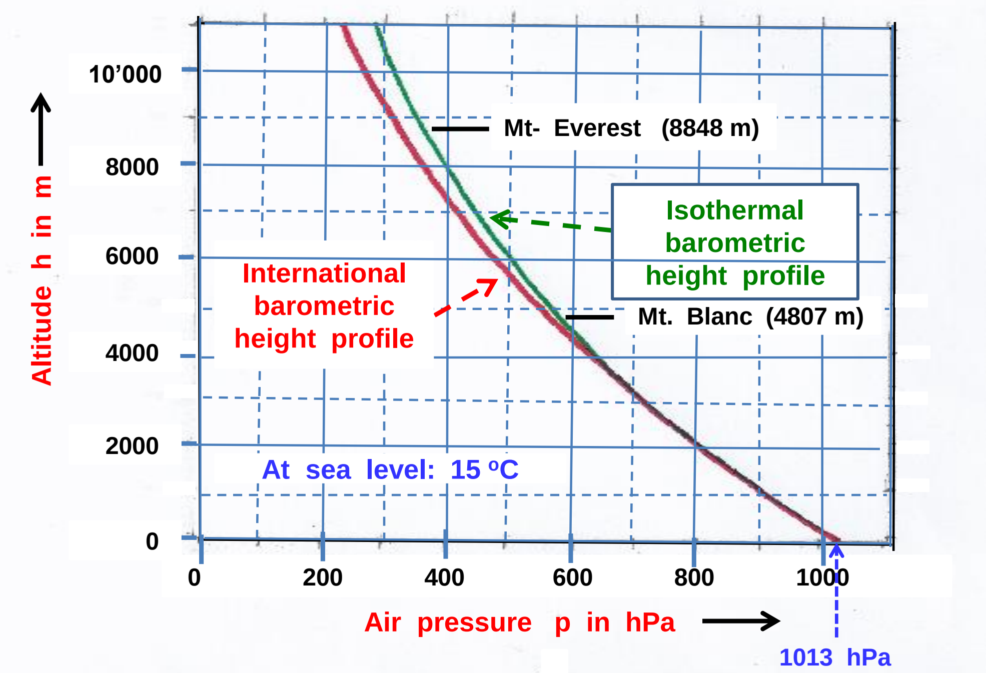
If the reference height is h_0 = 0 (sea level) and if we assume an average atmospheric state at sea level as defined by the Internationale Standard-Atmosphere (temperature = 15 ^{0}C, air presure = 1013.25 hPa, a = 0.0065 K/m), one obtains the International barometric height formula for the Troposphere (up to a height of 11 km):

$$p(h) = 1013.25 * [1 - 0.0065*\Delta h / 288.15]^{5.255} \quad \text{hPa} \qquad (9)$$

(*) An atmospheric inversion is an inversion of the normal temperature profile with increasing altitude, i.e. in the Troposphere the temperature is increasing instead of decreasing.

(**) For the actual application the accuracy of formula (9) is, however, limited, since a mean atmosphere has been assumed.

Barometric height profiles p(h)



30

Mean specific heat capacity of air

The specific heat capacity of a compound at constant pressure is given by

$$C_p = \Delta Q / (m \, \Delta T) \qquad (10)$$

ΔQ is the thermal energy transferred to an object with mass m, C_p is the specific heat at constant pressure and ΔT is the resulting increase in temperature. Lifting an air packet of weight G = mg by a height Δh requires the potential energy ΔQ = m G = m g Δh and we obtain

$$C_p = g \, (\Delta h / \Delta T) = g / a \qquad (11)$$

According to p. 29, the mean temperature gradient is $a = \Delta T / \Delta h = 0.0065$ K/m or $\Delta h / \Delta T = 153.8$ m/K. Substitution in eq. (11) and using $g = 9.81$ m/s² we obtain the mean value of C_p for all weather conditions (mean over dry and humid air), namely

$$C_p = 1509 \ (m^2/s^2K) = 1509 \ (Ws/kg\ K) \qquad (12)$$

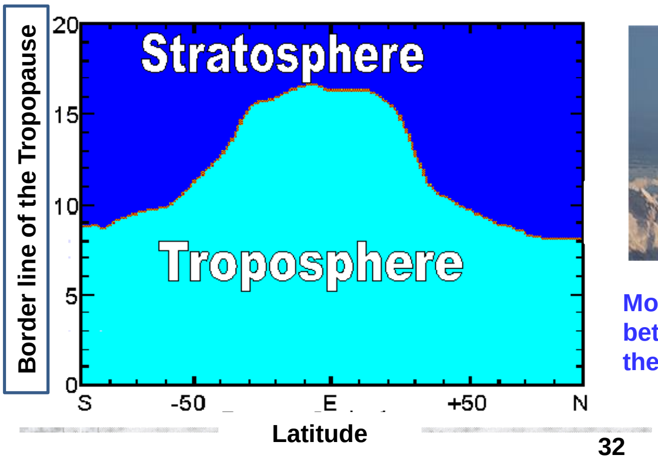
This value lies between the specific heat for dry air with C_p = 1005 (Ws/kg K) and the specific heat of water vapor with C_p = 2034 (Ws/kg K).

[Remark: The specific heat of dry air varies only slightly between – 100 °C and + 40 °C: C_p = 1009 (Ws/kg K) at – 100°C and C_p = 1005 (Ws/kg K) at + 40°C].

31

The Tropopause

The Tropopause is the small transition region (marked with small red points in the Figure) between the Troposphere and the Stratosphere. According to WMO (World Meteorological Organization) its thickness is very small, between some hundred meters and 2 – 3 km, and its vertical temperature gradient is - 0.2 K/100 m. The Figure show that the height of the Troposphere depends on the geographical place, mainly from the latitude. The height of the Troposhere is about 16 km above Australia and about 12 – 16 km in mean seasons. Its height decrease with increasing latitude and at the North- and South Poles it is about 9 km. The ozone layer starts just above the Troposphere and extends into the Stratosphere.



Most commercial airplanes are flying between the upper Troposhere and the lower Stratosphere.

32

2.4 The Stratosphere

33

General Properties

The Stratosphere is the second layer of the Earth's atmosphere. The interlayer region between the Troposphere and the Stratosphere is known as the Tropopause (s. p. 32). As shown at p. 32, the Tropopause is located in a height of about 9 km at the geographical Poles and between 12 and 16 km at the equator. At still higher altitudes the Stratosphere is followed by the Mesosphere (s. pp 7, 9 and 35). The interlayer between the Stratosphere and the Mesosphere is the so-called Stratopause in a height of about 50 km (p. 35).

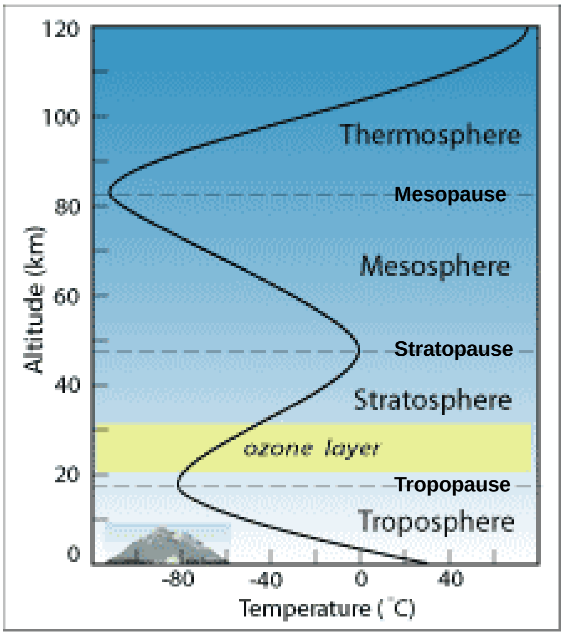
In the Stratosphere, the mean temperature increases again, but in the lower region of the Stratosphere, up to an altidude of about 20 km, this temperature increase is vanishingly small.

The increase of temperature in the Stratosphere with increasing height is opposit to the behaviour of the Troposphere and the Mesosphere (s. Figure p. 35). The reason for this inverse temperature behaviour is mainly due to the presence of ozone in the Stratosphere. Ozone absorbs UV-radiation of the Sun, whereby the electromagnetic radiation is transformed into heat. The warming by this heat is strongest in the region of the ozone layer where the temperature increses from – 60 ^{0}C to nearly 0 ^{0}C (s. p. 35 and Appendix 1-A-3-1).

As a consequence of the low temperature in the Tropopause, atmosphereic water vapor condenses almost completely. For this reason the atmospheric air is very dry. Clouds are therefore formed in the Stratosphere only in the case of extremely cold conditions. p. 36).

34

Temperature profile of the Atmosphere



The Stratosphere (15 – 50 km) is the layer following the Troposphere. Its temperature profile is layerd (or stratified), and its temperature <u>incre-ases</u> with increasing altitude, reaching about 0 ^{0}C near 50 km. This is contrary to the temperature profile in the Troposphere. The boundary layer between the Troposphere and the Stratosphere is the Tropopause (p. 32), while the boundary layer between the Stratosphere and the Meosphere is the Stratopause [The boundary between the Mesosphere and the Thermosphere is the Mesopause].

The increas of temperature with increasing altitude in the Stratosphere originates essentially from the <u>ozone layer</u>, which absorbs the short wavelength UV- contribution of the solar radiation (s. p. 37).

35

Polar Stratospheric Clouds (PSC's)

In the Stratosphere, the water vapour concentration of air is very small, and therefore, conventional water clouds can not be formed. Polar Stratospheric Clouds (PSC's) consist of Nitric assid (HNO_3 and/or of a mixture of Sulfuric acid (H_2SO_4) and Nitric acid, where both modifications are coated by a layer of water ice. They can also consist on pure water ice. For this reason, the following types are distinguished:

Typ Ia : Crystals of Nitric acid Trihydrate with a layer of water ice
Typ Ib : Sulfuric acid and Nitric acid with a layer of water ice
Typ II : Consisting of pure water ice

At the surface of the crystals, chemical reactions can take place, which are important for the <u>ozone depletion</u> in the Stratosphere and the formation of the <u>hole in the ozone layer</u>.

These stratospheric clouds, also called <u>mother of pearl clouds</u> or <u>nacreous clouds</u>, are formed in the Stratosphere in altitudes above 20 km, most often in the region between 22 and 29 km. During winter this appears always in the polar regions, beyond 80^0 northern or 80^0 southern latitudes.

Type I

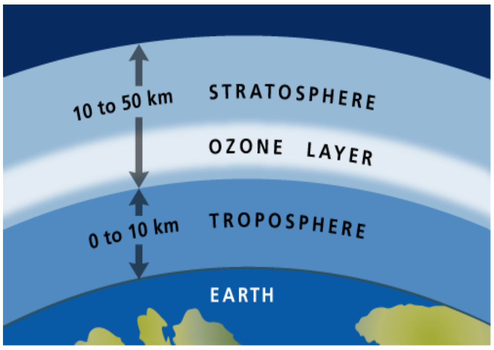
PSC of Typ I: uppermost whight cloud

PSC of Typ II: nacrous colored clouds

Type II

36

The Ozone layer of the Stratosphere



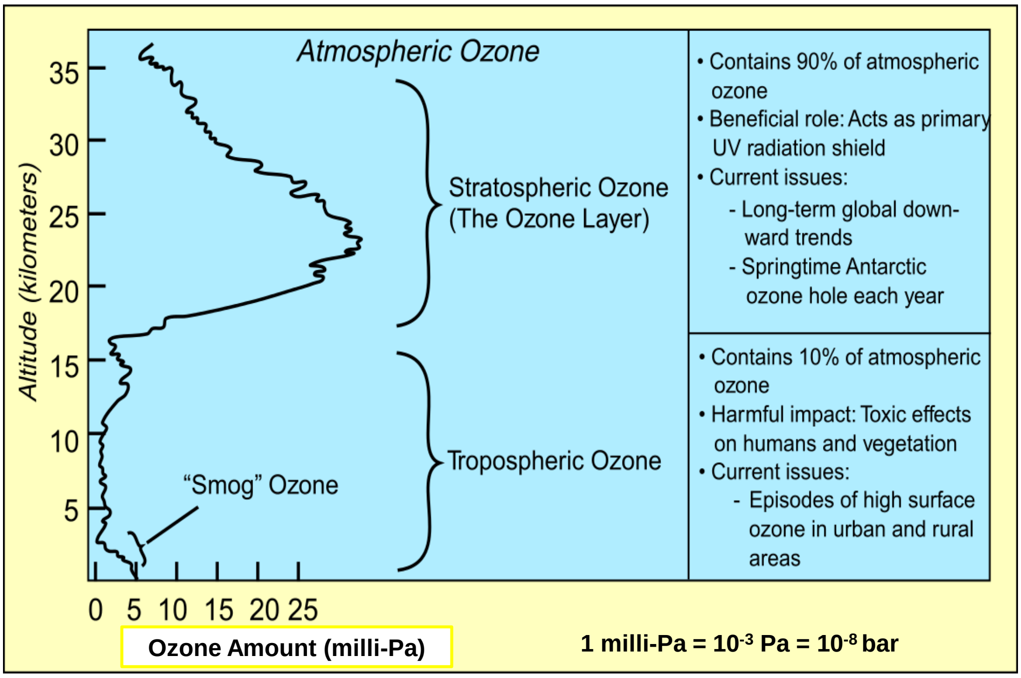
The ozone layer is a part of the Stratos-phere, in which under the influence of the energy-rich ultraviolet (UV)- radiation of the sun, oxygen in the form of O_2 is converted into ozon (O_3). The ozone. layer begins at an altitude of 10 to 17 km and extends to an altitute of about. 50 km. (Concerning the structure and layers of the ozone molecule s. pp 22 and 23.

Ozone O_3 is formed from molecular O_2. The comperatively high concentration of ozone [2–8 ml/m^3 or 2–8 ppm] absorbs UV-radiation, in particular UV-B, and part of this ozone is partially decomposed by this radiation into O_2: A chemical equilibrium is formed, the so-called <u>ozone – oxygen cycle</u>, in which the amount of ozone remains essentially constant. In equilibrium, the formation and decomposition of ozone are balancing each other:

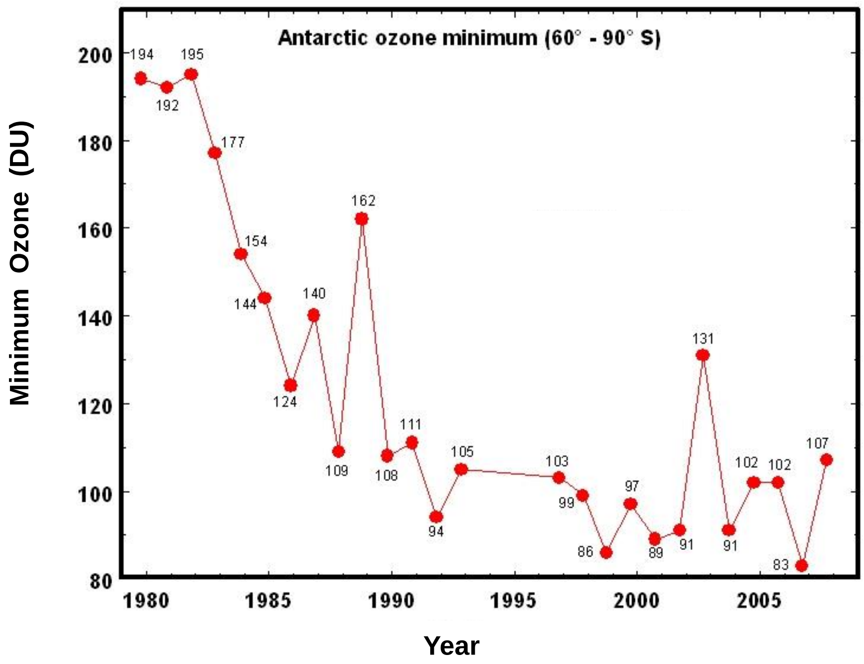
O_3- formation: $3\, O_2 \rightarrow 2\, O_3$ by radiation of UV-B and UV-C
O_3 - decomposition: $2\, O_3 \rightarrow 3\, O_2$ by radiation of UV-B and UV-A

Wavelengths of the UV- radiation:
UV-A: 400 – 315 nm ; UV-B: 315 – 280 nm ; UV-C: 280 – 100 nm
(1 nm = 10^{-9} m)

Ozone- Profils in Troposphere and Stratosphere

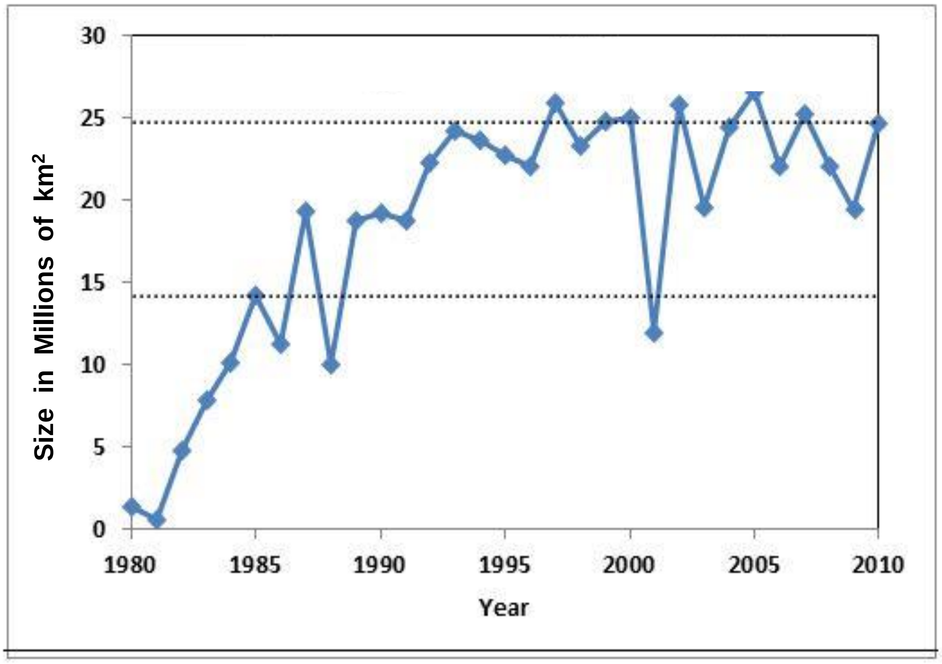


MInimum Ozone Concentration in the Stratosphere (1979 – 2008)



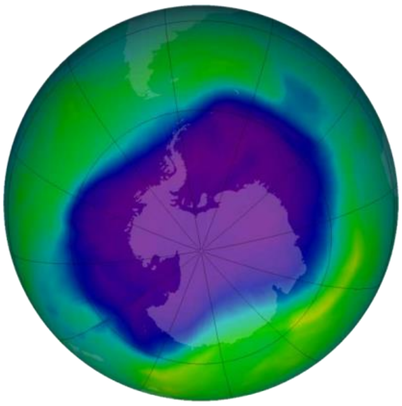
39

Average Area of Ozone Hole in the Stratosphere (1980 – 2010)



40

Largest Antarctic Ozone hole



Observation of the largest Antarctic Ozone hole which has been observed in September 2006.

The sizes of these Ozone holes can be as large as three times the area of USA.

The area of the Ozone hole is about $30*10^6$ km^2.

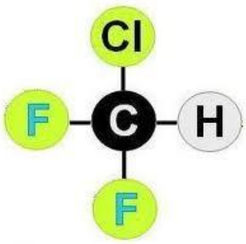
The area of USA is about $9.8*10^6$ km^2.

The Ozone hole has been discovered the first time in 1979 (s. pp 39 and 40) and is observed mainly over the colder part of the Antarctic. This discovery was based on the destructive chemical processes which are active most efficiently at cold conditions. The antarctic continent is colder than the arctic continent. During the following years, the size of the Ozone hole increased rapidly. The Ozone layer is present only during a period of three months per year. But it is just at the time of sun rise when plants and animals become active, that the sun also produces a dose of dangerous UV- radiation.

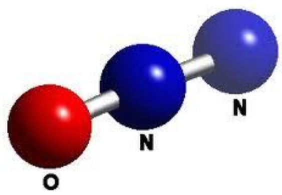
Ozon – killers and consequences for the Ozone hole

Some particular gases, such as chlorofluorocarbons (CCFC's) and nitrous oxides (N_2O), also called laughing gas, are able to increase a decomposition of ozone, thereby producing an increase of the O_2 concentration. As a consequence, this is responsible for the formation of the Ozone hole during the long polar nights.

If the end of the polar night is approached, the Sun starts to radiate light through the Ozone holes to the Earth. As a consequence, the intensity of the UV- radiation increases at the surface of the Earth. This can cause a distinct increase of skin cancer as well as a severe increase of eye diseases. Furthermore, the UV-radiation can disturb the immune system. In addition it can affect the Photosynthesis in the Chlorophyll of plants leading to severe harvest shortfalls.



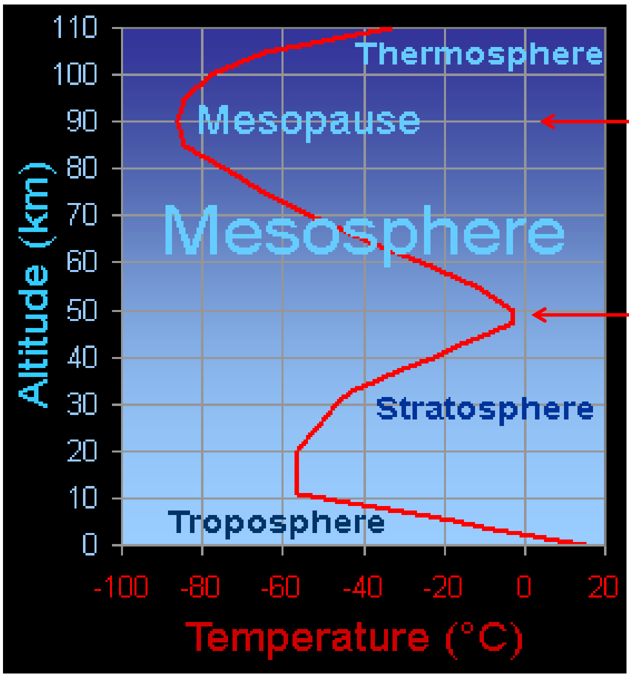
CCFC



N_2O

2.5 The Mesosphere

Mesosphere between Stratosphere and Thermosphere



Pressure about 10^{-6} atm

Pressure about 10^{-3} atm

Characteristics of the Mesosphere

The Mesosphere is the layer of the Earth's atmosphere that is directly above the Stratopause and directly bewlow the Mesopause. (s. p. 35). The exact upper and lower boundary of the mesosphere vary with latitude and with season, but the lower boundary of the Mesosphere is usually located at heights of about 50 kilometers above the Earth's surface and the upper boundary is usually at heights near 80 kilometers.

Because of the extremely diluted air in the Mesosphere as well as due to the fact that ozone is practically absent and the absorption of the energy-rich UV-radiation takes place in the Stratosphere, the temperature decreases from about 0^0C at the Stratopause to about – 90^0C at a height of about 80 kilometers (s. pp 35, 44, 47). The decrease of temperature is only about 3 $^0C/km$, i.e. substantially smaller than in the Troposphere. The temperature than remains essentially constant and it is only in the Thermosphere, where it strongly increases again to nominal values as high as to 2000 ^0C.

The chemical composition of the Mesosphere consists mainly on some gases which according to there masses are layered (light gases above denser gases). If Meteors are approaching the Earth, they burn-out upon entering the Mesosphere.

The carbon dioxide (CO_2) present in the Mesosphere contributes significantly to the cold temperature. By collislons of CO_2 molecules, heat is absorbed. Part of this energy is transformed into photons; this is a process known as radiation emission of light. In this way, heat is transferred from the Mesosphere into the Thermosphere,

45

2.6 The Thermosphere

46

The Thermosphere

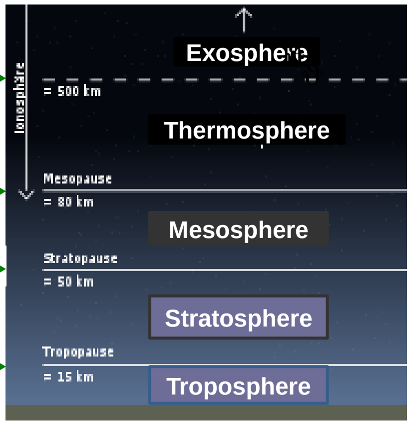
The Thermosphere is the layer of the Earth's atmosphere directly above the Mesosphere and directly below the Exosphere. The Thermosphere is an atmospheric layer which starts at about 80 km and extends up to about 500 km. In this range of altitude, the concentration of molecules is so small that it nearly resembles the free space of vacuum. The temperature is therefore not an equilibrium temperature: there are essentially no molecular collisions. The high temperature is only a consequence of the very high velocity of the molecules and is referred to as <u>radiation temperature</u>. Because the protecting activity of the atmosphere is not present, one is exposed to the full radiation spectrum of the Sun and the Universe. The Ionosphere extends from about 70 km to more than about 1000 km.

Thermopause →

Mesopause →

Stratopause →

Thermopause →



h ≈ 500 – 600 km;
Radiation temperature ≈ 1100 ^{0}C

Ionosphere: 70 < h < 1000 km
max. electron density at 300 km

h ≈ 82 km; ϑ ≈ – 110 ^{0}C

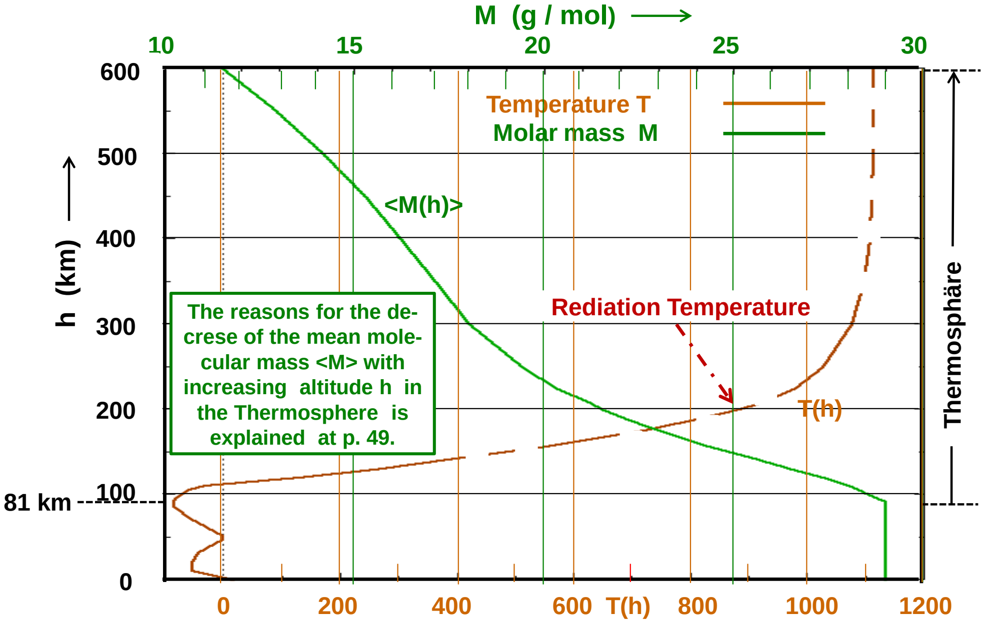
h ≈ 50 km; ϑ ≈ 0 ^{0}C

h ≈ 15 km; ϑ ≈ – 82 ^{0}C

For h (ϑ) compare also with diagram of p. 35

47

Temperature T and mean molar mass <M> of air as a function of altitude h



48

Properties of the Thermosphere

Despite its name the «heat» of the Thernosphere can not be felt. This is due to the fact that the air density is extrimely small compared to the density close to the surface of the Earth (s. pp 35, 54). The high temperature (300 to 1500 0^0C) implies only the rapid motion of the gas particles. Their mean free paths are of the order of several kilometers. This implies that interactions by collisions or energy exchange do not exist.

The International Space Station (ISS) has a stable orbit within the middle of the Thermo-sphere, between 320 and 380 kilometers.

The temperature of the Thermosphere first increases strongly with height and can rise up to 1700 ^{0}C. However, a person would not feel warm because of the Thermosphere's extremely low gas density (s. p. 52).

The solar X-ray radiation and the extreme UV-radiation decompose the gas molecules into ions and electrons. For this reason, the Ionosphere is part of the Thermosphere,

With increasing altitude, the average mass of the individual gas particles decreases with increasing height. There are three reasons for this fact: (1) residual molecules in the upper part of the Thermosphere are easily decomposed by cosmic radiation into there constituent particles. (2) because of the small pressure, the recombination rate of these constituents to molecules is very small. (3) At a given temperature, light particles have a larger velocity and are less attracted to the Earth by gravitational forces. These three effects cause an increasing enrichement of light molecules (H_2) and atomic He with increasing alititude which explains the decrease of the molar mass with increasing height h (s. green curve at p. 48).

49

The Thermopause

The Thermopause is the atmospheric boundary of Earth's energy system, located at the top of the Thermosphere (s. pp 9 and 47).

Below this, the atmosphere is defined to be active on the insulation received, due to the presence of heavier gases such as monoatomic oxygen. Beyond (above) this, the exosphere describes the thinnest remainder of atmospheric particles, mostly Hydrogen molecules anf Helium atoms, having very large mean free paths.

The exact altitude varies by the energy inputs of location, time of day, solar flux, season, etc. and can be between 500 – 1000 km high at a given place and time. The thickness of the Thermopause is not well defined.

Although these layers at very high altitudes are all named layers of the atmosphere, the pressure is so neglgible that the chiefly-used definition of outer space are actually below this altitude. Orbiting satellites do not experience significant atmospheric heating by collisions with particles, but their orbits do decay over time , depending on orbit altitude. Space missions such as the International Space Station (ISS), space shuttle, and Soyuz operate under this layer.

2.7 The Exosphere

51

The Exosphere - 1

The Exosphere is the outermost layer of Earth's atmosphere. It represents the continuous transition from Earth's atmosphere to interplanetary space. According to the definition of NASA it is already part of it.

The Exosphere is a part of the so-called Heterosphere, the part of the atmosphere higher than about 120 km in which the gases of different weights start to demix. Above a height of about 1'000 km only the lightest gas, namely Hydrogen (H_2) is present. This region is also known as geocorona.

The Thermosphere is followed by the Exosphere (s. p. 47). Depending on various Literature sorces, it starts in a height between 400 km and 1000 km. The outer limit of the Exosphere is approximately 10'000 km. This upper boundary is, however, not well defined since the density of the gas decreases continuously and theoretically never reaches exactly zero.

All particles in the Exosphere are almost completely ionized. The Exosphere is the sole atmospheric layer in which due to their high velocities, gas molecules can escape the gravitational forces. Note that due to their extremely low density, retarding frictions can be neglected.

The high temperature of more than 1'000 ^{0}C, which is seemingly present in the Exosphere, refers only to the high velocities of the particles (see dashed line of the temperature curve T(h) at p. 48). Due to the vanishingly small number density of the particles, the temperature is not due to collisions of particles, but is rather due to the heat radiation of the Sun. During day time, the temperature is therefore very high, but during night it is very low.

52

The Exosphere - 2

In the Exosphere, the temperature is not due to interactions, i.e. due to collisions between particles, since because of the extreme small concentration of the particles, collisions are extremly seldom.

In the Exosphere, the temperature is rather determined by the heat radiation of the Sun. This heat radiation depends extremely strongly of whether a part of the Exosphere is exposed to the Sun (during day) or whether it is screened from the radiation field of the Sun (during night). During day time, the radiation can generate temperatures well above 1'000 ^{0}C. During night, however, the temperatore is well below 0^{0}C.

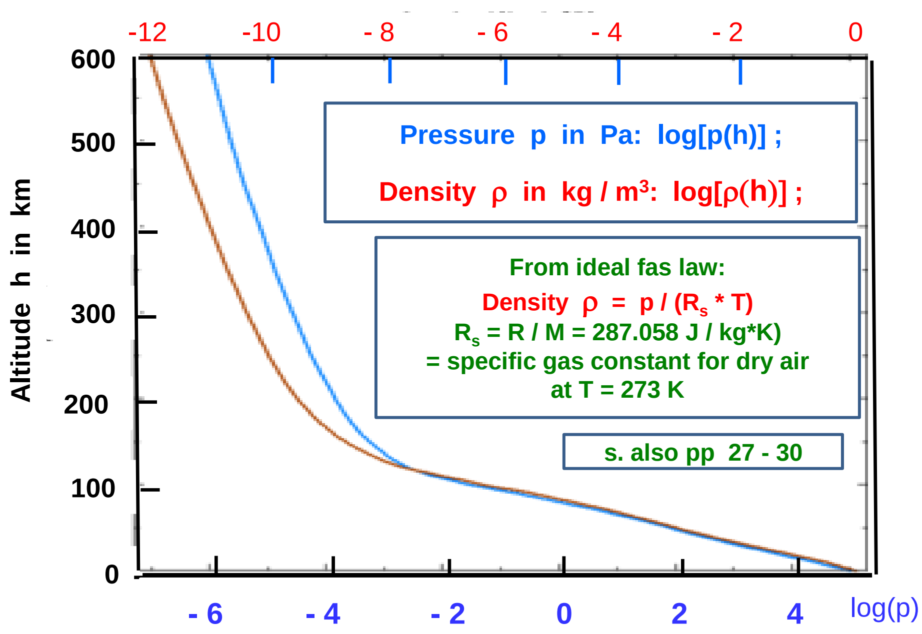
The Exosphere is almost a vacuum.

This picture shows the Hubble Space Telescope, which circles around the Earth in the Exosphere.

Those parts of the Telescope, which are exposed to the Sun, are extremely hot. On the other hand, the parts which are not exposed to the Sun are very cold.

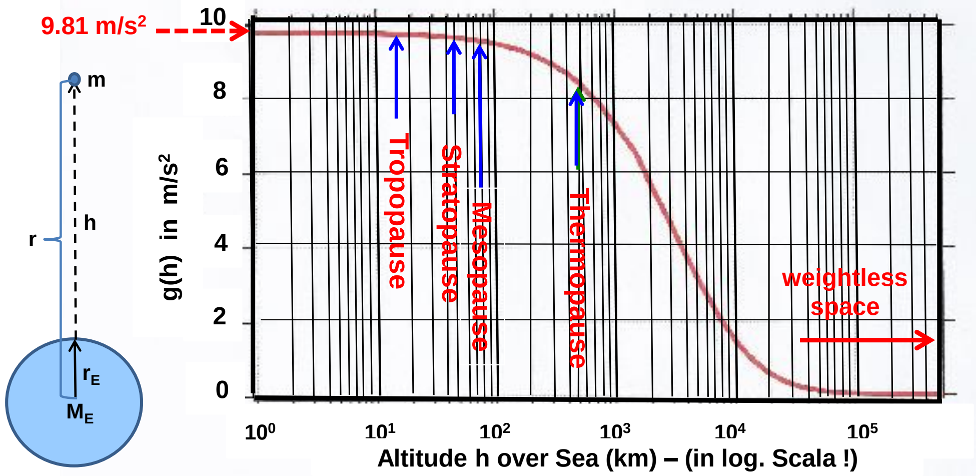
53

Pressure p and Density ρ as a Function of Altitude h



54

Gravitational acceleration g as a function of Altitude h



$g_E = g(h{=}0) = 9.81\ m/s^2$ = Gravitational acceleration at Sea level

Gravitational force $F(r) = G\,M_E\,m / r^2 = m\,g(r) \rightarrow g(r) = G\,M_E / r^2$; $r = r_E + h$;

with $f = 1 + h/r_E$ it follows: $g(h) = g_E / f^2$; $G = 6.674 \times 10^{-11}\ m^3/kg\ s^2$ = Gravitational constant;

$M_E = 5.972 \times 10^{24}$ kg = Mass of Earth; $r_E = 6371$ km = mean Earth radius.

55

Appendix - Chapter 2

2-A-0

Troposphere: Relation between Volumes and Masses of Gases in Air

Page 16 contains a Table of the volume- and mass contributions of the various gases of air contained in the Troposphere. Here, we establish the relation between volumes and masses.

Let M be the total mass and V the total Volume while M(k) and V(k) are the mass and volume of gase k. Furthermore, let $\rho(k)$ be the density of gas k at normal conditions. From $\rho(k) = M(k) / V(k)$, the mass ratio $\eta(k)$ of the gas k is given by:

$$\eta(k) = M(k) / M = \rho(k)\,[V(k) / V] \,/\, \{\Sigma\, \rho(k)\,[V(k) / V]\}$$

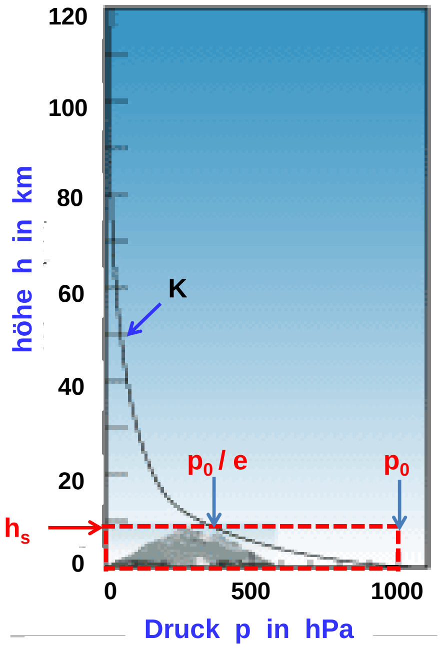
Example for N_2, O_2, and Ar : (s. p. 16); in a first approximation we calculate $\eta(N_2)$, $\eta(O_2)$ and $\eta(Ar)$ only from $V(N_2)/V$, $V(O_2)/V$ und $V(Ar)/V$, i.e. we neglect all trace gases listed in p. 16. For normal conditions $\rho(N_2) = 1.2503$ kg/m^3; $\rho(O_2) = 1.429$ kg/m^3 and $\rho(Ar) = 1.7813$ kg/m^3. By using the volume ratios listed in p. 16: $V(N_2)/V = 78.084$, $V(O_2)/V = 20.942$ and $V(Ar)/V = 0.934$, we obtain for the corresponding mass ratios:

$$\eta(N_2) = 75.5517\ \%\ ;\quad \eta(O_2) = 23.159\ \%\ ;\quad \text{und}\quad \eta(Ar) = 1.287\ \%\ .$$

These values are slightly larger than those listed in p. 16. This is due to the neglect of the trace gases listed in p. 16. If we would have included these trace gases (in particular CO_2), in the sum over k, we would have obtained the exaxt values for $\eta(k)$ listed in p. 16.

2-A-2-1

The scale height h_s of the barometric height formula



The most simple form of the barometric height formula is:

$$p(h) = p_0 \exp(-h / hs)$$

(p_0 = 1013.25 hPa, s. pp 27, 30).

We imagine that the total atmosphere under the curve K is compressed to a pressure of 1 atm = 1013 hPa. Let us then determine the height H of the resulting rectangle. If A is the surface under the curve K, than we have:

$$A = \int_0^\infty p(h)dh = p_0 \int_0^\infty exp\left(-\frac{h}{hs}\right) dh$$

$$= p_0 h_s = p_0 H ,$$

The height H = h_s is the so-called scale height h_s = (RT / (Mg) (s. p. 27)

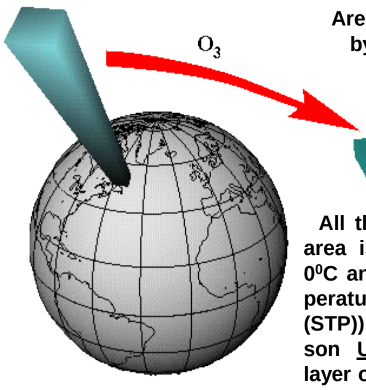
For a temperature T = 288 K = 15 ^{0}C we find

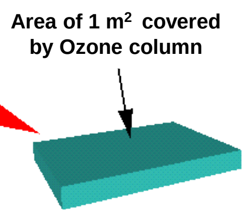
$$H = h_s \approx 8.4 \text{ km}$$

(s. red-dashed rectangle with area A)

2-A-3-1

Definition of Dobson Unit (DU)





All the Ozone over a certain area is compressed down to 0^{0}C and 1 atm (Standard Temperature-Pressure Conditions (STP)). Example: 300 DU (Dobson Units) correspond to a layer of 3 mm.

The Dobson Unit (DU) is a unit of measurement of the columnar density of a trace gas in the Earth's atmosphere. It is widely used as a measure of total-column ozone, which is dominated by ozone in the stratospheric ozone layer. One DU refers to a layer of 10 µm = 0.01 mm thick under Standard Temperature and Pressure conditions (STP: T = 273 K, p = 1 atm).

300 DU of ozone brought down to the Earth at 0^{0}C would occupy a layer of 3mm thickness.

Numerical example: Number of O_3- molecules contained in 1 DU

Ideal gas law: p V = n R T ; p = pressure, V = volume; R = ideal gas constant, T = temperature, n = number of moles. We calculate n and the number of ozone molecules in 1 DU. With p = 1 atm = 1.013 bar, R = 8.314 J/(mole K), T = 273 K and V = 1 m^2*10 µm = 1 m^2*10^{-5} m = 10^{-5} m^3 one obtains: n = p V/(R T) = 0.4462*10^{-3} mole. Since the Avogadro number N_A = 6.0224*10^{23}/mole is the number of molecules in 1 mole, 1 DU contains N_{DU} = = n*N_A = 0.4462*10^{-3} mole * 6.022*10^{23} (mole)$^{-1}$ = 2.69*10^{20} ozone molecules per m^2.

The Ozone concentration in the Stratosphere is not constant: a normal range is 300 to 500 DU. But due to anthropogenic activities, the ozone concentration decresed considerably (s. pp 39 – 42).

2-A-4-1

References: Chapter 2

R-2-0

2.2 Composition of dry Air in the Troposphere

R.2.2.1 p. 16: Gas composition - http://en.wikipedia.org/wiki/Gas_composition

R.2.2.2 p. 16: Atmosphere of Earth
Composition of dry atmosphere by volume - http://en.wikipedia.org/wiki/Atmosphere_of_Earth

R.2.2.3 p. 16: Luft - Zusammensetzung der Luft (Volumen- und Massanteile) - de-wikipedia.org/wiki/Luft-

R.2.2.4 p. 17: Nitrogen - http://en.wikipedia.org/wiki/Nitrogene

R.2.2.5 p. 17: Stickstoff - http://de.wikipedia.org/wiki/Stickdtoff

R.2.2.6 p. 18: Oxygen - www.en.wikipedia.org/wiki/Oxygen

R.2.2.7 p. 18: Sauerstoff - http://de.wikipedia-org/wiki/Sauerstoff

R.2.2.8 p. 19: Argon - http://en.wikipedia.org/wiki/Argon

R.2.2.9 p. 19 : Argon - http://de.wikipedia.org/wiki/Argon

R.2.2.10 p. 19: Radiogenic nuclide - http://en.wikipedia.org/wiki/Radiogenic - Radioaktiver Zerfall von ^{40}K in ^{40}Ar)

R.2.2.11 pp 20 – 21: The structures of the molecules and atoms of the trace gases of dry air have been found in different sources, including Google

R.2.2.12 pp 22 - 23: Ozone - http://en://wikipedia.org/wiki/Ozone

R.2.2.13 p. 23: [PDF] The concept of Resonance (in German: Mesomerie) (Example: Ozone)
www.wou.edu/las/physci/.../Ch08-s12-part2.pdf

R.2.2.14 pp 22 - 23: Ozon

a) http://de.wikipedia.org/wiki/Ozon - Ozon (Deutsch)
b) http://www,udo-leuschner.de/basiswissen/SB126-01.html
c) Mesomerie – http://de.wikipedia.org/wiki:Mesomerie
Ozon (Deutsch, Figur links: p. 22; Figur rechts aus:)

R-2-1

2.3 The Troposphere

R.2.3.1 p. 25: Graphic: Temperature variation in the Troposphere, Tropopause and low Stratosphere
Troposphere – Images (Graph from Elmar Uherek) :
«Untere Atmosphäre (Basis / Vertikaler Aufbau») (Figure Text tranlated from German to English by P. Brüesch)
http://www..xplora.org/downloads/Knoppix/ESPERE/ESPEREdez05/ESPEREde/www.atmosphere-mpg.de/enid.
(The scale of the altitude h is non-linear; the altitudes h ~ 20 km and h ~ 50 km have been added by P. Brüesch)

R.2.3.2 pp 25, 26: Troposphere

a) http.en.wikipedia.org/wiki/Troposphere
b) Why does the temperature of the atmosphere vary?
http://www.windows2universe.org/kids_space/temp_profole.htm
c) Atmosphere / Troposphere / Stratosphere/… - http://www.wheather-ciminate.org.uk/02.php

R.2.3.3. pp 25 – 26: Troposphäre : Allgemeine Eigenschaften
a) http://de.wikipedia.org/wiki/Troposp%C3%A4re
b) Inversion: In der Meteorologie, in der Tropopause, …. - http://www.wissen.de/lexikon/inversion-meteorologie

R.2.3.4 pp. 27 - 29: Barometric height formula

a) Barometric formula - http://en.wikipedia.org/wiki/Barometric_formula
b) On the barometric formula - Mário N. Berberan-Santos, Evgeny N. Bodunov, and Lionello Bogliani
Am. J. of Phys. 65 (5), May 1997
c) Barometrische Höhenformel - http://de.wikipedia.org/wiki/Barometrische_H%C3%B6henformel
[Alle auf den Seiten 27 – 29 angegebenen Resultate sind im oben angegebenen Literaturzitat ausführlich hergeleitet; hier beschränken wir uns auf eine Diskussion der relevanten Formeln]

R.2.3.5 p. 30: Graph: International barometric height formula

a) http://www.apt-huerth.de/APT_WebSite/GB/barometrische-hoenformel-html - (written in English)
b) The two curves for p(h) (Isothermal barometric height profile and International barometric height profile) have been calculated by P. Brüesch on the basis of Reference R.2.3.4 c)
- green curve: Barometric height profile for 15 ^{0}C, (p, 27, eq.. (1))
- red curve: Barometric height profile for T(h) linear in h according to:
$T(h) = T(h_0) – a*(h - h_0)$; $T(h_0) = 288.15$ K (15 ^{0}C) and a = 0.0065 K/m (s. pp 28 and 29).
c) Die internationale Höhenformel - http://wetter.andreae-gymnasium.de(interaktives/Druck/hoehenformel.html
Graph von p(h) für h < 11'000 m - Eingabe von h → p(h)

R-2-2

R.2.3.6 p..31: Mean specific Heat capacity of air

a) Air properties - http://www.engineeringtoolbox.com/air-properties-d_156.html
b) Specific Heat Capacity of Air - http://www.ohio.edu/mechanical/thermo/property_tables/air/air_Cp_Cv.html
c) Mittlere spezifische Wärme von feuchter Luft , von trockener Luft und von Wasserdampf
s. Referenz R.2.3.4 c: http://de.wikipedia.org/wiki/Barometrische_H%C3%B6henformel
d) In eq. (11) of this Chapter, Cp = g/a; for the heights considered, g is very close to 9.81 m/s^2 (s. Appendix 2-A-2-3)

R.2.3.7 p. 32: The Tropopause

a) The height of the tropopause (with left-hand image at p. 32)
http://www-das_uwyo.edu/.../geerts/cwx/notes/chap01/tropo.html
b) Tropopause (in Englisch) - www.http://en.wikipedia.org(wiki/Tropopau
c) Definition of the Tropopause in the Free Online Encyclopedia
www.http;//encyclopedia2.thefreedictionary.com/Tropopause
d) Tropopause - http://www,diplomet.de/Tropopause
e) Forschungsflugzeug HALO untersucht Atmosphäre über den Wolken (mit Bild rechts auf p. 32)
http://www.uni-heidelberg.depresse/meldungen/2012/m2012097_halo.html
f) Tropopause (auf Deutsch) - www.http://de.wikipedia.org.wiki/Tropopause

2.4 The Stratosphere

R.2.4.1 p. 34: Properties of the Stratosphere

a) Stratosphere – Wikipedia, the free encyclopedia
http://en,wikipedia.org/wiki/Stratosphere
b) The Stratosphere – Windows to the Universe
http://www.windows2universe.org/earth/Atmosphere/stratosphere.html
c) Stratosphäre - http://de.wikipedia.org/wiki/Stratosph%C3%A4re

R.2.4.2 p. 35: Temperature Profile in the Stratosphere

Visionlearning / Earth Science / The Composition of the Earth's Atmosphere - by Anne Egger, PhD
www.visionlearning.com/en/library/Earth-Sxience/6(The-Composition-of-Earth's-Atmosphere
(contains Graph showing the temperature variation with altitude in Earth's Atmosphere)
[Figure of T(h) itself only accessible under «Bilder»]

R-2-3

R.2.4.3 p. 36: Polar Stratospheric Clouds – PSC's
a) Polar stratospheric cloud - http://en.wikipedia.org/wiki/Polar_stratosheric_cloud
Left-hand Figure: Polar stratospheric cloud of type I - (PSC I)
Right-hand Figure: Polar stratospheric clouds of type II - (PSC II)
b) Polare Stratosohärenwolken - http://de.wikipedia.org/wiki/Polare_Stratosph%C3%A4renwolken

R.2.4.4 p. 37: The Ozone Layer in the Stratosphere

a) Ozone Layer – Wikipedia, the free enxycloprdia - http://en.wikipedia.org/wiki/Ozone_layer
b) Ozone Layer / Climate Education Modules for K-12 - http://www.nc.climate,ncsu.rdu/edu/k12/.ozonelayer
c) Ozonschicht - http://www.ping.de/schule/pg-herne/p-wetter/Luft/ozone1.htm

R.2.4.5 p. 38: Ozone Profils in Troposphere and Stratosphere

a) from Google unter «Atmospheric Ozon» (Bilder)
b) Ozone - From Wikipedia, the free encyclopedia - http://en.wikipedia.org/wiki/Ozone

R.2.4.6 p. 39: Ozone concentration (in DU): 1979-2011

a) Environmental Change on Earth
http://m.teachastronomy.cpm/astrpedia/article/Environmental.Change-on_Earth-
b) The Ozone Hole - EPA Bring Primatene Back – Use Some Common Sense
c) Ozone Hole History - http:// www.,theozonehole.com/ozoneholehistory.htm
d) Conversion of DU – Units - http://sacs.aeronomie.be/info/dobson.php
e) 1 Dobson Unit DU corresponds to $2.6867 * 10^{20}$ O_3 - molecules pro m^2 or $4.4615 * 10^{-4}$ mole $(O_3)/m^2$
Note: For the definition of the Dobson Unit (DU), the total amount of gaseous O_3 in the sky present over a a selected unit area F is compressed to Normal Conditions (STP). The result is a height h and the volume of the compressed Ozone is F*h. In other words, the height h is the hypothetical thickness of the Ozone layer at STP (p = 1 atm = 1.013 bar = $1{,}013*10^5$ Pa at T = 273 K (0^0C)). h(100 DU) = 1 mm.

R.2.4.7 p. 40: Average area of ozone hole in the Antarctis as a function of time
The Ozone Hole - http://www.e-edication.psu.edu/egee/102/node/1972

R.2.4.8 p. 41: Largest Antarctic Ozone hole

a) The Ozone Hole - http://www.theozonehole.com/ozoneholehistory.htm
b) Ozone depletion - http://en.wikipedia.org/wiki/Ozone.depletion - Bild mit grösstem Ozonloch (2006)
c) http://de.wikipedia.org/wiki/Ozonloch - Text und Bilder von 1980 bis 2010

R-2-4

R.2.4.9 p. 42: Ozone – killer and consequences for the Ozone hole

a) Ozone Facts: History of the Ozone Hole - http://ozonewatch.gsfc.nasa.gov/facts/history.html
b) The hole in the ozone layer – a solved problem?
http://www.globaömarshallplan.org/en/hole-ozone-layer-solved-proble,
c) The ozone layer - [PDF] www.fisica.ufmg.br/~/dickan/transfers/…/Taylor8…
d) The Ozone Layer - http://www.research.noaa.gov/climate/t_ozonelayer.html

R.2.4.10 p. 42: Ozone killer und Konsequenzen für das Ozonloch

a) Fluorchlorkohlenwasserstoffe - http://de.wikipedia.org.wiki/Fluorchlorkohlenwasserstoffe
b) Fluorkohlenwasserstoffe FCKW und das Ozonloch
http://www,atmosphere.mpg.de/emd/2_Ozonloch-_Ozonloch_FCKW_Imi-html
c) Distickstoffmonoxid - FCKW und N_2O unter Googl: Bilder - http://de.wikipedia.org/wiki/Distickstoffmomoxid
d) Stratosphärisches Ozon - http://wiki.bildungsserver.de/klimawandel/index.php/Stratosph%C3%A4risches_Ozon
e) Ozonloch - http://de.wiki.org/wiki/Ozonloch
f) Ozonschicht - http://de.wikipedia.org.wiki/Ozonschicht

2.5 The Mesosphere

R.2.5.1 p. 44: Mesosphere between Stratosphere and Thermosphere
see «Images: Mesosphere» - Mesosphere : windows2.org
For temperatures at the lower and upper layer of the Mesosphere: s. p. 35
http://www.atoptics.co.uk/highsky/hmeso.htm

R.2.5.2 p. 45: Characteristics of the Mesosphere

Mesosphere - http://en.wikipedia.org/wiki/Mesosphere

R.2.5.3 p. 45: Charakteristika der Mesosphäre

a) http://www.uni-protokolle.de/Lexikon/Mesosph%E4re.html
b) http://de.wikipedia.org/wiki/Mesosph%C3%A4re - Zum Text über CO_2 in Mesosphäre

R-2-5

2.6 The Thermosphere

R.2.6.1 pp 46 – 50: Thermosphere

a) Thermosphere - . http://en.wikipedia.org(wiki/Thermosphere
b) Thermosphere – Review - http://scied./ucar.edu/shortcontent/thermospher-overview
d) Atmosphere of Earth - http://en.wikipedia.org/wiki/Atmosphere_of_Earth

R.2.6.2 p. 47: Thermosphere - Text and representation - http://de.wikipedia.org/wiki/Thermosph%C3%A4re

R.2.6.3. p. 48 Average pressure and molar mass as a function of altitude
http://de.wikipedia.org/wiki/Thermosph%C3%A4re

R.2.6.4 pp 47 – 49: Thermosphere

a) Thermosphere - http://www.iwf.oeaw.ac.at/de/forschung/erdloerper/atmosphere/therm
b) Thermosphäre - http://universal_lexikon.deacademic.com/192060/Thermosph%C3%A4re
c) Thermosphäre - http://www.uni-protokolle.de/LexikonThermosph%E4re.html

R.2.6.5 p. 50: The Thermopause

a) Thermopause - http://en.wikipedia.org/wiki/Thermopause
b) Die Thermopause - http://de.wikipedia.org/wiki/Thermopause

2.7 The Exosphere

R.2.7.1 p. 52: Exosphäre-1: Text - www.http://de.wikipedia.org/wiki/Exosph%C3%A4re

R.2.7.2 p. 53: Exosphere-2: Hubble – Space - Telescoppe
http://www.windows2universe.org/earth/Atmosphere/exosphere_temperature

2.8 Varia

R.2.8.1 p. 54: Average pressure and density as a function of height
Logarithmic representation for large altitudes- Graph - Reference R.2.3.4, p. 1 ; Graph adapted by P. Brüesch

R.2.8.2 p. 55: Earth's gravitational acceleration g(h) - (Calculation and Figure from P. Brüesch)
s. also : www.de.wikipedia.org/wiki/Erdbeschleunigungung - www.http://wikipedia.org/wiki/Gravity_of>_Earth

R-2-6

Appendix

2-A-2-1 Appendix: Relation between volume and masses in air - (calculated by P. Brüesch)
s. als : Allgemeine Chemie: http://www..athematik-forum.de/forum/showthread.php?t=98546

2-A-3-1 Scale height: Effective height of atmosphere after compression to 1 atm

a) Scale height: http://de.wikipedia.org/wiki/Skalenhöhe%C3%B6he - Figure and Text from P. Brüesch
b) Scale height: http://en.wikipedia.org/wiki/Scale_height

2-A-4-1 The Dobson Unit

a) Dobson Unit: http://wikipedia.org/wiki/Dobson_unit
bl The Ozone Hole - http://www.theozonehole.com/dobsonunit.htm
c) What is the Dobson Unit (DU) ? - http://sacs.aeronomie.be/info/dobson.php
d) Definition der Dobson-Einheit - http://www.atm.ch.cam.ac.uk)tour/tour_de/dobson.html
e) Dobson-Einheit - Typische Grössenordnungen - http://de.wilipedia.org/wiki/Dobson-Einheit

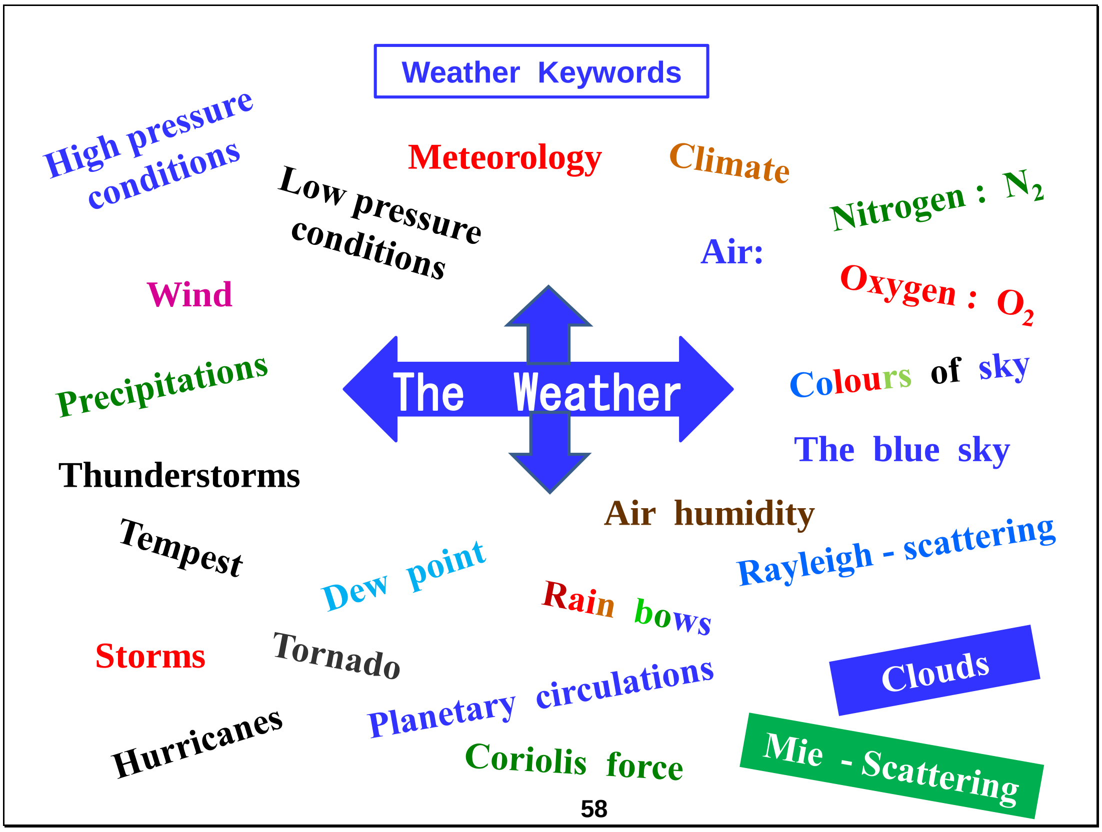
R-2-7

3. The Weather of our Planet

56

3.1 Weather: General

57



Weather: Meteorology – Driving force - Development

Weather is defined as the sensible, short-range state of the atmosphere, i.e. the observable state of the Troposphere at a particular location of the surface of the Earth. Important states are sunshine, cloudness, rain, wind, storms, hotness or coldness.

Meteorology classifies the spatial weather at a specific time on the basis of various phenomena in the Troposphere (Section 2.3).

In a strikt physical sens, weather is a specific state at a well-defined location on the surface of the Earth. It specifies several properties such as gas pressure, gas density as well as the composition of the gas.

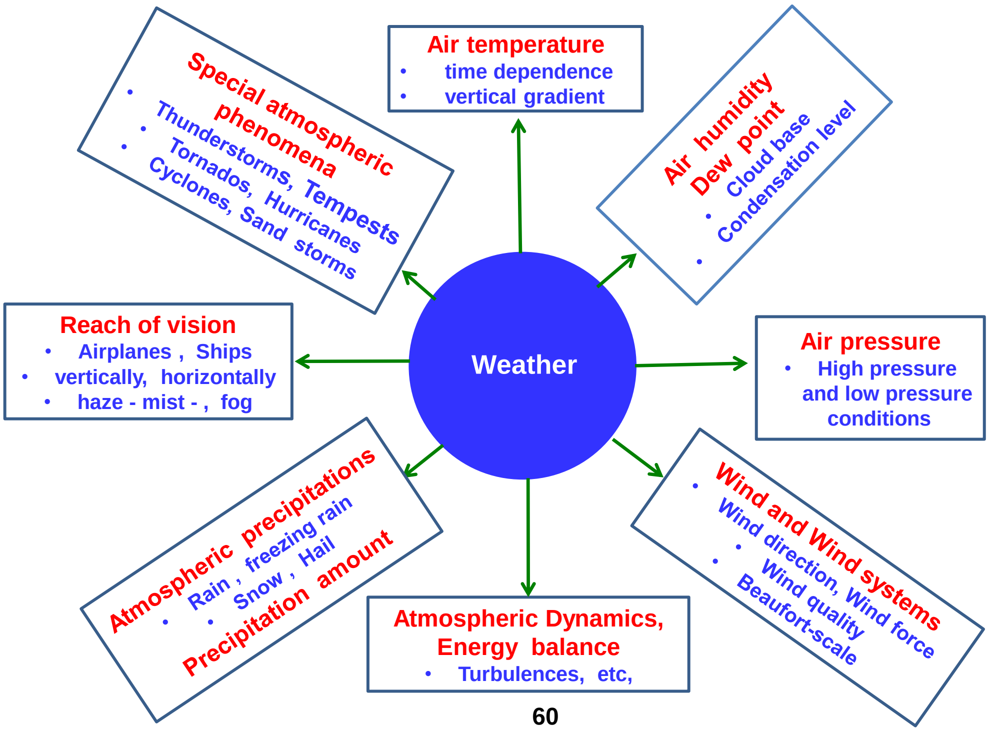
On the one hand, the primary driving force of weather is the energy radiation of the Sun, and on the other hand, it is the heat radiation from the Earth in the visible and infrared region back to the clouds and into free space,

The development of weather is, however, determined by the flow conditions in the atmosphere. The flow conditions depend on the air humidity and on the global wind systems. An other factor is the regional Albedo (strength of back radiation from the Earth's surface), as well as other factors.

«April weather» is synonymous for fitful and rapidly changing weather in quick succession of sun, clouds and showers.

59

Weather: Properties – Phenomena and basic Concepts



60

The color of sky at day

If the sunlight penetrates the atmosphere, part of the light is scattered and lights up the sky, producing the blue color. Without this scattering, i.e. without the atmosphere, the sky would be nearly black similar to the color of space. This diffuse radiation is due to a large part by the scattering of light by the oxgen and nitrogen molecules. Especially at twilight it is the absor-ption characteristic of Ozone in the Stratosphere which contributes to the color of sky.

During day, the blue color of the sky is due to scattering of the solar radiation by the molecules of Earth's atmosphere. Visible light contains light with all wavelengths λ, ranging between about 400 nm (blue) and 700 nm (red) (s. Appendix 3-A-1-1). Thereby, light with short wavelengths is much stronger scattered that red light with long wavelengts. It is the so-called Rayleigh-scattering which explains why during day the sky is blue. For the ratio of the cross section σ, which is a measure for the intensity of scattered light, one obtains for λ_{blue} = 450 nm , λ_{red} = 650 nm and with the corresponding refractive indices of air, n_{blue} = 1.000275319 and n_{red} = 1.000270901:

$$\frac{\sigma_{blau}}{\sigma_{rot}} = (\lambda_{rot}|\lambda_{blau})^4 \left(\frac{n_{blau}-1}{n_{rot}-1}\right)^2 \approx 4.5$$

For the wavelength λ_{blue} = 390 nm and λ_{red} = 780 nm we would even obtain a scattering ratio of about 16. Thus, blue light is much more strongly scattered than red light and for this reason the sky appears blue during a nice day.

61

The colors of sky at morning and evening

In the morning and in the evening the grazing incidence of the sun light through the atmosphere causes considerably longer path ways than during the day. For this reason, the blue light is much more strongly attenuated due to scattering by nitrogen-, oxygen- and water molecules than the red light. As a consequence, much more red light than blue light reaches the Earth's ground during morning and evenening. Both, the blue day-light (p. 61) as well as the dawn and red sunset of the cloudless sky can be explained by Rayleigh-scattering (colors of Sun-light: s. p. 3-A-1-1).

Red dawn sky before sunrise | Red sunset before sundown

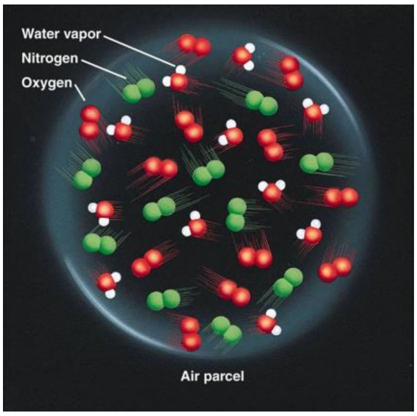
of the cloudless sky

62

3.2 Weather of the Troposphere

63

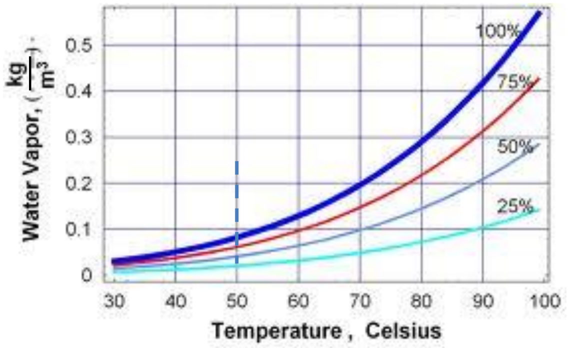
The humid Troposphere: Water vapor



The Figure illustrates a Section with the most important molecules in the Troposphere: Nitrogen (N_2: green), Oxygen (O_2: red) and Water molecules (H_2O: red – white). In contrast to other forms of water, water vapor is invisible. For typical atmospheric conditions, water vapor is continuously generated by evaporation of liquid water and continuously removed by condensation to liquid water. By these two processes, an equilibrium concentration is established which depends on the temperatures of the water sources (rivers, seas and oceans). [For information about water vapor see: P. Brüesch: p. R.0.B, Reference R.0.4, (WATER: pp 28 – 30)].

64

Absolute and relative Humidity, Saturation concentration



Example: at 50 ^{0}C one obtains from the Figure or more precisely from a Table:

$f_{abs}(50^0C) = 0.04135$ kg / m^3

$f_{max}(50^0C) = 0.08278$ kg / m^3

$f_{rel} = f_{abs} / f_{max} \approx 50$ %

The Figure shows the absolute humidity f_{abs} as a function of temperature. It is the mass m_W of water vapor contained in a certain volume V, i.e. $f_{abs} = m_W / V$.

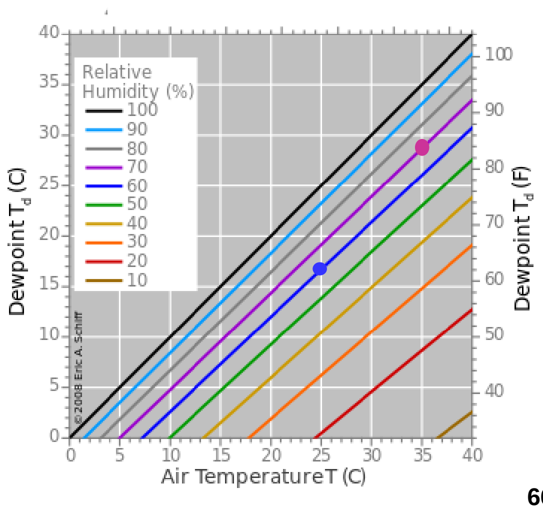
The maximum humidity f_{max} is the maximum possible absolute humidity of air at a given temperature, i.e. $f_{max} = m_{W,max} / V$. It is reached if the partial pressure of water vapor in the air is equal to the saturation vapor pressure of water at the corresponding temperature.

The relative humidity is the ratio of the actual mass present in the air and the maximum possible mass. Or stated differntly: it is the ratio of the absolute humidity of air and the maximum humidity of air at a given temperature: $f_{rel} = f_{abs} / f_{max}$.

The variations of water vapor in the air are very large, namely between 0 and 4 volume percent.

Dew Point (T_d) – Relative Humidity (RH) – Temperature (T) - 1

The dew point is the temperature to which humid air must be cooled down until it is completely saturated with water vapor. Hence, if the air is cooled down to the dew point, condensation of water begins.



If the air temperatur T is cooled down to T_d, condensation of water vapor to liquid water starts (dew, fog or clouds). The dew point T_d is always smaller than or equal to the air temperature T: $T_d \leq T$.
The Figure to the left show the temperature of the dew point T_d as a function of the air temperature T for different Relative Humidities RH: $T_d = f(T, RH)$.

For RH > 50% a simple approximate equation can be used:

$$T_d = T - (100 - RH) / 5$$

Example 1: RH = 60% , T = 25^{0}C
→ $T_d = 25 - (100 - 60) / 5 = 17^0$C
(s. point marked on blue line)

Example 2: RH = 70% , T = 35 ^{0}C
→ $T_d = 35 - (100 - 70) / 5 = 29$ ^{o}C
(s. point on dark pink line)

For RH < 50% the relation for T_d = f(T,RH) is more complicated (s. p 67).

Dew Point (T_d) – Relative Humidity (RH) – Temperature (T) - 2

A well-known equation for TP (in °C) as a function of RL (in %) and T (in °C) is the so-called August – Roche – Magnus Relation given below:

$$T_d = \frac{b\,\gamma(T,RH)}{a - \gamma(T,RH)} \quad \text{with} \quad \gamma(T, RH) = \ln(RH/100) + \frac{a\,T}{b+T}$$

here $a = 17.271$ and $b = 237.7\,°C$.

This relation is valid for $0\,°C < T < 60\,°C$, $1\,\% < RH < 100\,\%$ und $0\,°C < T_d < 50\,°C$

Examples:

1. RH = 100 % → $T_d = T$; 2. RH = 30 %, T = 35 °C → T_d = 14.81 °C;

3a) RH = 50 %, T = 10 °C → T_d = 0 °C;

3b) RH = 50 %, T = 25 °C → T_d = 13.84 °C;

4. RH = 70 %, T = 30 °C → T_d = 23.9 °C .

A comparision with the values for T_d shows, that the results are in good agreement with the values of the Figure at p. 66.

For RH > 50 % a very simple linear approximation for $T_d = f(T,RH)$ with an accuracy of about 1 % exists. This relation is:

$$T_d \approx T - f * (100 - RH) \quad \text{mit} \quad f \approx 0.2\,°C$$

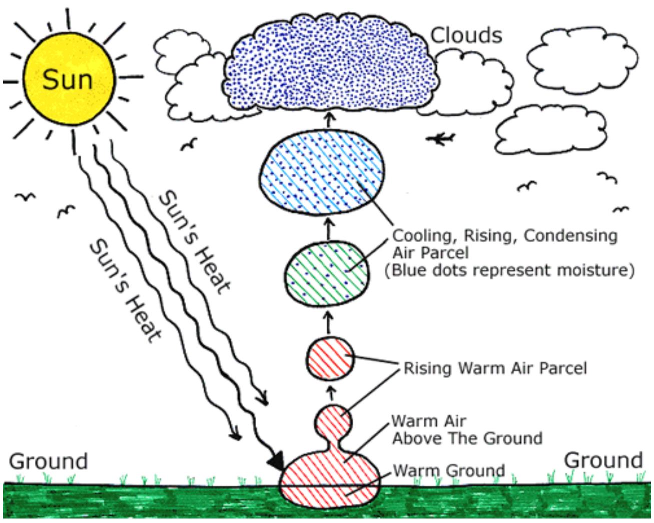
Examplel: RH = 70 %, T = 30 °C → T_d = 24 °C.

67

3.3 The World of Clouds

68

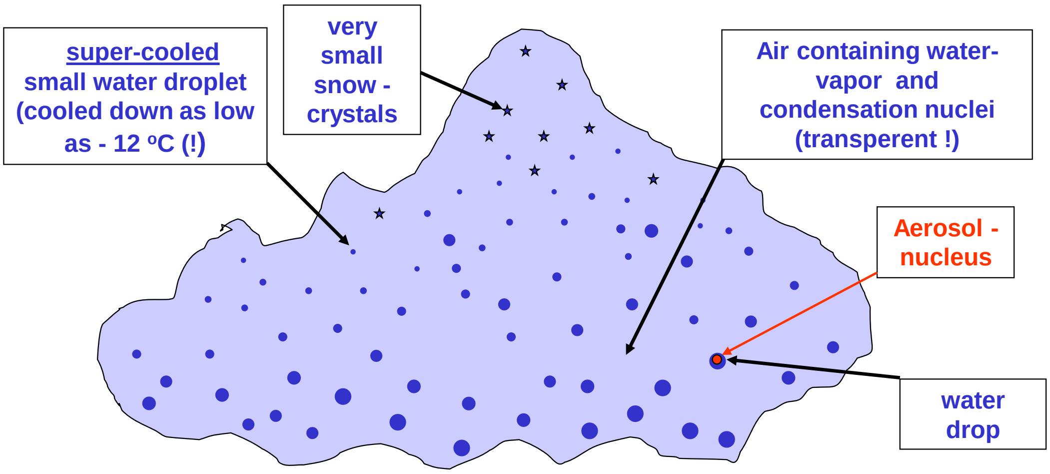
Formation of Clouds



Warm and humid air is lighter than its surrounding colder and dryer air and for this reason it rises to height. During this rise it cools down and hence the (molecular) vapor condenses into microscopic small droplets: a cloud is formed.

69

Droplets and crystalites in clouds



Nice weather cloud: Accumulation of water droplets with diameters within the range between 1 to 15 μm (1 μm = 0.000'001 m). Droplets are forming often at condensation nuclei (Aerosols). (Note that the droplets are pictured much too large!)

Rain clouds: Diameters of droplets as large as 2 mm → rain out !

70

Cumulus - Clouds

Cumulus - cloud with anvil at the top (anvil cloud) :
contains very small water droplets and ice crystals .

71

Why do clouds not fall from the sky ?

A water droplet in a cloud has a typical diameter of 10 μm and a small **speed of fall** of some cm / s (several 100 m / h).

But **upwinds** are counteracting the small speed of fall , causing the drops to float or even to move upwards .

72

Colours of clouds : white

This cloud is composed of very small and densely packed droplets such that the sunlight can not penetrate deeply before it is reflected . Since all colours are contained in the reflected light , its superposition combines to the observed characteristic white colour .

73

Colours of clouds : blue - white

The sunlight is composed of several colours (red – green – yellow – blue ,…) , which combine to the white colour .

The colour of the cloud is the result of the scattering of the sunlight by the water droplets . Our eye observes the scattered (and reflected) light . The latter depends on different factors such as of the size of the droplets , of the viewing angle , the distance and the dust between the cloud and the observer .

74

Colours of rain - clouds : white – grey - dark-grey

If a large number of small droplets combine to large rain drops , then the distances between the drops become larger . As a consequence , light can penetrate much deeper into the cloud and is partly reflected and partly absorbed . Thus the reflection – absorption process gives rise to a whole range of cloud colors , which extends from grey to black .

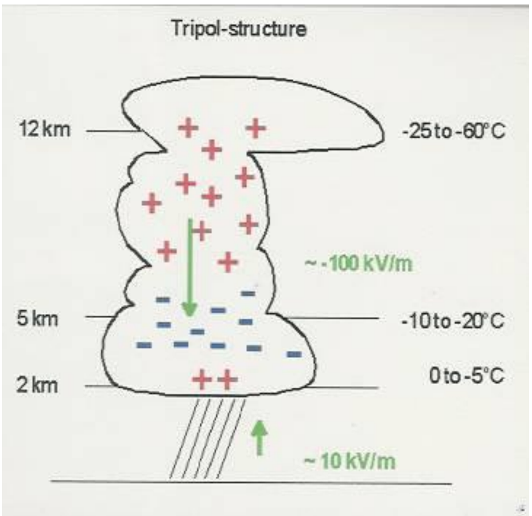
75

Clouds at sunrise and sunset : dark-red - orange-pink

Such clouds can almost always been observed during sunrise or sunset . Their color is the result of scattering of sunlight by the atmosphere where the short-wavelength blue light is scattered most strongly . The clouds then reflect the remaining light which contains mainly the long-wavelength red light .

76

Structure and charge distribution of thunderstorm clouds



• uper part : positive charge range , which can extend up to the anvil .

• negative charge range in the lower part of the cloud.

• small positive charge layer close to the base of the cloud which is generated by precipitations .

The detailed mechanism of the charge formation and of the charge separation is not clarified until know .

77

Threatening Thunderstorm Cloud

78

3.4 The Wind

79

The Wind - General

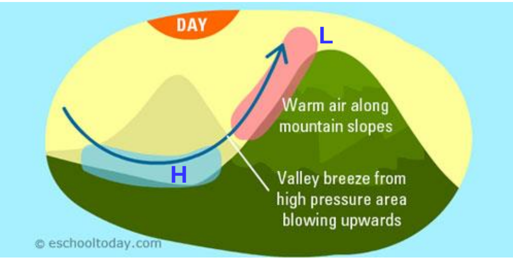
The normal pressure of air is 1013 hPa (or 1031 mbar). Areas in which the air pressure is higher than this value are called High pressure areas, areas with lower pressures are Low pressure areas. Winds are pressure equilibrium currents flowing from high- to low pressure regions. This current persits until the pressure difference is equilibrated. Wind can therefore be considered as a mass flow, which according to the Second Law of Thermodynamics aspires an equipartition of particles in space towards a maximum entropy. The associated force is a pressure gradient. The stronger the differences between air pressures are, the stronger is the current of the air masses flowing from regions of high pressures towards regions of low pressures, and the stronger is the resulting wind.

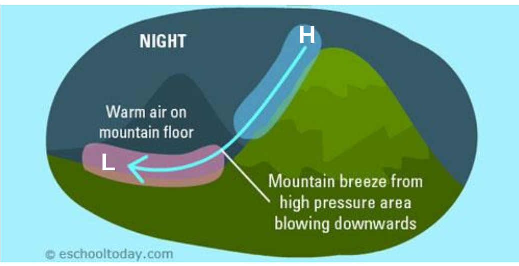
The wind direction, most often in the direction of a principle wind direction, is determined by the locations of the high- and low pressure areas. However, this direction is deviated by the Coriolis force (pp 83–86): in the northern hemisphere it is deviated to the right, in the southern hemisphere to the left. Furthermore, below the free atmosphere, i. e. near the ground, the wind is also affected by frictional forces. In addition it can also be changed by morphological structures such as by mountains, valleys and canions (examples: foehn winds, fall winds, upcurrents (updrafts), valley winds, mountain winds). For rotating systems such as for cyclones (hurricanes), centrifugal forces play also an important role.

Beaufort scale for wind forces: In units of Beaufort (Bft) one is referring to brease (between 2 and 5 Bft), strong winds, near gale and stormy winds between 6 und 8 Bft. For wind forces of 9 Bft one is referring to a storm. For wind forces of 12 Bft we speak about hurricanes. The relation between the wind velocity v and the Beaufort force B (1 B = 1 Bft), is discussed in Appendix 3-A-4-1.

80

Mountain and Valley Breeze





Valley Breeze

During the day, the air over the mountain slope heats up more than at the foot of the mountain. The warm air over the slope reduces in density. A low pressure (L) is created at the top of the mountain and a high pressure (H) from the cool air below, forces a cool breeze to move upward. This condition generates a breeze which we call <u>Valley breeze</u> (it starts at the Valley), and it is very common during warmer months when there is a lot of heating from the sun.

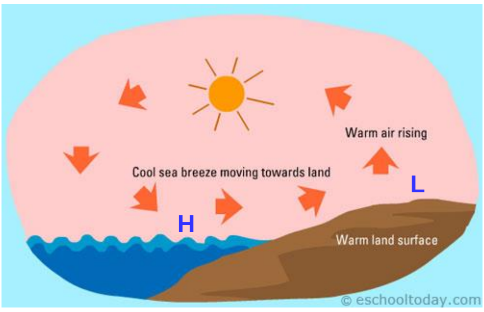
Mountain Breeze

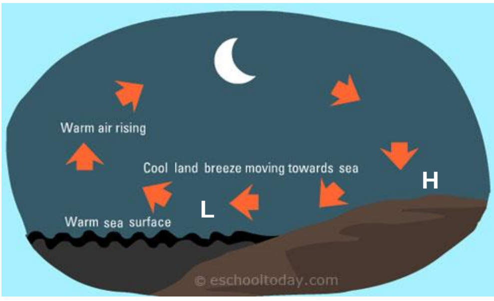
In the evening, it is a lot cooler as the sun goes to sleep. So the air at the upper slope of the mountain cools off very quickly and becomes dense. A high pressure (H) is created. At this time, the air at the valley floor is a lot warmer (low pressure L) and is forced to give way to colder air moving down the slope towards the valley floor. This is called <u>mountain breeze</u> (it starts from the mountain). And it is a lot common in the colder months where there is less warming from the sun.

81

Land and Sea Breeze

As the names suggest, the two breezes occur along coastal areas or areas with adjacent large water bodies. Water and land have different heating abilities (heat capacities). Water takes more time to warm up and is able to retain the heat longer than land does.



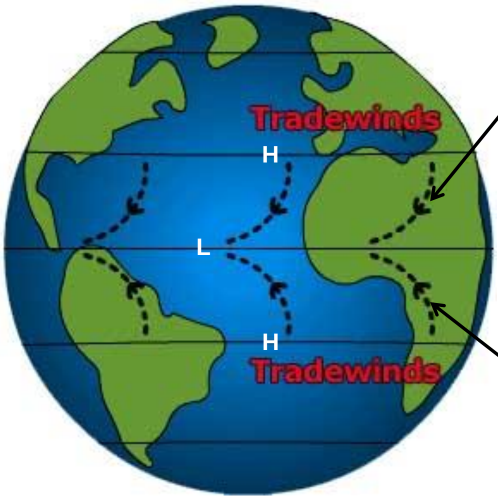


In the day, when the sun is up, the land heats up very quickly and the air above it warms up a lot more than the air over the water. The warm air over the land is less dense and begins to rise. Low pressure (L) is created. The air pressure over the water is higher (H) with cold dense air, which moves to occupy the space created over the land, The cool air which comes along is called a <u>Sea Breeze</u> (it starts from the Sea).

In the night, the reverse happens. The land quickly loses its heat, while the water retains its warmth. This means the air over the water is warmer, less dense and begins to rise. Low pressure (L) is created over the water. Cold and dense air (H) over the land begins to move to water surface to replace the warmer rising air. The cool breeze from the land is called a <u>Land Breeze</u> (it starts from the land).

82

Trade Winds



North-east trade

The Trade Winds do not directly flow from the tropics to the equator, but rather theire directions are deviated by Coriolis – Forces. As the Figure shows, the North-east trade wind and the South-east trade wind are deviated in opposit directions. (s. pp 84 und 85).

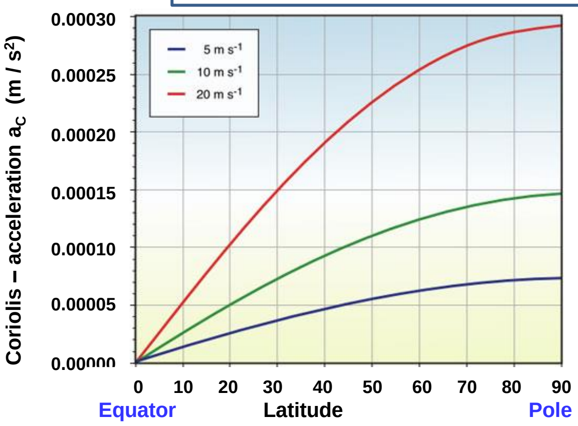
South-east trade

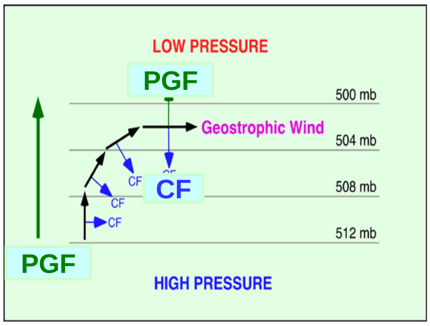
The direction of the wınd gives it hıs name:
North-east trade: north-east wind (H → L); South-east trade: south-east wind (H → L)

IZCZ: «International Convergence Zone» = zone near the equator in which there is very strong convection. The reason for this strong convection is the heating by the Sun. The ITCZ is limited by the zones of the trade winds of the two Hemispheres. In the ITCZ there are substantial precipitations every day.

83

Coriolis force caused by Earth - rotation





The srength of the Coriolis force depends on the rotational velocity and the latitude of the Earth. At the equator, the Coriolis force is zero and its strength increases by approaching the Poles. Furthermore, with increasing velocity the Coriolis force increases and as a consequence, the deviation of the wind direction increases with respect to the direction of the pressure gradient. If m is the mass of the air package moving with velocity v and if ω is the angular velocity of the Earth-rotation, then the Coriolis force F_C is proportional to the mass m and to the vector product of v and ω (s. p. 85).

Air under the influence of both the <u>Pressure Gradient Force (PGF)</u> and <u>Coriolis force (CF)</u> tend to move parallel to isobars in conditions where friction is low (1000 m above the surface of the Earth) and isobars are straight. Winds of this type are usually called <u>geostrophic winds</u>. Geostrophic winds come about because PGF and (CF) come into balance after the air begins to move.
As the movement begins, th CF begins to influence the moving air causing it to deflect from the right of its path. This de-flection continues until the PGF and CF are opposit and in balance with each other.

84

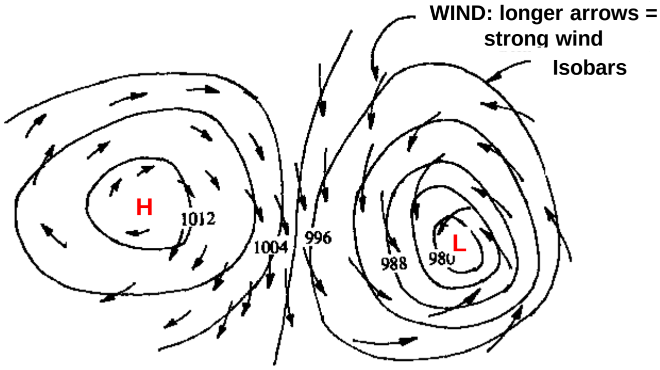
Wind current from High- to Low Pressures - Coriolis-Force

In the absence of Earth's rotation the winds would simply follow the pressure gradient from the High-pressure areas H to the Low-pressure areas L. Because of the rotation of the Earth, this wind direction is deviated by the Coriolis force (pp 83, 84). The Coriolis force $\vec{F}_C$, which acts on an air package of mass m, is proportional to the mass m and to the vector product of the velocity $\vec{v}$ of the air package and the angular velocity $\vec{\omega}$ of the system; in the present case it is the angular velocity of the Earth around the North – South axis:

$$\vec{F}_C = 2\,m\,(\vec{v} \times \vec{\omega}) \,.$$

$\vec{v} \times \vec{\omega}$ is the vector product of $\vec{v}$ and $\vec{\omega}$, i.e. $\vec{F}_C$ is perpendicular to both $\vec{v}$ and $\vec{\omega}$.

The magnitude of $\vec{v} \times \vec{\omega}$ is equal to $v * \omega * \sin(\phi)$; ϕ = angle between $\vec{v}$ und $\vec{\omega}$.



Directions of air currents in High- (H) - and Low pressure (L) areas

Wind flows from High pressure area (H) to Low pressure area (L)

The numbers indicate the air pressure in hPa;
1 hPa 100 Pa
1 Pa = 1 Pascal = 1 N/m^2
1013.25 hPa = 1 atm

Isobars are lines with constant pressures

Since the wind directions at the northern and southern hemispheres are opposite (s. p. 83), also the directions of current are opposite.

85

Effect of Coriolis force on rivers

All motions on our Earth are subjected to the Coriolis force. As an example, the picture shows the undermining of a riverside by the Coriolis force acting on a river. At the northern hemisphere, the riverside to the right of the flow direction is underwashed, while at the southern hemisphere the riverside at the left of the flow direction is affected.

Two other examples: The motion of projectiles and trade winds (s. p. 83) are affected by the Coriolis force.

86

3.5 Precipitations and extreme Weather conditions

87

Shape of a Raindrop in a Wind channel

Simuation of a falling raindrop in the wind-channel

Only very small raindrops with diameters smaller than D = 140 μm = 0.14 mm are perfectly spherical. This is due to the high surface tension of water. Larger drops are, however, flattened.

If larger raindrops start to fall, their shape is also spherical but only at the beginning. After a short time their shape changes to a Hamburger-like bun: their ground base is flat but their upper face is rounded (s. Figure). This deformation is caused by their relative motion against the air.

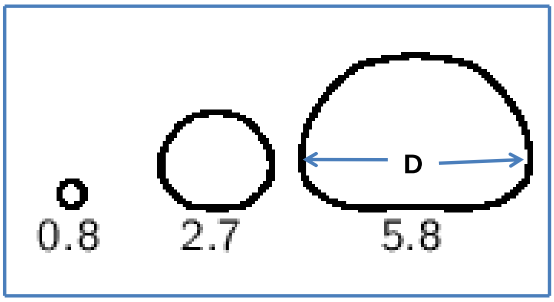
This “pancake” shape of the drop is observed for individual drops of a uniformly falling rain. In a rain, drops with a whole distribution of drop diameters exist.

Fall velocities of raindrops:

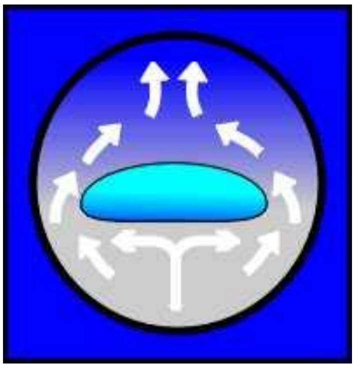
d = 0.5 mm: 7 km / h; d = 1 mm: 14 km / h
d = 3 mm: 29 km / h ; d = 8 mm: 43 km / h

88

Shapes of vertically falling raindrops of different sizes



Shapes of falling raindrops having different diameters (D in mm)

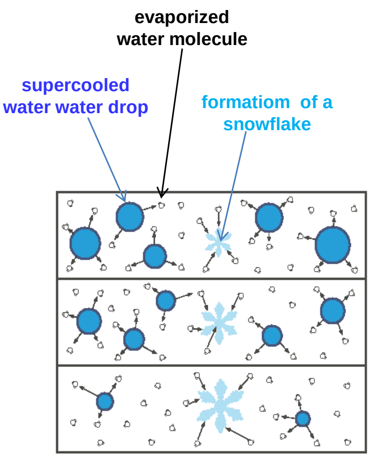


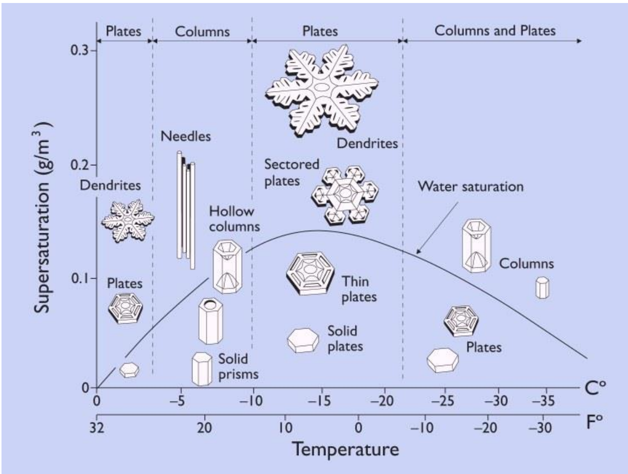
The white arrows indicate the air stream around a large falling water drop. The raindrop is flattened on the bottom and with a curved dome top.

Air flow on the bottom of the drop is greater than the airflow at the top. At the top, small air circulalation disturbances create less air pressure. The surface tension at the top allows the raindrop to remain more sperical while the bottom gets more flattened out.

89

Bergeron – Findeisen: Formation and Morphology of Snowflakes



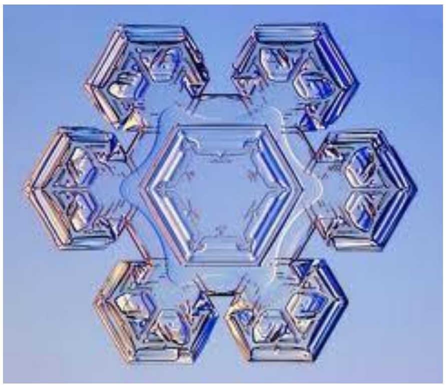


Left-hand picture: Snow crystals develop, if water molecules of supercooled water droplets directly condense to ice which is followed by a subsequent growth of ice crystals.

Right-hand picture: The hexagonal symmetry of a snow crystal is ultimately due to the hexagonal symmetry of Ice Ih , which in turn develops from the hexagonal structure of H_2O – clusters (Ref. R.0.4. Chapter 2 - pp 41, 50). The shape of snowflakes depends on different factors, such as the temperature, the relative humidity and air currents. The „Water saturation“ – curve corresponds to the difference between the saturation vapor pressure of supercooled water droplets and snow crystals (Ref. R.0.4: Appendix 4-A-3-1).

90

The Fascination of Snowflakes

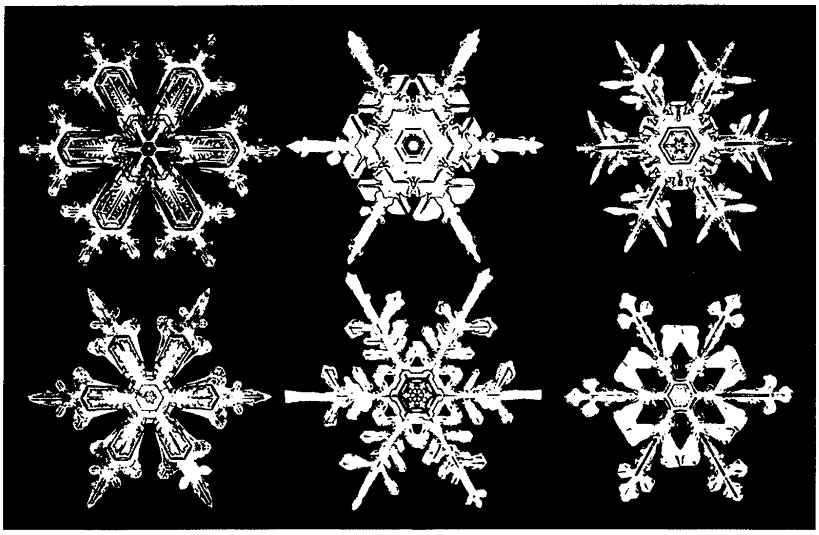


Snowflakes always have a hexagonal symmetry. This symmetry is already pre-formed in the hexagonal crystal structure .
All snowflakes consist of a large number of small snow crystallites which stick together to form flakes during descending in air

According to Bentley (1880), who collected and studied thausends of snowflakes during 40 winters, came to the conclusion that all of them had different detailed shapes !!

91

All snowflakes have hexagonal symmetry



All snowflakes have hexagonal symmetry, but the detailed structure of all flakes are different !

92

Hail

Formation : Hailstones are formed in the inner layers of the thunderstorm cells where supercooled water transforms into ice with the help of crystallizing nuclei .

The cycle of ice grains : They are first lift upwards by the upwind , then they fall bag to lower air layers , take up more additional water , rise up again to higher levels whereby additional water is frozen at the surfaces .

This process is repeated several times up to the point where a hailstone is too heavy to be carried by the upwind .

Fall velocity : normally , the diameter d of hailstones are about 0.6 to 3 cm . For d = 3 cm , the fall velocity is about 90 km/h .

Exceptions : diameters up to 10 cm with weights of more than 1 kg and fall velocities of more than 150 km/h have been observed !!

93

Hailstones after a Hailstorm

After a hailstorm

Picture of one of the largest hailstones : diameter about 10 cm , weight about 154 g (from M. Schletter)

The hailstorm is compared with the size of a 9 Volt accumulator .

[The erinaceous structure is clearly observed which indicates the freezing of smaller grains to a larger one] .

94

Cross section through a hailstone

The rings have been produced by the different depositions of layers during the complex vertical growth of the hailstone .

95

Lightnings and Thunder - Zeus has strock a terrible blow !!

In nature, a lightning is a spark discharge or a short-time arc of light between clouds or between clouds and Earth. As a rule, a lightning occurs during a thunderstorm due to an electrical charge of the water droplets or raindrops. The lightning is accompanied by thunder and it belongs to the so-called electrometeors. During this process, electrical charges (electrons and gas-ions) are exchanged and strong electrical currents are flowing. Depending on polarity, discharges can occur also from ground to clouds (upward lightnings).
A more detailed discussion of the formation, properties and dangers of lightnings is given in Chapter 8, Section 8.1, pp 335 – 348.

electrical voltage :	some 100 million Volts !
electrical currents :	several 100’000 Ampère !
maximun air temperature :	up to 30’000 °C !
local air pressure :	up to 100 atmospheres !
explosion of air :	thunder !

96

Tornadoes

Tornado, 1949 inKansas (USA)

Tornados are packed into tight, swirling spirals of power. The winds of the most powerful Tornadoes can reach speeds of approaching 515 km/h; they are the most violent winds on Earth. They are faster than many airplanes can fly, and almost half the speed of sound. The wast majority of tornadeos, however, range at less than 322 km/h.

Tornadoes are quite small as atmospheric phenomena go. The width of the funnel at ground-point usually ranges from a few dozen to several hundred meters at ground-poimt. Yet, because Tornadoes move rapidly along the ground, they can cause damage over a larger area than their small size might suggest.

Tornadoes tend to occur over flat terrain, but can travel across mountains and form over water. Tornadoes are most common and most powerfull in the United States.

When Tornadoes strike near populated areas, the damage can be severe. Due to their slze and behavior, most damage is localized and random.
Tornados are powerfull killers ; in the US, an average of 100 people is killed each year. Tornadoes pack the most destructibe force of any atmospheric phenomenon, possessing a violence unmatched by any other force of nature.

97

Hurricane Isaac

Isaac at 28. 8. 2012 offshore Louisianas

- Formation at: 21. August 2012
- Ending at: 1. September 2012
- Top speed: 130 km/h: (during 1 Minute)
- Deepest air pressure: 968 mbar

- Victims: 41 (direct) , 3 (indirect)
- Damages: 2 Billions US $
- Affected areas: Cuba, Jamaica Bahamas, Florida, Alabama, Missisippi, Louisiane, Texas …

A Hurricane is defined as a tropical cyclone if it reaches at least hurricane strength. This means that its wind strength is at least 12 in the Beaufort scale. This corresponds to more than 118 km/h. A Hurricane develops over warm tropical areas. As a rule, Hurricanes arise between May and December, most of it between July and September.

The word «Hurricane» originates from the notion «Huracan». In the language of the Taino- and Maya-languages this means the «God of Winds».

98

Hurricane Sandy - 2012

Wind path of Hurricane
(bottom up)

Canada ←
← East coast USA
← Bahamas ←
← Cuba ←
← Jamaica ←
← Dominican Republic ←
← Haiti

- **Formation at:** 19. October 2012
- **Ending at:** 29. October 2012
- **Top speed:** 185 km/h
- **Lowest air pressure:** 940 mbar (hPa)
- **Victims :** 209 (direct)
- **Damages :** 52.4 Billion US $

3.6 Utilisation of Wind - Energy

100

Wind - Energy: General Remarks

If we speak about wind energy, it is the kinetic energy of the moving air masses of the atmosphere. Since this energy is replaced relative quickly through the influence of the Sun, this energy is referred to as a renewable energy..

The wind energy utuîlisation by using windmills (today for the production of electrical current with the aid of wind energy stations), has been used since the antiquity for the production of energy from the environment. The windmill is an antic technical structure, which produces energy by setting in motion the wings of the windmill.

Historically, windmills and watermills were the only pre-industrial power machines of humanity. They have been used for a variety of applications such as for grinding mills,oil mills (for the production of plant oil from oil seats), for processing of raw materials (by means of sawmills, for example), as well as for pump stations and sewage pumping stations.

In addition to the production of mechanical power, today, the electrical power is of great importance. The kinetic energy is $E_{kin} = (1/2)\ dm\ u^2$ where $u = ds/dt$. The power is $P = dE_{kin}/dt = (1/2)\ (dm/dt)\ u^2 = (1/2)\ (dm/ds)\ (ds/dt)\ u^2 = (1/2)\ (dm/ds)\ u^3$. If $dV = A\ ds$ is the volume element of the wind package, ρ its density and dm its mass, it follows $dm = \rho\ dV = \rho\ A\ ds$ and $dm/ds = \rho\ A$. Replacing dm/ds in the expression for P and adopting an efficiency factor $k < 1$, we obtain:

$$P = k^* (1/2)^*\rho^*A^*u^3 \ .$$

Thus, the power is proportional to the cube of the wind velocity u. A realistic value for the efficiency factor is $k \approx 0.4$.

101

Britz – Windmill in Berlin

The Britzer Windmill has been constructed at 1865 in the Britz Garden in Berlin. The 20 meter, twelve-cornered Dutch- type windmill rises high in the air with its 12 meter wings at the centre of an expansive orchard at the edge of the Britz Gardens.

Britzer – Windmill in Berlin

A windrose automatically turns the cap mounted on cast-iron rollers. The Britz Windmill (Britzer Mühle) is equipped with two stone millstones and operated until 1936: after that it converted to the use of a Diesel engine,

Grinding pass with millstone

102

Electrical Power from Wind farms

Wind farm in Denmark

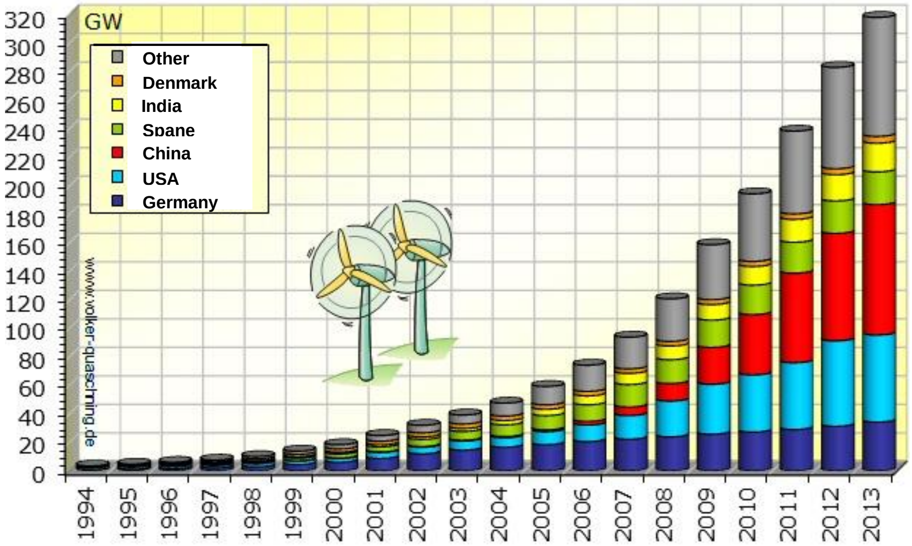
Achievable electric Power P is proportional to the third power of the wind velicity u: P ~ u^3 (s. p. 101). Based on conservative assumptions, scientists from Harvard University evaluated at 2009 the global potential of wind energy. They came to the conclusion that the global wind energy surpasses the electrical energy demand by a factor 40, while the total wind energy is 5 times larger than the overall needed energy.

Because of the irregular nature of wind current, the generated electrical energy must be combined with other energy sources in order to achieve a continuous energy supply. An other possibility is <u>storage</u> via <u>wind gas</u>. (From the electrical current produced by wind energy, natural gas (~ CH_4O) can be produced).

Transmission of high voltage DC (<u>D</u>irect <u>C</u>urrent) as produced by Wind farms over large distances is not easy because of transmissionl losses and electrical breakdown, but laboratory experiments of ABB and other Companies are promising.

103

Worldwide installed Wind power



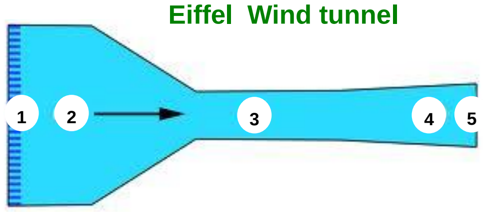
The installed power is the maximum power of a Wind farm, in our case the maximum power of all built wind power plants. In other words, we are referring to the so-called rated power. This is the maximum possible power and not the actually produced power.
[1 GW = 1 Gigawatt = 1000 millions Watt = 10^9 Watt].

104

The Wind Tunnel

A wind tunnel is used to study and measuring the aerodynamic and aeroacoustic properties of objects. Very well known examples are the wind tunnel study of cars and of aeroplanes (s. Chapter 4). Concerning cars, it is important to achieve a low air resistance and an optimal lift coefficient. For airplanes (Chapter 4), considerably more aspects play a role: in addition to to air resistance and lift, other important factors are airfoil, stability and control. etc.
Today, other objects are raylways and ships which are evaluated extensively in wind tunnels. Of importance are also areodynamic properties buldings. especially high-rise buildings, of chimneys and of bridges.

Eiffel Wind tunnel



1) Rectifier: avoids air turbulances and ensures a uniform distribution of air in the wind tunnel.
2) Assures a uniform velocity profile in the wind tunnel
→ The arrow marks the flow direction
3) Section for measuring the model object
4) Diffuser: for pressure regain
5) Blower: for suction of air, thereby creating the air current

The open design of the wind tunnel is also known as the Eiffel wind channel in memory of the man who constructed the Eiffel-Tower. In this design, the air is sucked off from the environment, flows through the air channel and finally escapes out of the tunnel. Advantages of this desigh are: Coast-effective, easy to implement and moderately susceptible with respect to self-contamination such as by smoke. Disadvantage: Dependence on the sucked air which can cause temperature- and pressure fluctuations.

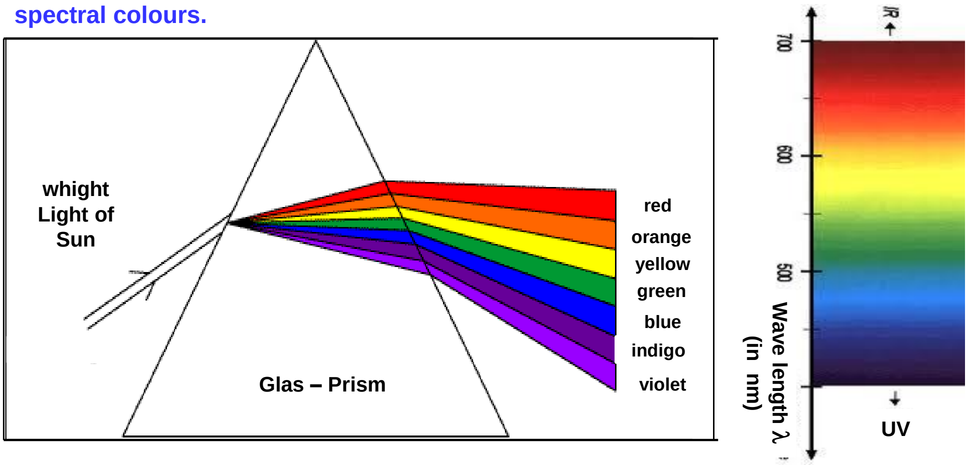
105

Anhang - Kapitel 3

3-A-0

Dispersion of Sunlight

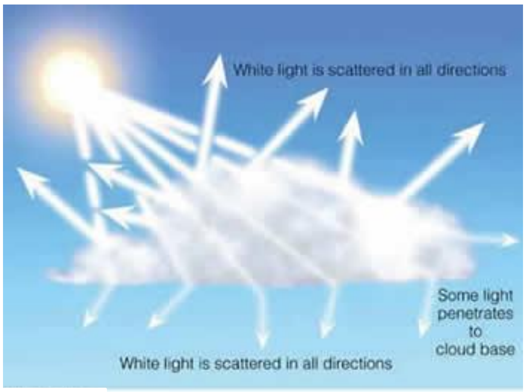
In connection with the colours of the sky at day and at night (pp 61, 62), we consider the spectral decomposition of white light emitted by the Sun into its spectral colours.

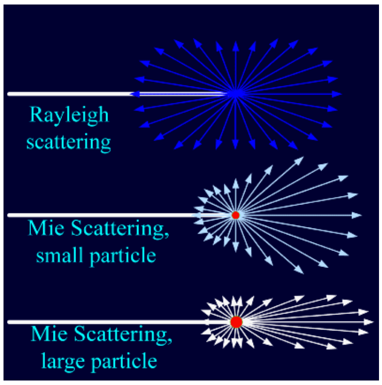


Due to the non-normal incidence of light and due to the refractive index $n = n(\lambda)$ (λ = wavelengths of sunlight) of the prism, the incident light beam is refracted by the prism at different angles. This effect is reinforced at the exit surface of the prism, where the refracted light beam leaves the prism at widely different exit angles. [For quartz (SiO_2), n((400 nm) = 1.55773 and n(650 nm) = 1.54205]. Visible range (VIS): 380 nm $< \lambda <$ 780 nm; (1 nm = 10^{-9}).

3-A-1-1

Scattering of Sunlight by Clouds: Mie - Scattering





Mie scattering dominates at days where large particles are in the air – examples are water droplets in clouds, dust or smoke. These particles are considerably larger than the wavelengths of visible Sunlight with which they interact. [wathelength λ of green light is ≈ 500 nm = 0.5 µm (s. p. 3-A-1-1); diameters of water dropleds for nice weather clouds range between ≈ 1 – 15 µm (s. p. 70)].

If such radiation interacts with particles of this size, there is no preferential scattering of particular wavelenghts. All wavelengths are uniformally scattered and for this reason, the scattered light remains white (s. p. 70). For large particles (water droplets of nice weather clouds), the incoming sunlight is strongly forward scattered (right-hand Figure).

3-A-3-1

Stratospheric Clouds

Arctic PSC

Polar Stratospheric Clouds (PSC's) are present in the Stratosphere in altitudes above 20 km, often between 22 km and 29 km. The formation of PSC's is possible if the temperature is lower than - 78 ^{0}C. This happens regularly in the polar regions beyond 80^0 of northern and southern latitudes, respectively. On the southern hemisphere, PSC's are considerably more frequent.

In the stratosphere, the concentration of water vapor is very low, and therefore water clouds as in the Troposphere do not exist. PSC's consist of crystallites of sulfuric acid (H_2SO_4) or of nitric acid (HNO_3). If the temperaures are very low, the acidic crystallites can be covered by a thin layer of water ice. On the surface of the crystallites, chemical reactions can take place. These reactions are of importance for ozone depletion.

The defraction and interference of sunlight by these ice crystallites often produces pearly colors. It is for this reason that PSC's are also referred to as «mother-of-pearl clouds». This coloration is most clearly visible if the Sun is already one to six degrees below the horizone.

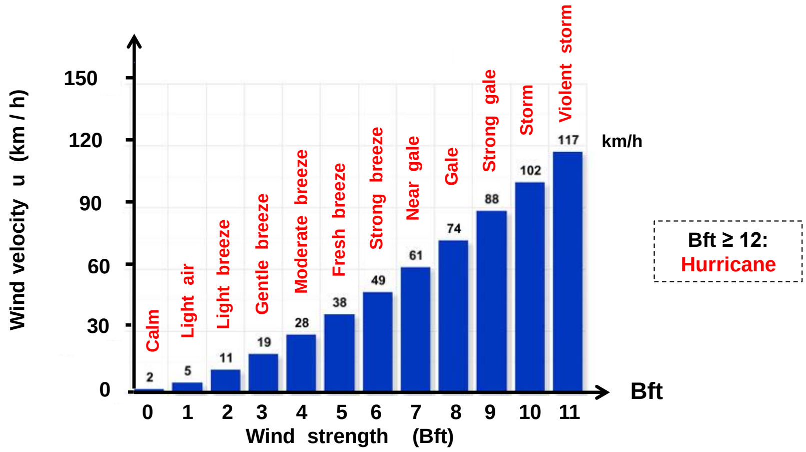
3-A-3-2

The Beaufort - Scale

The Beaufort scale is a scale for the classification of winds according to theire velocity. It is the most widespread system for the description of wind velocities. The scale is named after Sir Beaufort (in units of Bft), although his contribution to its development is rather modest. After a Revision at the year 1946, the following relation between the wind velocity u and the wind strength in Bft has been adopted:

$$u = 0.8360 \text{ m/s} * Bft^{3/2} \quad \text{or solved after Bft :} \quad Bft = (u / 0.8360)^{2/3} ,$$

Here, u is the wind velocity at 10 m above the surface. If u is expressed in units of km/h, the relation is : $u = 3.010$ km/h * $Bft^{3/2}$. (The Beaufort scale varies between 0 and 12: $0 \le Bft < 12$).



3-A-4-1

Dynamics of falling Hailstones and Raindrops

Let v(t) be the velocity of the particle in the air (Graupel, Hailstone or water drop) at time t. At t = 0 we assume that the velocity of the particle is zero: v(0) = 0.The total force acting on the particle of mass M has three contributions: the weight G, the friction force R and the buoyant force L; K = G – R – L. Since the densities of hailstones or raindrops are much larger than the density of air, L can be neglected i.e.

$$K = G - R \qquad (1)$$

The weight is M g (g = 9.81 m/s² = gravitational acceleretion). For larger particles one has to use the Newton friction force which is proportional to the v^2 [for falling dust particles, R is proportional to v (s. Chapter 5, pp 221 – 231)]. In the present case, Newton's friction force is

$$R = (1/2)\ \rho_A\ C_W\ A_H\ v^2 \qquad (2)$$

Here, ρ_A is the density of air, A_H is the cross section of the particle and C_W is the so-called drag coefficient. To calculate v(t) of a Hailstone H with mass M_H and density ρ_H, the following differential equation must be solved:

$$K_H = M_H\,(dv/dt) = M_H\, g - (1/2)\,\rho_A\ C_W\ A_H\ v^2 \qquad (3)$$

The solution of this equation with the initial condition v(t = 0) = 0 (s. Ref. 3.A.5.1) is

$$v(t) = v_{term} * \tanh[(g\, t / v_{term})] \qquad (4)$$

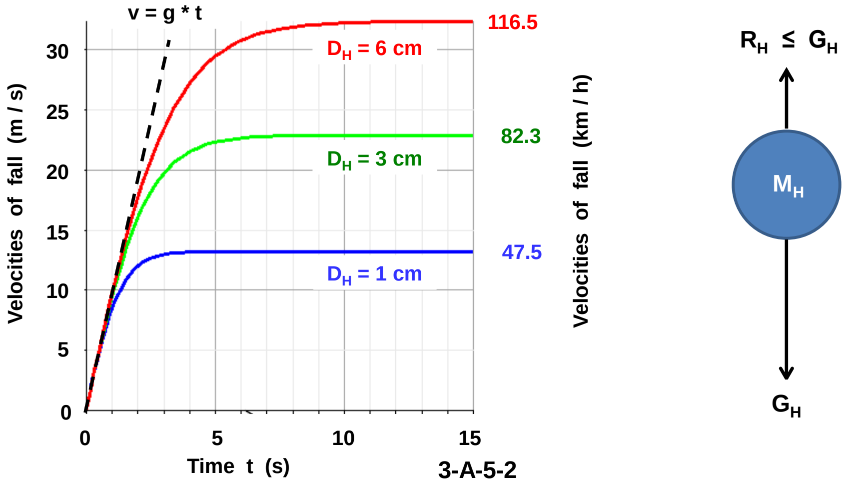
where tanh (x) is the hyperbolic tangent function of x. v_{term} is the constant rate of descent after a sufficiently long time:

$$v_{term} = \sqrt{2\, M_H\, g / (\rho_A\, A_H\, C_W)} \qquad (5)$$

3-A-5-1

Velocities $v(D_H,t)$ of falling Hailstones

The Figure below illustrates the fall velocities $v(t) = v_{term} \tanh[(g\, t / v_{term})]$ (eq. 4). Let ρ_H be the density of the Hailstone and $V_H = (4\pi/3)\, R_H^3 = (\pi/6)\, D_H^3$ its volume; then we have $M_H = \rho_H V_H = (\pi/6)\, D_H^3 \rho_H$ and $v_{term} = 2\, [(D_H\, g / 3\, C_W)\, (\rho_H / \rho_A)]^{½}$ (eq. 5). Density of Hail: $\rho_H \approx 0.8$ g/cm³ = 800 kg/m³; density af air: $\rho_A \approx 1.2$ kg/m³; drag coefficient $C_W \approx 0.5$. The curves have been constructed by P. Brüesch with the help of the Maple 13 Program. The black dashed line v = g t is the tangent to the curves passing through the origin of the coordinate system and describes the free fall of the masses in vacuo.



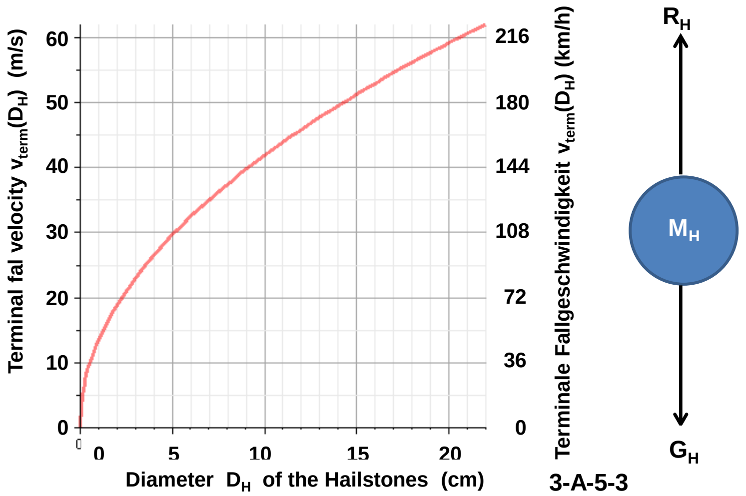
3-A-5-2

Terminal velocity of fall of a Hailstone as a function of diameter

In the following we discuss the terminal velocity of fall, v_{term}, as a function of the particle diameter D_H of the Hailstone. For a spherical Hailstone, the mass M_H appearing in eq. (5) of p. 3-A-5-1 is given by $M_H = (\pi/6)*D_H^3\rho_H$ and its cross section is $A_H = (\pi/4)\, D_H^2$. Substitution into eq. (5) gives:

$$v_{term} = 2\sqrt{(D_H\, g / 3\, C_W)*(\rho_H / \rho_A)} \qquad (6)$$

The diagram below has been calculated with a drag coefficient $C_W = 0.5$ which corresponds to a large Reynolds number (s. p. 3-A-5-3, d).



3-A-5-3

Parameters for calculating $v_{term}(D_H)$:

$g = 9.81$ m / s²
$C_W = 0.5$
ρ_H = 800 kg / m³
ρ_A = 1.2 kg / m³

$R_H = G_H$

For the terminal fall velocity $v_{term}(D_H)$ shown in the Graph, the values of the forces G_H and R_H are equal and hence, the resulting force is zero.

Size distributions of Hailstones - Mathematics

For describing the distribution of Hailstones we adopt the so-called two-parametric Gamma-distribution. This distribution is defiend as follows:

$$y_{\alpha,\beta}(x) = [\beta^{\alpha} / \Gamma(\alpha)]\, x^{\alpha-1} \exp(-\beta x) \qquad (1)$$

Here, α and β are two positive parameters; $\Gamma(\alpha)$ is the Gamma function of α and $\exp(-\beta x)$ is the exponential function of the varable x.

For the distribution of the diameters D_H of Hailstones we use an equation analogous to eq. (1) but with different notations:

$$f(D_H/D_0) = N(D_H)/N_0) = [\lambda^n / \Gamma(n)]\, (D_H/D_0)^{(n-1)} \exp[-\lambda\,(D_H/D_0)] \qquad (2)$$

$N(D_H)$ is the number of Hailstones with diameter D_H per m^3, N_0 is the total mumber of Hailstones per m^3, and D_0 = 1 cm is the unit diameter. In eq. (2), n corresponds to α, λ to β and D_H/D_0 to x of eq. (1). By equating the first derivative of $f(D_H/D_0)$ with respect to the variable D_H/D_0 equal to zero (maximum of $f(D_H/D_0)$), one obtains $\lambda^*(D_m/D_0) = n - 1$, where D_m is the diameter of the maximum of $f(D_H/D_0)$. For simplification we put n = 3 and using $\Gamma(3) = 2$ we obtain:

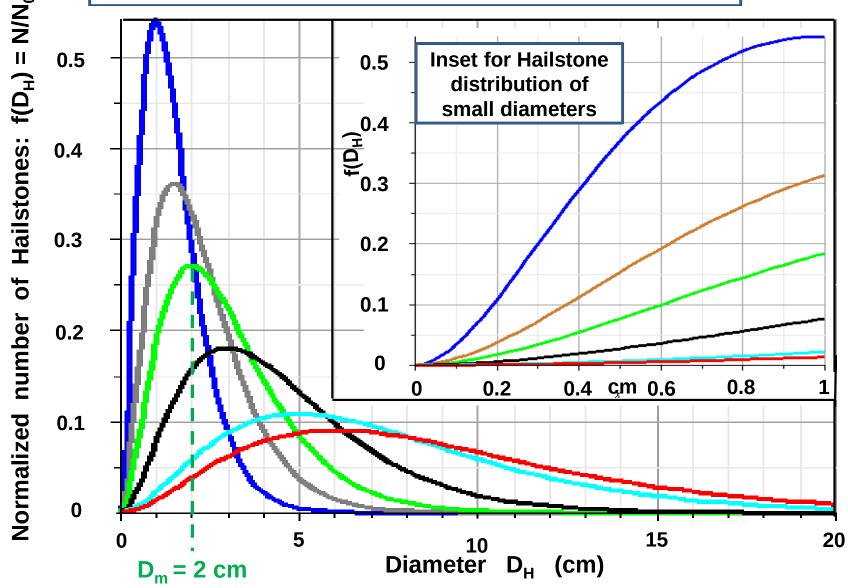
$$f(D_H/D_0) = N(D_H)/N_0) = [\lambda^3 / 2]\, (D_H/D_0))^2 \exp[-\lambda\,(D_H/D_0)] \qquad (3)$$

Some examples (compare with the Figure of p. 3-A-5-5):

$D_m = D_0 \rightarrow \lambda = 2$, $f_m(1) = 0.541$; $D_m = 2\,D_0 \rightarrow \lambda = 1$, $f(2) = 0.270$: $D_m = 3\,D_0 \rightarrow \lambda = 2/3$, $f(3) = 0.180$; $D_m = 5\,D_0 \rightarrow \lambda = 0.4$, $f(5) = 0.108$; $D_m = 6\,D_0 \rightarrow \lambda = 0.3333$, $f(6) = 0.090$.

3-A-5-4

Size distributions of Hailstones - Graphs



Normalized number of Hailstones $f(D_H) = N(D_H)/N_0$ as a function of diameter D_H. (N_0 = total number of Hailstones per m^3. The curves have been calculated for 6 mean diameters D_m = 1, 2,.3, 4, , 5 and 6 cm on the basis of two-parametric Gamma-distributions (s. p. 3-A-5-4). Inset: at the origin $D_H = 0$, the curves have zero slope. Graupel, also called soft hail, are not shown in the Inset; they have diameters ranging between 0.2 und 0.5 cm and are composed of snow pellets encapsulated by ice.

3-A-5-5

References: Chapter 3

R-3-0

3-0 General Literature about Weather, Clouds and Climate:

R.3.0.1 The Weather Handbook - Alan Watts
2nd Edition; Copyright @ 1994, 1999 by Alan Watts
Library of Bongress Cataloguing-in-Publication Data
SBN 1-57409-081-8

R.3.0.2 Geomorphological impact of extreme weather
Case studies from central and eastern Europe
Series: Soringer Geography
Loczy, Denis (Ed.) - 2013, XXI

R.3.0.3 Insiders: Extreme Weather
Michel Mogin, Barbara G. Levine
Publisher: Simon and Schuster
July 2011: ISBN 184011746X

R.3.0.4 Weather - http://en.wikipedia.org(wiki(Weather

R.3.0.5 Meteorology - http://en.wikipedia.org/wiki/Meteorology

R.0.3.6 Wetter und Klima - Kompakt und Visuell
Vorhersagen - Wetterphänomene – Klimaänderungen – Meteorologie
Dorling Kindersley - London, New York, Melbourne, München und Delhi

R.3.0.7 Physische Geographie (von Julius Wagner)
Begründet von Heinrich Harms: bearbeitet von Julius Wagner
List Verlag München; 8. Auflage (1979); pp 301 – 350

R.3.0.8 Fundamentals of Weather and Climate
Robin Mcllveen (Author)
Dispatched from and sold by Amazon

R.3.0.9 Atmosphere, Weather and Climate
Roger G. Barry (Author), Richard J. Chorley Author)
Kindle Edition (2009)

R-3-1

3.1 Weather: General Aspects

R.3.1.1 High-pressure area - http://en.wikipedia.org/wiki/High-pressure_area

R.3.1.2 Low-pressure area - http://en.wikipedia.org/wiki/Low-pressure_area

R.3.1.3 Meteorology - From Wikipedia, the free encycopedia
www.en.wikipedia.org/wili/Meteorology

R.3.1.4 Atmospheric circulation - http://en.wikipedia.org/wiki/Atmospheric_circulation

R.3.1.5 Water vapor - www.http://en.wikipedia.org/wiki/Water_vapor

R.3.1.6 p. 58: The Weather: Keywords
Illustration from P. Brüesch

R.3.1.7 p. 59: Weather – Meteorology – Motor – Development

a) Comments and picture from «Wetter» - http://de.wikipedia.org/wiki/Wetter
b) see also Reference R.3.0.5
c) Weather . Wikipedia, the free encyclopedia - http://en-wikipedia.org./wiki/Weather

R.3.1.8 p. 60: Weather – Properties – Phenomena abd Base Items
Information from: http://de.wikipedia.org/wiki/Wet - (Illustration from P. Brüesch)

R.3.1.9 p. 61 : Die Farben des Himmels am Tag

- Rayleigh Streuung - http://wikipedia.org/wiki/Rayleigh-Streuung
- www.planet-schule.de/warum/himmelsblau/.../t9/himmelsblau.pdf
  mit Herleitung der Rayleigh – Streuung und entsprechenden Literaturangaben
- Rayleigh scattering - http://en.wikipedia.org/wiki/Rayleigh_scattering
- Why is the sky blue ? - http://spaceplace.nasa-gov/blue-sky/ - (mit Bild zu p. 61)
- Himmel (planetär) - http://de.wikipedia.org/wiki/Himmel_planet%C3%A43

R-3-2

R.3.1.10 p. 62: Red dawn sky and red sunset sky

a) Sunset - http://en.wikipedua.org/wiki/Sunset
b) Morgenröte - http://de.wikipedua,org/wiki/Morgenr%C3%B6te
c) Wie entsteht Himmelsblau und Abendrot?
http://www.weltderphysik.de(thema/hinter-den-dingen/klima-und-wetter/jimmelsblau-undabendrot/
www.planet-schule.de/warum/himmelblau/.../t9/himmelsblau-pdf
Left-hand picture: Sunrise . fom: www.google.ch/search - Images
Right-hand picture: Sunset: from www.google.ch/search - Bilder

3.2 The humid Troposphere

R.3.2.1 p. 63: Weather of the Troposphere (Title)

R.3.2.2. p. 64: The humid Atmosphere – Water vapor

a) Absolute Humidity
http://apollo-lsc.vsc.edu/classes/met130/notes/chapter4/absol_hum.html
see: image von http://www.google.ch - *The Troposphere_Air parcel»; Images→ Absolute Humidity
b) Absolute humidity -- cyclopedia.net - http://www.cyclopedia.es/wiki/Absolute_humidity

R.3.2.3. p. 65: Absolute and relative humidity of air

a) Picture in «Orographic Clouds»
«Water content of air at 25, 50, 75 and 100 % relative humidity
http://windowoutdoors.com/WindowOutdoors/Why%20clouds%20form%20on%20mountain%20tops.html
b) Humidity: http://en.wikipedia.org/wiki/Humidity
c) s. also: «Luftfeuchtigkeit» - from Wikipedia, der freien Enzyklopedie
http://de.wikipedia.org/wiki/Luftfeuchtigkeit
d) s. also: Humidity and Dew Point: Table http://rolfb.ch/tools/thtable.php

R-3-3

R.3.2.4 p. 66: About the Dew point

a) Dew point - http://en.wikipedia.org/wiki/Dew_point
Definition of dew point - Figure of: Dew polnt – relative Humidity as a function of air temperature
b) Taupunkt: http://de.wikipedia,org/wiki/Taupunkt

R.3.2.5 p. 67: Dew point: Equation for T_d as a function of T and RH

a) MET4 AND MET4A CALCULATION OF DEW POINT
http://www.paroscientific.com/dewpoint.htm
b) The Relationship betweeb Relative Humidity and the Dewpoint Temperature in Moist Air
American Meteorological Society - February 2005 BAM ʃ / 225 – 233

The World of Clouds

R.3.3.1 p. 69: Formation and ascent of clouds

a) How Clouds form: https://www.nc-climate.ncsu.edu/edu/k12/.cloudformation
b) Why is moist air less dense than dry air at the same temperature?
c) Density of Dry Air, Water Vapor and Moist Humid Air -
http://www.engineeringtoolbox.com/density-air-d_680.html

R.3.3.2 p. 70: Droplets and crystallites - Figure from P. Brüesch

R.3.3.3 p. 71: Cumulonimbus clouds - Cumulonimbus Clouds; bretaniongroup.com

R.3.3.4 p. 72: Why do Clouds not fall from the Sky ?

a) http://www.islandnet.com/~see/wheather/elements/cloudfloat.html
b) Why do clouds float when they have tons of water in them ? - Scientific American - June 10, 2002
http://www.scientificamerican.com/article/why-do-clouds-float-when/

→

R-3-4

R.3.3.5 p. 73: Colors of Clouds - white

a) Colours of Clouds: white - http://en.wikipedia.org/wiki/Clouds
b) Streuung des Lichts an Wolken - http://de.wikipedia.org/wiki/Mie-Streuung

R.3.3.6 p. 74: Colors of Clouds: blue – white - http://weathersavvy.com/cumulonimbus5_OPT.jpg

R.3.3.7 p. 75: Colours of Clouds: white-gray – dark-gray - Regenwolken: foto community.de

R.3.3.8 p. 76: Colours of Clouds at Sunset: dark-red – orange-pink - www.yunphoto.net/es/photobase/hr/hr545.html

R.3.3.9 p. 77: Structure and charge distribution in Thunderstorm Clouds
(Struktur von Ladungsverteilung in Gewitterwolken)
U. Funke: Atmosphärische Elektrizität (2003) - www.sferics.physik.uni-muenchen.de/Messgrund/

R.3.3.10 p. 78: Very Threatening Thunderstorm Cloud - Sehr bedrohliche Gewitterwolke
Google: Bilder; unter «Sehr bedrohliche Gewitterwolken»

3.4 The Wind

R.3.4.1 p. 80: Wind - www.en.wikipedia.org/wiki/Wind

R.3.4.2 p. 80: High pressure area - http://en.wikipedia.org/wiki/High-pressure-area

R.3.4.3 p. 80 : Low pressure area - http://en,wikipedia.org.wiki(Low-pressure-area

R.3.4.4 p. 80: Der Wind – Allgemein - Wind - www.htttp://de.wikipedia.org/wiki/Wind

R.3.4.5 p. 81: Mountain – Valley Breeze - What are Mountain and Sea Breezes ? - eSchooltoday
www.eschooltoday.com/.../mountain-and-vakkey-bre:::

R.3.4.6 p. 82: Land – Sea Breeze
What are Mountain and Sea Breezes ? – eSchooltoday - www.eschooltoday.com/.../mountain-and-vakkey-bre..

R-3-5

R.3.4.7 p. 83: Trade Winds

a) Trade Wind - http://en.wikipedia.org/wiki/Trade_wind
b) Trade Winds - http://www,rossway.net/trades.htm (Picture of Trade Winds)
c) Passat (Windsysteme) - http://de.wikipedia.org/wiki/Passat_(Windsystem)

R.3.4.8 p. 84: Coriolis force caused by Earth - rotation

a) Forces Acting to Create Winds - http://www.physicalgeography.net/fundamentals/7n.html
Left-hand Figure: Coriolis acceleration as a function of latitude:
Right-hand Figure: Air under the influence of both the pressure gradient forces and the Coriolis Force
Note: Force = mass m x acceleration a: Coriolis Force: $F_C = m \times a_C$
(For clarity, both Figures have been slightly modified by P. Brüesch)
b) The Climate System - EESC 2100 Spring 2007
Atmospheric Forces, Balances, and Weather Systems
http://eesc.columbia.edu/corses/ees/climate/lectures/atm_dyn.html
c) Coriolis Effect - Essay Web - http://essay.web.net/geology/quicknotes/coriolis.shtml
d) Corioliskraft - http://de.wikipedia.otg/wiki/Corioliskraft

R.3.4.9 p. 85: High- and Low pressure wind areas – Coriolis – force

a) What causes weather ? - Weather Questions
http://www.weatherquestions.com/What_causes_weather.htm
(Figure of p. 85; Text from, P. Brüesch)
b) Forces Governing The Wind
http://www.lakeeriewx.com/CaseStudies/MesoscaleWind/ForcesGoverningWind.html
c) Mechanik in bewegten Bezugssystemen
http://e3.physik.uni-dortmund.de/~suter/...A3.../2.6_Bezugssysteme.pdf
d) Elemente des Wetters - Alpenwetterfibel für Hänge- und Paragleiter
http://www.kerschhofer.net/wetterkunde-paragleiter/1.htm

R.3.4.10 p. 86: Effect of the Coriolis force in rivers (picture)
a) Wissen.de - Coriolis Kraft - . http://www.wissen.de/coriolis-kraft
b) The Gravity of the Situation - http://www.dyarstraights.com/gundan.test/the.gravuty.of.the.situation
c) Meandering Rivers (No, 2453) - by John H. Lienhard - http://www.uh.edu/engines/epi2453.htm

R-3-6

3.5 Precipitations and extreme Weather conditions

R.3.5.1 p. 88: Falling raindrop in the wind channel

Source : Falling raindrop in the wind channel: jpg: Film und Standard
http://www.cloudgalery.mpich.de/Precipitation/FallingDrop/tropfen_neu.htm
R. Jaenicke, IPA Universität Mainz, 2002

R.3.5.2 p. 89: Shapes of falling water drops of different sizes

a) The Shape of Raindrops
James E. McDonald - pubeb1.princeton.edu/…/mcdonald_sa_190_2_64_54.pdf
b) 2.2 Rain - 2.2.1: Raindrop size - http://sts.bwk.tue.nl/drivingrain/fjrvanmook2002/node8.htm
contains also left-hand picture
c) Philipp Lenard: Brushing the Teardrops from Rain
Weather People and History - http://www.islandnet.com/~see/wheather/history/lenard.htm
contains also right-hand picture:
d) The Shape of a Raindrop - http://pmm.nasa.gov/node/145

R.3.5.3 p. 90: Formation and Morphology of Snowflakes

a) Bergeron process: http://en.wikipedia.org/wiki/Bergeron_process
b) left-hand picture: from «Der Bergeron-Findeisen-Prozess-ethz.ch»
iacweb.ethz.ch/staff/eszter/…/Bergeron-Findeisen.pdf
right-hand picture: The hexagonal symmetry of snowflakes
http://www.its.caltech.edu/~atomic/snowcrystals/primer/primer-html
www.its.caltech.edu/~atomic/snowcrystals/photos/photos.htm

R.3.5.4 p. 91: The Fascination of Snowflakes

a) Fotos found under - «Snowflakes» – Bilder → Schneeflocken w0401226077.jpg
b) see also Description by Philip Ball :
«A Biography of Water»
Wiedenfeld R. Nicolson M ; London (1999)
(Snowflakes : pp 170 – 181)

R-3-7

R.3.5.5 p. 92: All snowflakes have hexagonal symmetry
s. Google,ch, Schneeflocken - Snowflakes (with Fotos)

R.3.5.6 pp 93 – 95: Hail und Hailstormes
a) Hail: www.http://en.wikipedia.org/wiki/Hail
b) Hagel: www.http://de.wikipedia.org/wiki(Hagel

R.3.5.7 p. 94: Hailstones after a Hailstorm / Very large Hailstone
a) http://de.wikipedia.org/wiki/Bild:Hailstorm.jpg
b) Very large Hailstone - http://home.arcor.de/student.martin/wetter/pdf/Extremhagel.pdf

R.3.5.8 p. 95: Cross section through a hailstone with grow rings
www.fotocommunity.de/pc/pc/display/17206268

R.3.5.9 p. 96: Lightnings and Thunderstorms
a) Thunderstorm: http://en.wikipedia.otg/wiki/Thunderstorm
b) Unwetter: http://de,wikipedia,org/wiki/Unwetter (contains Figiure of p. 96)
Text zu Blitz: www.daikymail.cu.uk/ ; aus Wikipedia, der freien Enzyklopedie
c) Blitz: http://de.wikipedia.org/wiki/Blitz

R.3.5.10 p. 97: Tornados and Hurricanes
a) Hurricanes vs. Tornadoes http://www,erp.oissel.onac.org/anglais/hurricanestonadoes.htm
b) Tornado: http://de.wikipedia.org/wiki/Tornado

R.3.5.11 p. 98: Hurricane «Isaac»

a) Hurricane Isaac (2012): http://en.wikipedia.org/wiki/Hurricane_Isaac_(2012)
b) Hurrikan Isaac (2012): http://de.wikipedia.org/wiki/Hurrikan_Isaac_(2012)

R.3.5.12 p. 99: Hurricane «Sandy» (November 2012)

a) Hurricane Sandy - http://www.wunderground.com/blog/weatherhistorian/article.html
b) Atlantische Hurrikansaison 2012 - http://de,/wikipedia.orrg/wiki/Atlantische_Hurrikansaison_2012
c) Hurrikan Sandy - http://de.wikipedia.org/wiki/Hurrikan_Sandy

R-3-8

3.6 Wind energy

R.3.6.1 p. 101: Wind power

a) Wind power: http://en.wikipedia.org/wiki/Wind_power
b) Windenergie – Allgemein - http://de.wikipedia.org/wiki/Windenergie
c) Wie wird die Leistung einer Windkraftankage berechnet ?
http://www.e-genius.at/fikeadmin/user_upload/windkraft/07_wie_wird_die_leistung_einer_windkraftankage_berechnet.html

R,3.6.2 p. 102: Britz Windmill

a) Britz Windmill - http://www.museumsportal-berlin.de/en/museum/britzer-mühle
b) Britz Windmill - http://www.top1Oberlin.de/en/cat/occasions-260/unforgettable-marruage-2114/britz-windmill
c) Britzer Mühle - http://de.wikipedia.org/wiki/Britzer_M%C3%BChle
d) Windmühle - http://de.wikipedia.org/wiki/Windm%C3%BChle

R.3.6.3 p. 103: Wind farm in Denmark

a) Text and Photo from Reference R.3.6.1 – b) ; translated from German to English by P. Brüesch
b) Wind Power - http://en.wikipedia.org/wiki/Wind_power
c) Breakthrough Could Carry Solar, Wind Power Long Distances
http://smartplanet.com/blog/bulletin/breakthrough-could-carry-long-distances
d) ABB archieves another milestone in electrical engineering
http://www.abb_conversations.com/2012/11/abb-achieves-milestone-in-electrical-engoneering

R.3.6.4 p. 104: Worldwide installed Wind Energy

a) Reference R.3.6.1 // Graph of globally installed windpower from:
www.volker-quaschbing.de/darserv/windinst/index.php
(The names of the Countries have been changed from German to English by P. Brüesch)
b) Wind power - http://en.wikipedia.org/wiki/Wind_power
c) Wind power by country - http://en.wikipedia.org/wiki/Wind_power_by_country
d) Installierte Windenergieleistung weltweit in den Jahren 2001 bis 2013 in MW
http://de.statista.com/statistik/daten/studie158323/umfrage/installierte-windenergieleistung-weltweit-seit-2001/

R-3-9

R.3.6.5 p. 105: The Wind Tunnel

a) Wind tunnel - http://en.wikipedia.org/wiki/Wind_tunnel

b) Wind Tunnel Simulation Lessons - http://www.grc.nasa.gov/WWW/Wright/airplane/tunnlesson.html
c) Windkanal - www,http://de.wikipedia.org/wiki/Windkana
(contains part of the Text; translated to English by P. Brüesch)
d) Bau eines Windkanals // Teil 1: Planung – Die Bauart - http://windkanal.blogspot.ch/2011/04/t
(Contains Figure and part of the Text; Text translated to English by P. Brüesch)

Appendix

3.A.1.1 Dispersion of Sunlight by a prism (Optics)

a) Colours of Clouds - http://www,weather.gov.hk/education/edu06nature/ele_cloudcolours_e.htm
b) Dispersion of white light - http://www.tutorvista.com/physics/dispersion-of-white-light
c) http://de.wikipedia,org/wiki/Prisma_Optik

3.A.3.1 Mie - Scattering; White clouds

a) Colours of Clouds - http://www,weather.gov.hk/education/edu06nature/ele_cloudcolour
b) Mie Scatterung - http://en.wikipedia.otg/wiki/Mie:scattering
c Image and Text found under «Mie – Streuung» -
http://www.fe-lexikon.info/lexikon-m.html
http://de.wikipedia,org/wiki/Mie-Streuung
d) Atmospheric Stuff - http://homework.uoregpn.edi/pub/class/atm/optics.jtml
(contains right-hand picture of Rayleigh- and Mie scattering)
e) Atmospheric light scattering - http://wiki/flightgear.org/Atmospheric_light_scattering
f) Rayleigh. Mie. and Optical Scattering - http://user.engineering.uiowa.edu/~ece/2006/does/Rayleigh.pdf
g) Mie Streuung - http://de.wikipedia.org/wiki/Mie-Streung

R-3-10

3.A.3.2 Polare Stratospheric Clouds

a) Polar stratospheric clouds - http://en.wikipedia.org/wiki/Polar_stratospheric_clouds
b) Nacrous and Polar Stratospheric Clouds - http://www.atooptics.co.uk/highsky/psc1.htm
c) Polar Stratospheric Clouds
http://www.windows2universe.org(earth/Atmosphere/clouds/polar_stratospheric.html
d) Polar stratospheric clouds - http://glossary.ametsoc.org(wiki/Polar_stratospheric_clouds
e) Polare Stratosphärenwolken - http://de.wikipedia.org/wiki/Polare_Stratosph%C3%A4renwolken
(Basis-Information für p. 3.A.3.2 – von P. Brüesch auf Englisch übersetzt)
f) Polare Stratosphärische Wolken
http://www.meteotos.de/themen/atmos/beugung-interfernz/polare-stratosphärische-wolken
g) Clouds above the Troposphere - B. Geerts and E. Linacre)
http://www-das.uwyo.edu/~geerts/cwx/notes/chap08/noctilucent.htm
(Picture of the stratospheric cloud)

3.A.4.1 The Beaufort – Scale

a) Beaufort scale - http://en.wikipedia.org/wiki/Beaufort_scale
b) http://www.unc.edu/~rowlett/units/scales/beaufort.html
c) http://de.wikipedia.9rg./wiki/Beaufortskal
Graph found: under: www.google.ch : Beaufortskala :
«Graphik zu Beafortskala»: Windstärkeskala.jpg // Bild von P. Brüesch retouchiert und ergänzt

3.A.5.1 Dynamics of falling Halstones and Raindrops in Air

a) Forces on a Falling Object. (with air resistance) - www.grc.nasa.gov/WWW/k-12/falling.htm
b) Drag coeffivient - http://en.wikipedia.org/wiki/Drag_coefficient
c) Differentialgleuchungen für den Fall des Falles
H.R. Schneebeli (Version vom 13. Oktober 2014)
www.swissed.ch/.../differentialgleichungen/.../differentialgleichungen
d) Freier Fall mit und ohne Luftwiderstand
www.virtual-maxim.de/.../freier%29fall%20mit%20und%20und%20ohne520Luft...

3.A.5.2 Velocities v(D,t) of falling Hailsdtones
Figures from P. Brüesch; left-hand Figure with Maple 13 – Program

R-3-11

3.A.5.3 Terminal fall velocities of Hailstones

a) Hail - http://en.wikipedia.org/wiki/Hail
b) Hagel - http://de.wikipedia.org/wiki(Hagel
c) Aerosol Transport - Inertia - Newton's Resistance Law and Stoke's Law
http://://aerosoll.ees.ufl.edu/aerosol_trans/section03_c.html
(The Paper contains a Figure of the Drag coefficient as a function of Reynolds numberl)
d) Drag (physics) - http://en.wikipedia.orgwiki/Drag_%28physics%29
e) Drag of a Sphere - www.grc.basa,gov/WWW/k-12/.../dragsphere.html
f) Reynolds number - http://en.wikipedoa.org(wiki/Reynolds_number
g) Reynolds Zahl - http://de.wikipedia.org/wiki/Reynolds-Zahl

3.A.5.4 Size distribution of Hailstones - Mathematics

a) Gamma distribution - http://en.wikipedia.org/Gamma_distribution
b) Inverse Gamma Distribution
John D. Cook (October 3, 2008) - www.johndcook.com/inverse-gamma.pdf
(Our probability distribution is not the «Inverse Gamma-distribution», but rather the so-called.
Gamma(α,β) – distribution which is also discussed in the Paper)
c) Übersicht über die gängigen Wahrscheinlichkeitsverteilungen - http://www,seehun.de/verteilungen
d) Wetterrekorde .- http://de.wikipedia.org/wiki/Wetterrekorde
(enthält Informationen über ein beobachtetes Hagelkorn mit einem gigantischen Durchmesser
von 20.3 cm , einem Umfang von 47.3 cm und einem Masse von 875 g !!!)

3.A.5.5 Size distributions of Hailstones - Graph

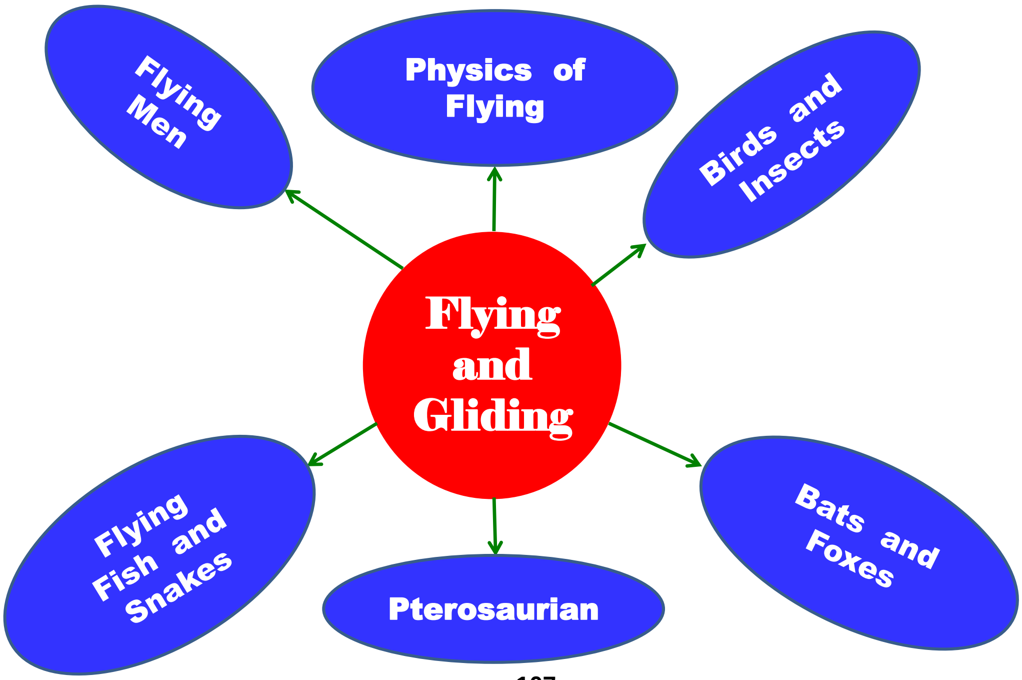
a) Distribution of Graupel and Hail With Size - August H. Auer, JR.
Monthly Weather Review / Vol. 100, No. 5, May 1972
docs.lib.noaa.gov/rescue/…/mwr-100-05-0325.pdf
b) Note in Hailstone Size Distributions
Stanley A. Cjangnon, JR. - Journal of Applied Meteorology, Vol. 10, pp 168 – 170 (1970)
c) More on hail - E. Linacre and B. Geerts
http://www-das.uwyo.edu/~geerts/cwx/noteschap09/more_hail.html
(Contains «Monthly Hail Size Distribution» in the USA - 1955 – 1977
d) Graupel - http://en.wikipedia.org/wiki/Graupel

R-3-12

4. Flying and Gliding

106

4.0 Flying and Gliding: Overview



107

Flying of Birds and Airplanes

White Storke in Flight

The length of White Storks (from legs to beak) is 80 to 100 cm and their wingspan is 200 to 220 cm. Except for the black wing feathers. the feathering is purely whight. White Storkes have a mass of about 2.5 to 4.5 kg.

Boeing 747

(Data for 747-100)

- Length: 70.6 m
- Wing span: 59.6 m
- Wing area: 511 m^2
- Takeoff velocity: ~ 300 km/h
- Range of Flight: 9'800 km
- Max. Takeoff mass: 333'400 kg
- Average number of passengers: 366
- Average cruise speed: 895 km/h
- Max. operating altitude: 13'000 m

108

4.1 Physical Basis of Flying

109

Physics of Flying: Aerodynamics

Flying usually means the movement of flying beings (animals and men) through the air. In Physics, flight movements are described on the bais of Aerodynamics.

This first Section contains an overview of the basic principles of flying. A systematic derivation from aerodynamic principles is obtained on the basis of coupled partial differential equations of Navier-Stokes and Euler, (s. Appendix 4-A-1-1). Such a rigorous approach is well beyond the scope of this representation. We rather content ourselves with the simplest possible discussion based on the well-known Bernoulli-equation, from which we derive heuristically the Kutta-Joukowski equation and discuss the most important implications.

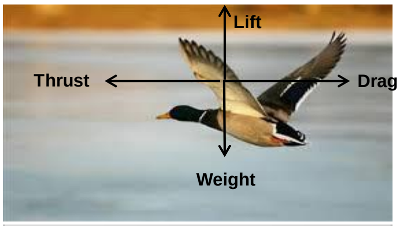
On the basis of these strongly simpified equations it is already possible to explain qualitatively the most important aspects of flying. Then, we shall discuss the simple empirical equations for lift and drag, equations which are used by aircraft manufacturers. With some adaptations, these equations will then be used to describe the flight of birds. It is found that the exact shape of the wings and their orientation relative to the airstream is of decisive importance. In addition, it is found that optimum performance is obtained with slightly curved and assymetric shapes of the wings .

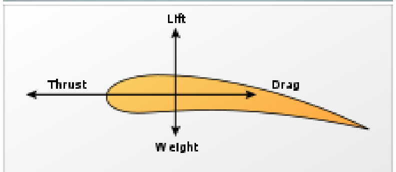
110

Air flow acting on an Airfoil

Physicaly, the air flow around the wing of an animal or an airplane is a highly complex process. During Takeoff, the air flow is usually a turbulent flow and for this reason, the streamlines (lines of constant pressure) around the wings are very complicated.

For a well defined shape of the wing and air flow, the flow pattern can, in principle, be determined experimentally. On the other hand, the flow pattern can be calculated on the basis of theoretical methods of aerodynamics. For this purpose it is, however, necessary to use complex theoretical equations of aerodynamics such as the Navier-Stokes equations, Euler's flow theory, the Kutta-Joukowsky Theorem and the Bernoulli equation (s. Appendix 4-A-1-1). In the following, we confine ourselves to Bernoulli's equation and to the Kutta-Joukowsky Theorem. On this basis we obtain qualitative results for the Lift and the drag (air resistance) of the system (s. Figure below).





The forces acting on the flapping wings of a bird:
Thrust – Drag – Weight – Lift
The resulting force acting on a bird is the superposition of the forces acting on the two wings. The arrows for the forces have been added by P. Brüesch.

The Figure showa the 4 forces which act on the wing of a bird or an airplane.
Thrust: A fixed-wing aircraft generates forward thrust when air is pushed in the direction opposite to flight. Birds normally achieve thrust duirng flight by flapping their wings.

111

The Bernoulli Equation

The Bernoulli-Equation derived in Appendices 4-A-1-2 and 4-A-1-3 reads

$$p + (1/2)\,\rho\, u^2 + \rho\, g\, z = \text{const.} \qquad (4.1.1)$$

or
$$p_1 + (1/2)\,\rho\, u_1^2 + \rho\, g\, z_1 = p_2 + (1/2)\,\rho\, u_2^2 + \rho\, g\, z_2 \qquad (4.1.2)$$

Here, p is the pressure, $(1/2)\,\rho\, u^2$ the dynamic flow pressure and $\rho\, g\, z$ the hydrostatic pressure due to gravity; u is the velocity, ρ the density, g the gravitational acceleration and z the height. The equation asserts that for a stationary and incompressible flow with negligible friction, the sum of these pressures is constant. This equation can alo be expressed as a law of cnservation of energy: Using the designations of Appendix 4-A-1-2 and 4-A-1-3, $\rho = dm/dV$ is the (constant) density. From $p\, dV + (1/2)\,\rho\, dV\, u^2 + \rho\, dV\, g\, z = \text{const}$, we obtain the equation: $(dm/\rho)\, p + (1/2)\, dm\, u^2 + dm\, g\, z = \text{const}$. Here, $(dm/\rho)p$ is the pressure energy, $(1/2)\, dm\, u^2$ the kinetic energy and $dm\, g\, z$ is the potential energy. The total energy of a fluid particle of mass dm following a streamline is constant.

If in equation (4.1.2) the altitude difference $z_2 - z_1$ in a flow is negligibly small, equation (4.1.1) simplifies to

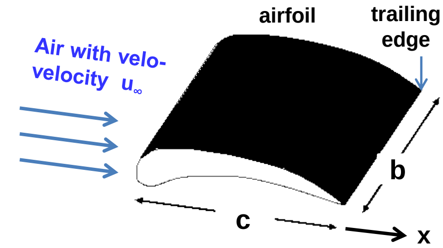
$$p + (1/2)\,\rho\, u^2 = \text{const.} \qquad (4.1.3)$$

From this equation it folows, that in a streaming fluid the pressure is the smaller the larger is the velocity: in a horizontal tube, the pressure is smaller in the narrow passages than at passeges with larger diameters. The same is also true for the air flow around an air foil (s. Ref. R.4.1.13 and pp 113 - 118).

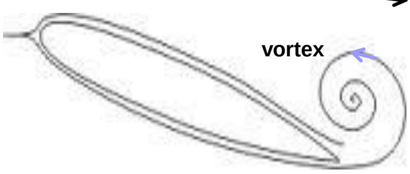
112

Air flow around Airfoil - 1

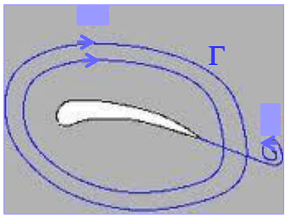
In the following we discuss the vortices occuring at the wings of an airplane and the resulting flow pattern. If the air flow passes the airfoil from left to right (see first Figure), one part of the air flows over the airfoil and the other part flows below it.



At the trailing edge, there is a velocity difference of the upper and lower partial air flows. Due to the asymmetric shape of the wing, the upper partial air flow has to pass a longer distance and is decelerated more strongly by friction than the lower partial air flow. [2 c = wingspan, b = mean wing depth of the airfoil].



At the trailing edge of the wing, this produces a free vortex. This is shown in the middle Figure in a two-dimensional representation. It is the so-called starting vortex which is detached slowly from the trailing edge of the airfoil and moves away.

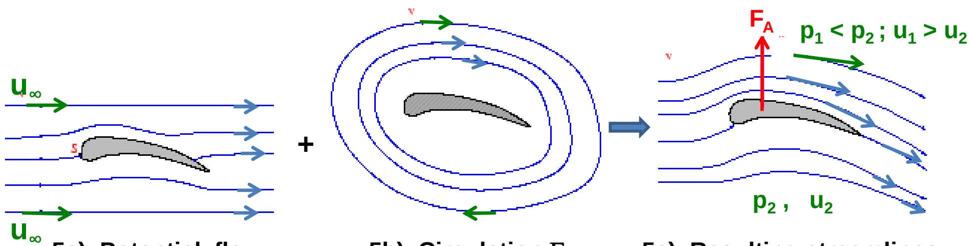


The principle of angular momentum requires a second vortex having a reversed sense of rotation with respect to the starting vortex. This latter vortex circulates around the airfoil as shown in the last Figure. It is called the circulation flow Γ, which is superimposed to the parallel flow around the wing (see p. 114).

113

Air flow around Airfoil - 2

From the technically important theory of airfoils we shall discuss here only the most important aspects. If the airfoil of an airplane is moving through the air, an air flow develops which can be regarded as the superposition of a potential flow (without rotation) (Figure 5a) and a circulation Γ (Figure 5b). The development of the circulation has been discussed on p. 113. The resulting air flow is shown in Figure 5c): The streamlines above the airfoil are squeezed together, while they are much less dense below it. Therefore, according to Bernoulli's equation (4.1.3) on p. 112) the air pressure above the airfoil is smaller than below it. Hence, the airfoil experiences an upward force which is also called the dynymical lift F_A. F_A carries the airplane. A qualitative explanation of the lift force F_A is given on p. 115.



5a) Potential flow 5b) Circulation Γ 5c) Resulting streamlines

The lift force F_A depends on the air density ρ, the flow velocity u_∞, the wing depth b (s. p. 113) as well as on the circulation Γ(c) where c is the wing span (s. pp 113, 118). Since the circulation is anti-clockwise, Γ is negative: $\Gamma < 0$. A heuristic derivation of Γ and of F_A is given on pp 117 and 118. The different vortices of an airplane are shown in Appendix 4-A-1-4.

114

Qualitative explenation of dynamical Lift

The **dynamical lift F_A** is defined as the force which acts on a body immersed in a uniforme flow perpendicular to the flow direction. This is the case if the circulation around the body is different from zero (s. p. 114).

The circulatory flow Γ which is superimposed to the potential flow increases the flow velocity u_1 around the upper surface area ($u_1 > u_\infty$), while the flow velocity u_2 around the lower surface area is decreased ($u_2 < u_\infty$). Therefore, $u_1 > u_2$. (s. Figure, p. 114).

According to **Bernoulli's equation** the difference of the flow velocities is approximately equal to the pressure differnce (s. p. 117), i.e. $p_2 > p_1$. Since $p_1 = p_1(x)$ and $p_2 = p_2(x)$ (x-coordinate s. pp 113, 117) the lift force is given by

$$F_A = b \int_0^c [p_2(x) - p_1(x)]\, dx \qquad (4.1.4)$$

where b is the effective or average wing depth and c is the wing span (s. Figures pp 113, 117).

The Kutta-Joukowsky equation (pp 116 - 118) is a quantitative relation between the circulation Γ, the approaching velocity u_∞ , the density ρ of air and the lift force F_A for the case of frictionless flow around the airfoil (s. Figures on pp 113, 117):

$$F_A = - \rho\, b\, \Gamma\, u_\infty \quad . \qquad (4.1.5)$$

The circulation $\Gamma(c)$ will be defined on pp 116 – 118 and a discussion is given on the basis of a simple example. Due to the direction of rotation $\Gamma < 0$ and hence $F_A > 0$.

115

Theorem of Kutta - Joukowski and Lift of an Aifoil

According to equation (4.1.5) the lift force F_A is given by

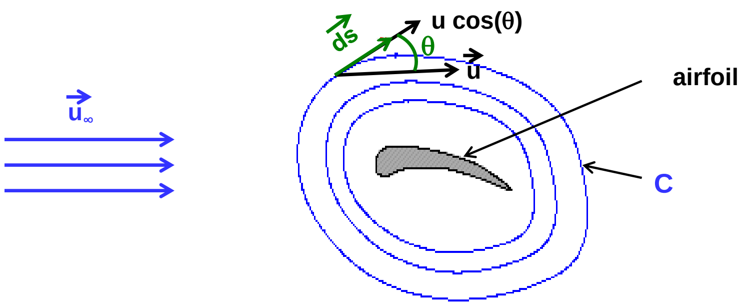
$$F_A = - \rho\, b\, \Gamma\, u_\infty \qquad (4.1.6)$$

ρ = density of air; b = average wing depth (see pp 113, 115)
u_∞ = undisturbed wind velocity (see pp 113 - 115);
Γ : circulation around airfoil ($\Gamma < 0$, s. pp 113 - 115) → $F_A > 0$.

The circulation Γ introduced by Kutta-Joukowski is defined as the line integral

$$\Gamma = \oint_C \vec{u}\, d\vec{s} = \oint_C u \cos(\theta)\, ds \qquad (4.1.7)$$

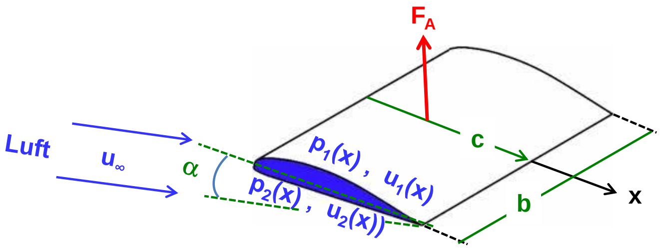
over a curve C surrounfing the airfoil (see Figure below).



116

Heuristic Model for the Circulation Γ and the Lift F_A - 1)

The circulation Γ as defined by Kutta-Joukowski (Eq, (4.1.7)) is required for the cal-, culation of the lift force F_A (Eq. (4.1.6)). An exact evaluation of Γ is beyond the scope of this presentation (see Ref. R.4.1.4 for a derivation). The following heuristic consideration is not exact but illustrative (Ref. R.1.4.5 e). We first consider the airfoil shown below.



α = angle of attack = angle between air and wing profile

The velocity of the incoming air flow is u_∞. At the uper side of the airfoil, the pressure and velocity are $p_1(x)$ and $u_1(x)$, the pressure and velocity at the lower side are $p_2(x)$ and $u_2(x)$. As explained on p. 114, the Bernoulli – equation (4.1.2) (witth $z_1 = z_2$) requires $p_2 > p_1$ and $u_1 > u_2$. The pressure difference $\Delta p(x) = p_2 - p_1$ is given by

$$\Delta p(x) = p_2 - p_1 = (1/2)\,\rho\,(u_1^2 - u_2^2) = (1/2)\,\rho\,(u_1 + u_2)\,(u_1 - u_2) \qquad (4.1.8)$$

In a first approximation we put $(1/2)\,(u_1 + u_2) = u_\infty$ and $u_1 - u_2 = \Delta u(x)$. We then obtain $\Delta p(x) = \rho\, u_\infty\, \Delta u(x)$. If c is the wing span and b the average wing depth of the airfoil, the lift force F_A is given by eq. (4.1.9) on the following page:

Heuristic Model for the Circulation Γ and the Lift F_A - 2

$$F_A \approx b \int_0^c \Delta p(x)\,dx = b\,\rho\,u_\infty \int_0^c [u_1(x) - u_2(x)]\,dx \qquad (4.1.9)$$

A closer inspection of the integral shows that it corresponds to the negative circulaton around the airfoil. The circulation is given by

$$\Gamma \approx \int_0^c u_2\,dx + \int_c^0 u_1\,dx = -\int_0^c (u_1 - u_2)\,dx = -\int_0^c \Delta u(x)\,dx \qquad (4.1.10)$$

From (4.1.5) we obtain a relation between the lift force F_A and the circulation Γ:

$$F_A = -\,b\,\rho\,u_\infty\,\Gamma = +\,b\,\rho\,u_\infty \int_0^c \Delta u(x)\,dx \qquad (4.1.11)$$

In a first approximation we replace $u_1(x)$ and $u_2(x)$ by constant mean velocities u_{1m} and u_{2m}. Then we obtain for the mean circulation Γ_m:

$$\Gamma_m = -\,c\,(u_{1m} - u_{2m}) \qquad (4.1.12)$$

and the mean lift force F_{Am} is then given by

$$F_{Am} = -\,b\,\rho\,u_\infty\,\Gamma_m = +\,b\,c\,\rho\,u_\infty\,(u_{1m} - u_{2m}) \qquad (4.1.13)$$

Let $u_{1m} \approx u_\infty + u_{circ}$ and $u_{2m} \approx u_\infty - u_{circ}$, where u_{circ} is the circukation velocity; Then we obtain with $u_{1m} - u_{2m} \approx 2\,u_{circ}$ and

$$\Gamma_m \approx -\,2\,c\,u_{circ}\;; \quad \text{therefore} \quad F_{Am} \approx 2\,b\,c\,\rho\,u_\infty\,u_{circ} \qquad (4.1.14)$$

Lift coefficient: Technical relation and Kutta – Joukowski

In the technical Literature the following formula for the lift force is often used:

$$F_{At} = (1/2)\, C_A\, b\, c\, \rho\, u_\infty^2 \qquad (4.1.15)$$

Here, C_A is the so-called Lift coefficient. Among others, C_A depends on the details of the airfoil (inclination α, s. p. 117) and shape). In order to gain an approximate expressen of C_A we identify F_{at} with the theoretical formula (4.1.6) or (4.1.11): $F_{at} = F_A$. We then obtain

$$(1/2)\, C_A\, b\, c\, \rho\, u_\infty^2 = -\, b\, \rho\, u_\infty\, \Gamma \qquad (4.1.16)$$

or

$$C_A = -\, 2\,\Gamma / (c\, u_\infty) \quad \text{bzw.} \quad \Gamma = -\, (1/2)\, C_A\, c\, u_\infty \qquad (4.1.17)$$

[note that $\Gamma < 0$ and therefore $C_A > 0$] .

In order to illustrate eq. (4.1.17) we replace the exact expression of Γ by its expression from the heuristic model, namely $\Gamma_m = -\, 2\, c\, u_{circ}$ (Eq. (4.1.14)), and obtain for the the corresponding lift coefficient C_{Am} :

$$C_{Am} = 2\, (u_{1m} - u_{2m}) / u_\infty = +\, 4\, u_{circ} / u_\infty \qquad (4.1.18)$$

Example: let $u_{1m} = 1.28\, u_\infty$ and $u_{2m} = 0.72\, u_\infty$; then $u_{circ} = (1/2)\,(u_{1m} - u_{2m}) = 0.28\, u_\infty$ and $C_{Am} = 1.12$.

119

4.2 Flying and gliding animals

120

4.2.1 Invertebrates and Vertebrates

Invertebrates

Invertebrates are defined as animal organisms without backbones. Invertebrates do not have an internal skeleton, but often they do have an exoskeleton.

The majority of the living creatures belongs to this animal species.

Examples of Invertebrates:

Insects
Molluses (e.g. Snails)
Ringel worms (e.g. Leeches)
Cnidarians (e.g. Jellyfishes)
Protozoas (e.g. Amebas
Squids

Vertebrates

The species of Vertebrates has an endoskeleton with a backbone at the centre.

Vertebrates belong to the higher developed animals.

Examples of Vertebrates :

Mammals (e.g. Humans)
Birds
Fishes
Reptiles (e.g. Snakes)
Amphibians (e.g. Frogs)

121

The biological – geological time scale

Contraction of geologic age on one day

Age in Mio. years)	Development	Age in days
0.01	Agriculture and stock farming	0.2 s
0.13	Homo sapiens	2 s
1.5	Homo habilis	25 s
7	Upright walking	2 min
10	Pre-hominids	3 min
33	Grate apes	10 min
80	Monkeys	20 min
200	Mammals	1 h
280	Reptiles	1 h 20 min
360	Amphibians	1 h 45 min
420	Fishes	2 h
470	Vertebrates	2 h 15 min
600	Multicellular organ.	3 h
1000	Sexuality	5 h
1500	Eukaryotes	7 h
2200	Photosynthesis	11 h
3200	Protozoons	15 h
4600	Earth	23 h

The geological time scale is a Table which structures the history of the Earth chronologically and hirargically. (in the Table from the bottom up)

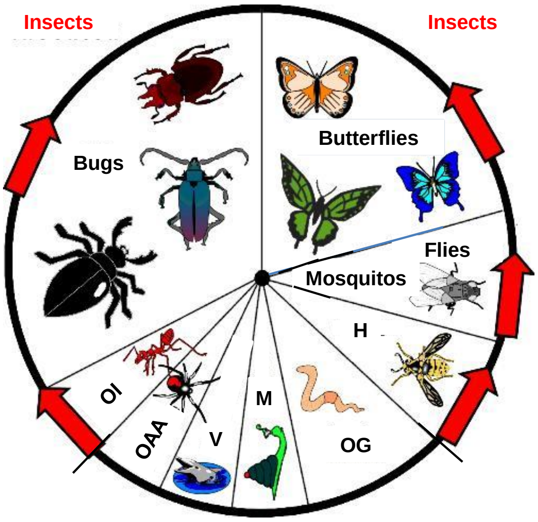
Since the beginning of the ages of verifable life 542 Mio. years ago, the continuous fossil record sets in. Based on the methods of biostratigraphy, a differentiated classification was possible.

In the opposite geological Table, the older periods are below, the younger above, similar to the series of the sedimenatary rocks within an idealized and undisturbed tectonic layered segment.

Examples of flying or gliding invertebrates and vertebrates are shown at p. 123 and discussed in Sections 4.2 and 4.3, respectively.

122

Known living beings on Earth



Insects are divided into many groups. Examples of these groups are bugs, butterflies, gnats and others. As can be seen from the picture, the largest group contains the bugs. There exist over 250’000 species of bugs.

H: Hymenoptera
OI: Other Insects } Insects

OG: Other Groups
M: Molluscs
V: Vertebrates
OAA: Other Articulate Animals } no Insects

Although these 250’000 species of bugs are all different, they do have something in common: All bugs are protected by a hard chitinous exos-skeleton. Below this skeleton, there are two delicate foldable wings.

As all Insects, bugs are moving with three pairs of jointed legs. The pair of antenna is used for palpation. After birth, the bugs are grubworms. Later, the grub pupates and develop into a bug. The red flashes of the Figure indicate the different species of Insects.

It should be noted, that the vertebrates constitute only a small part of all living beings.

123

4.2.2 Flying and Gliding Invertebrates: Insects

124

What are Insects ?

The notion «Insects» derives from the Latin word «Insecare», what means «incise» and refers to the three body segments (head , breast and abdomen) .

The science of Insects is called Entomology.

Insects are Invertebrates, i.e. in contrast to mammals, fishes , reptiles, amphibians and birds, they do neither posses a backbone nor an inner skeleton. They belong to the stem of Anthropods, which are characterized by theire segmented legs and their rigid, protecting exoskeleton.

Insects differ from the other arthropods by having only three pairs of legs and that they posses only one to two pairs of wings. For this reason, spiders and scorpions do not belong to the class of Insects.

A very large number of Insects are flying animals. However, besides the flying Insects there exist also non-flying Insects. Examples of the latter are cicadas, moths and stoneflies.

For the present topic of «flying animals» we are only concerned with flying Insects.

125

The Planet of Insects

The animal world can be subdivided into Protozoon and multicellular organisms. The latter contain about 30 animal phyla, to which belong the arthropodes (arthron = limb and podes = feet). Arthropodes comprise more than 80% of the animal world, and 75% of them are Insects. Every day, new species are dicovered. Some scientists believe that more than 50 millions of new species are waiting for discovery.

Bugs are the largest family, containing more than one Million of species; they are followed by the Butterflies with about 180’000 known species (s. p. 123). Butterflies are followed by Flies and Gnats. These are finally followed by Hymenopterans (Hautflügler). In addition, there exist many other Insects: at p. 123 they are contained under «Other Insects (OI)».

The first Insects populated our Earth about 400 Million years ago; they belong to the most original animals of our Planet. In addition, they are the most adaptable animals of the Earth. In contrast, while species such as the Dinosaurs died out, Insects always developed further and continously reproduced themselves. Because of their enormous adaptability, Insects were able to populate each place of the Earth: they are living in the Air, in water in woods, etc.

Corresponding to the special physiology of the Insects, bugs have two pairs of wings, but only the hindwings are adapted for flying, the forewings are sclerosed. Most bugs are able to fly, many of them very well, others less well. There exist bugs who are able to fly excellently and reach maximum velocities up to 8 m/s.

126

Largest and smallest flying Insects of the world

If one is searching in the Literature for the largest or smallest flying Insects of the world, it is not possible to find a clear answer. Below, two examples are shown which belong to the best candidates.

Queen Alexandra’s birdhwing

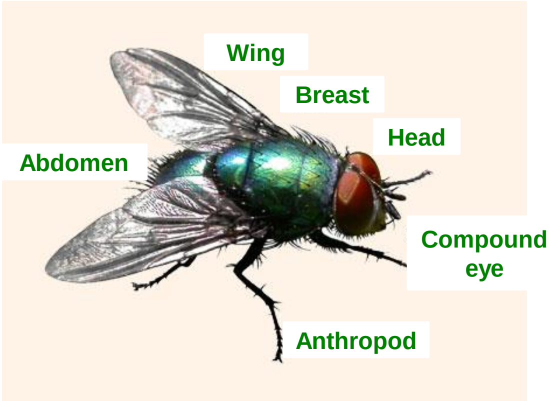
Male

One of the Earth’s largest Insect is a butterfly. The largest known butterfly is the Queen Alexandra’s birdwing. The female wingspan slightly exeeds 25 cm and its body length is 8 cm. The wingspan of males is smaller, about 20 cm but more usually about 16 cm.

The smallest Insect ever found is a fairy wesp, the so-called «Dicopomorpha Echmepterygis». (I am indepted to Mister Peter Etter for giving me this indormation).
The mail has a length of only 0.14 mm but it is unable to fly and is blind. The femails have a length L of about 0.2 mm and are capable of flight. The Reynolds number Re = (ρ/η) L*u (s. 4-A-2-1), has an order of magnitude of Re ≈ 1 (s. p. 4-A-2-2).

127

Morphology of Insetcs

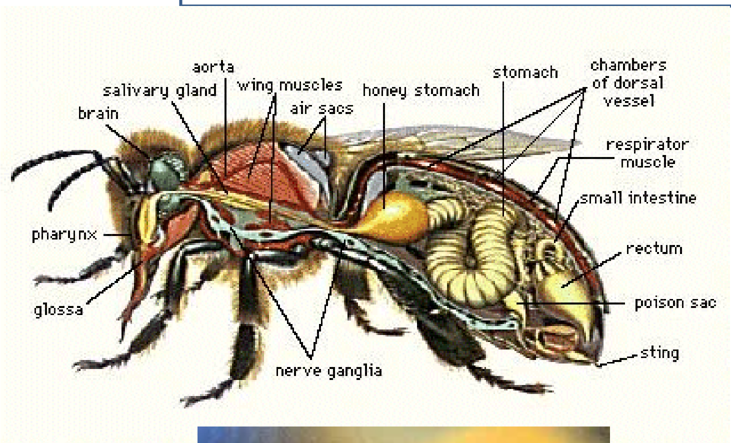


Insects are invertebrates: they do not have a backbone. They do have, however, a solid exaskeleton-chitin crust and six segmented legs. The body of the Insect is segmented into three sections (s. also p. 129): head, breast and abdomen. Eyes, mouthparts and feelers are part of the head, while legs and wings are connected to the middle thoracic segment. The abdominal segment contains the heart, the intestine and the reproduction organ of the Insect.

Not every creepy-crawlies is, however, an Insect ! Spiders and crustaceans are similar to Insects, but they are forming their own group of animals. The most characteristic feature of Insects is really the separation of their body into three segments.

128

Internal Anatomy of a Bee – Flying Bee



Bees are social Insects (s. p. 130). For the regeneration, often very view sexual animals are active. In the case of bees, only the Queen is lying fertilized and unfertilized eggs.

Flying Bee

129

Bees , Ants and Termites

Bee swarm on tree branch

The highlight of the bee's year is the swarming season, during which part of the natural reproduction takes place (from April to June). This happens if the beehive is over-flowing from honey and bees.

The bees rush out of the emergence hole as a waterfall and produce a raging sound. This 10 to 20 m large cloud of bees is mooving peacefully and at walking pace. The queen recides in the centre of this cloud. If they have found an appropriate location, they settle down again.

Ants

Only sexually mature males and females possess wings. For the purpose of mating, the flying ants leave in swarms their anthill and set off for honey-moon: The mating takes place at a height of 10 to 15 m.

Ants take care for an intact eco-logical equilibrium: To these belong the destratification of the upper soil levels, the elimination of waste products and of small harmful insects from their hills.

Swarm of Termites

Termites are a colonising order of insects and belong to the class of flying insects. A colo-ny of termites can comprise several millions of individuals.

The sexually fully developed animals have compound eyes. After swarming (nuptial flight), they quickly get rid of the wings with a simple body flick. The remnant of a wing is a distinct triangular scale.

130

4.2.3 Butterflies

Butterflies are Insects (Lepidoptera). From the biological systematics they form an own order within the Insects. Worldwide there exist about 200'000 different species of butterflies. In Middle-Europe, more than 3'000 species are known. In contrast to other Insects, they are distinct in that they possess wings with scales (see p. 133).

Peacock burterfly

The comma is an adult animal. Its primary task is to produce descendants (p. 132), and to insure that the fertilised eggs are oviposited at places where they can develop without disturbance.

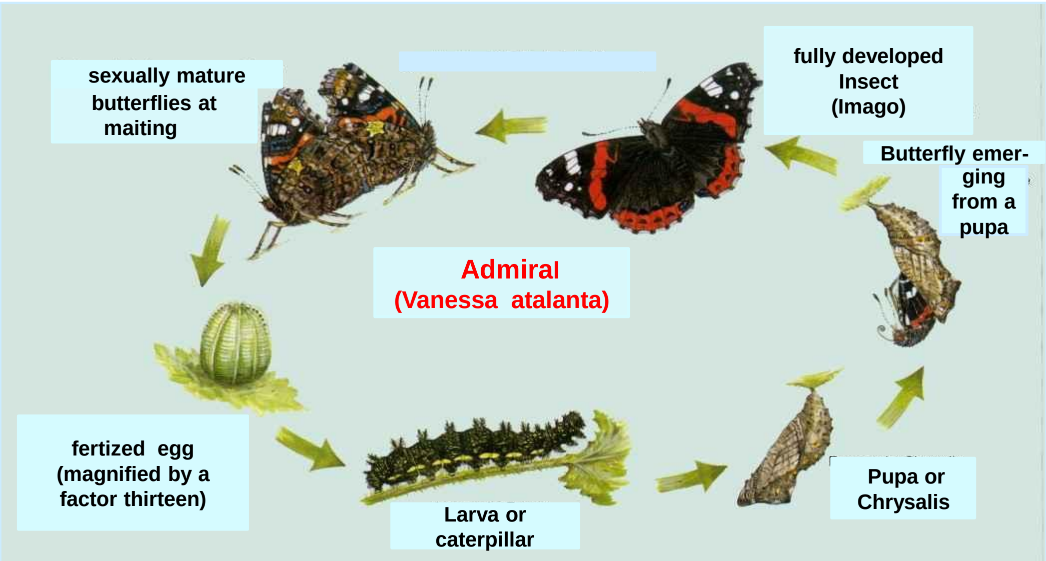
For this purpose, the females oviposit the eggs at secure locations, for example at the underside of a plant's leaf, where they are protected from rain and sunshine.

Depending on the species, the eggs of butterflies vary in size and in shape but as a rule, the eggs have diameters between 0.4 and 2.6 mm. The larvas emerge from the eggs after a few days; for butterflies, these larvas are called popating butterfly caterpillars (p. 132).

131

Development of a Butterfly

Depending on the climate, the life cycle of a species varies between a few days and four years.



132

Wings and Flight characteristics of Butterflies

With a few exceptions, the wings are the musculoskeletal system of butterflies. The forewings and the hindwings are individually suspended but during flight, they are coupled by special mechanisms. Day-flying butterflies do not, hovever, possess such a coupling.

The wings of butterflies are much more sensitive then those of flies. Both, the upper and lower wing surfaces are covered with scales; these scales provide the necessary stability of the very thin wing-skins which is important for their flight capability. The interference of light at the scales produces impressive colors of the wings.
Left: Scales of a wing enlarged by a factor 25.

Flight characteristics

Depending on the butterfly species and the wing shape it is possible to distinguish between different flight patterns. The latter depend on the characteristics and velocity of the wing flap and the locomotion: flapping flight, quiet hovering flight, gliding flight, soaring flight, etc. The wings are set in motion by various muscles of the thorax. They are not only flapping up and down but rather rotate simultaneously around the wing base thereby executing a complicated «figure-8 motion».The so-called howkmoths belong to the rapidly flying butterflies. They can move at a speed up to 50 km/h. If they are sucking nectar they can stop their flight or even fly backward. The very small butterflies do not fly by flapping the wings but are rather floating through the air by the force of the wind. In general, the wind is an important means of transport.

133

Some Butterflies

Monarch: 80 mm

Admiral – 40- 60 mm

Black-veined white : 50 – 70 mm

Large emerald: 50-60 mm

Birdwing butterfly: up to 280 mm !

Fritillary: 40-45 mm

Dark clouded yellow: 45 – 50 mm

Small tortoiseshell: 45 – 50 mm

Peacock butterfly: 50 – 60 mm

4.2.4 Flight of Flies and Gnats

Fruit fly (Drosophila) and Tsetse fly

Fruit fly in gliding flight: the wings do barely move. The length of the fly is only a few mm.

Fruit fly in active flight; the flapping frequency of the wings is very high !

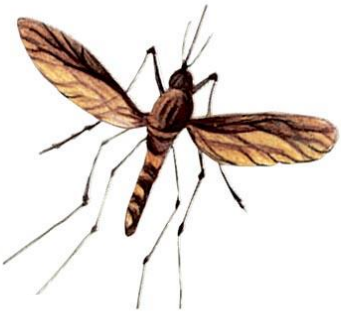
In order to be able to fly efficiently in active flight inspite of their small wings (picture below), a rapid wing beat is required. The fruit fly (Drosophila melan-ogaster), is flapping their wings with a frequency of 200 – 250 vibtations per second (200 – 250 Hertz). Their flight muscles are thus contracting and relaxing 200 to 250 times per second.

How can the fruit fly achieve such a high flappimg frequency ? Their trick of flying is astonishingly simple: The contractions of the flight muscles are not only controlled by nerve impulses but also by tension. For this purpose, the fly has two kinds of flight muscles: one of them are moving the wings downwards, thereby expanding the other muscles which are then contracted again. In this way, the wings are moving again upwards – a highly effective interplay.

The ordinary fruit fly can change the direction of its flight by 90 degrees in about 50 milli-seconds !

Tsetse flies are living in Africa; they live on human blood and on animal blood, thereby transmitting the dangerous sleeping thickness.

Mosquitos



Flying mosquito

Gnats or mosquitos are a family of insects belonging to the order of diptera. Worldwide, there exist more than 3'500 species of gnats.

With the help of their specialized mandibles, the femail mosquitos are able to pierce the skin of their hosts and to suck their blood. The proteins obtained in this way are needed for the production of eggs. In addition, the mosquitos subsist on nectar and on other sucrose-containing plants.

Some distinct mosquitos are known as pathogens such as Malaria or Dengue fever. Even today, over one million people worldwide die from mosquito-born diseases every year!

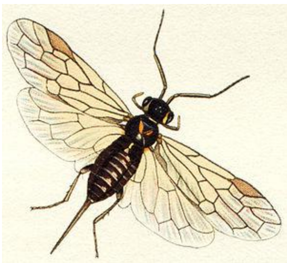
Flight characteristics

Mosquitos are able to fly with a velocity up to 1.5 to 2.5 km/h. In general, their flying height depends on the actial species, on the altitude above sea level, on weather and air pressure, on the temperature and on the conditions of illumination. In the case of warm, calm and slightly cloudy weather and in the absence of direct sun exposer, the activity of mosquitos is particularly strong. In this case, some species are able to reach large flying heights of more than 100 meters. At cool or rainy weather, however, many mosquitos are flying only small distances and rather remain near the ground. If there are fresch breezes and temperatures near the freezing point, they stop completely their flight activities.

136

4.2.5 Hymenoptera (Hautflügler)

Wood wasp



Sawfly in flight

To the family of hymenoptera there belong such well known insects as the bees, wasps and bumblebees. For human beings, bees are probably the most important group of insects.

The number of hymenoptera known up to day is of the order of 100'000. But it is to be expected that this number will increase considerably, if in tropic regions small wasps are investigated on a systematic way. Species of the order of hymenoptera are present in nearly all habitats: from the tropic rainforest to the desert areas.

The majority of the hymenoptera has two membranous and transparent double-wings, from which the hindwings are smaller than the forewings. The functional double-wings have a very positiv effect on the air worthiness.

137

Dragonfly with stretched wings

4.2.6 Dragonflies (Drachenfliegen = Libellen)

The flying skills of dragonglies are spectacular, perfected in millions of years of evolution. Large dragonfles, for example, can accelerate very rapidly and reach velocities up to 40 km/h. From full flight they can decelerate abruptly and change their flight direction very quickly and they can even fly backwards. With the help of wind assistance, some species are able to fly distances up to 1000 km in just a few days: they can fly from mediterranean areas across the Alps to middle Europe. On the other hand, small dragonflies (damselflies) are especially impressive by their extreme maneuverability.

These accomplishements are achieved by a very strong flight musculature and by light but nethertheless strong stable wings (the mass of the 4 wings of a large dragonfly is only about 10 mg, while their total mass is about 1 g). Furthermore, the two pairs of wings can be moved independently and since each wing is controled by its own pair of muscles, it can be adjusted individually according to the specific requirements. At normal flight, the flapping frequency of the wings is relatively small. only about 30 times per second and they are flying nearly soundlessly. The corresponding frequency of flies and gnats (p. 135) is much higher, namely 200 to 250 times per second.

Dragonfly in flight

138

Comparison between Dragonfly and Helicopter

The flight characteristics of a Dragonfly is comparable with that of a Helicopter:

- Both can perform «Vertical Take Off and Landing» (VTOL)
- Acceleration from full flight
- Abrupt deceleration
- Sudden change of direction of flight
- Backwards flight
- Excellent maneuverability

[The lift of Helicopters is due to the flow of air around the rotating propellers. Their profiles resemble that of a static airfoil (s. pp 113 – 119) and Reference R.4.2.19); therefore, the lift is due to the reduced pressure at the upper surface of the rotor blades where the velocity of the air stream is larger than at the lower surface of the blade. Helicopter: see pp 188, 189].

139

4.3 Flying and Gliding Vertebrates

The Phylum (Stamm) of Vertebrates contains 5 Classes:

Birds

Fishes

Rebtiles

Amphibians

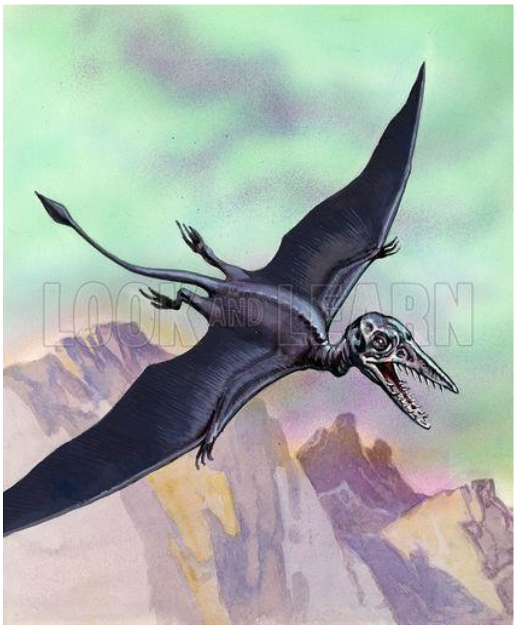
Mammals

140

4.3.1 Flying Pterosaurs

141

Pterosaur in Gliding Flight



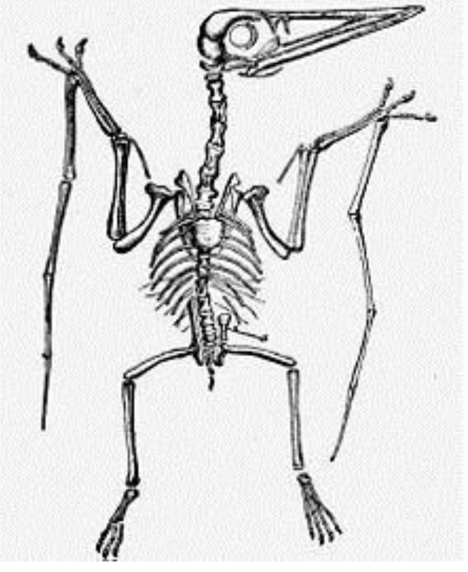
Pterosaurs (Flugsaurier) are extinct animals and similar to the Dinosaurs they can be assigned classically to the Reptiles. In contrast to Dinosaurs they were able to glide or even to fly.

The earliest archeological finds of Pterosaurs showed that they existed from the late Triassic to the end of the Cretaceous period (228 to 66 million years ago). Pterosaurs are the ealiest vertebrates known to have evolved powered flight. Their wings are formed by a membrane of skin, muscle, and other tissues stretching from the ankles tp a dramatically lenghtened fourth finger.

The Pterosaur shown in the picture is the largest known flying creature. Scientist estimate that the Texas Pterosaur had a wingspan of about 15 m, - larger than most of modern supersonic aircrafts !

142

Pterosaurs: Anatomy



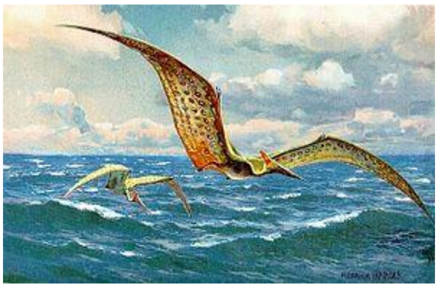
The most apparent characteristic of Pterosaurs are the front legs which were modified into large wings. With the help of these wings, the Pterosaurs were able to glide or even to fly.

As a rule, the long wing bones were hollow and very thin walled. They contained many air-filled regions. As a consequence, the weight of the bones was small. By trabeculae, the bones were strenghened, in particular the long bones. [The bone is spongy and consists of a lattice of delicate bars of bones called trabeculae and is less dense than compact bone. The orientation of the trabeculae is affected by the mechanical stress to which the bone is exposed]. For this reason, only fragments of the wing bones have been found; intact wing bones have been seldomly discovered.

Compared to the other Reptiles, the backbone of the Pterosaurs are distinctly different and is adapted to the flying lifestyle. Some parts of the backbone are very similar to the backbones of birds: a very pronounced shoulder region and a massive region in the area of the pelvis («Becken» in German).

143

Characterization of Pterosaurs



The wingspan of the largest Pterosaurs was 11 – 13 meters. Because of their hollow bones, the mass of these large animals was comparatively small, only about 100 kg; according to other sources, their mass was up to 200 kg. In contrast to their very large wingspan, the body was small. This species was presumably not an enduring flyer, but was rather able to cover long distances by gliding in thermal air currents. In this way, they were able to remain in the air for hours with a minimum of energy expenditure.

How exactly they were able to fly upward from the ground into the air in spite of the weight and their huge wingspan is still controversial. While the smaller animals were probably good flyers, it is assumed that also the large Pterosaurs were able to leave the ground by their one force; but to achieve this they required favourable wind conditions.

It is unclear of whether the long and pointed bill was equipped with teeths; furthermore, it is not known of whether the animals were walking on two or on four legs.

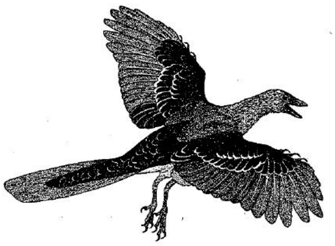
144

4.3.2 Die Vögel: Physiologie, Flugtechnik und Beispiele

145

Birds : History - Masters of the Air - Examples

History of Birds



The history of birds started about 200 million years ago. The picture alongside shows the alleged appearence of a fossile bird, the Archeopteryx (redesigned after the original of Maurice Wilson in W.E. Swinton: Fossil Birds, London (1965).

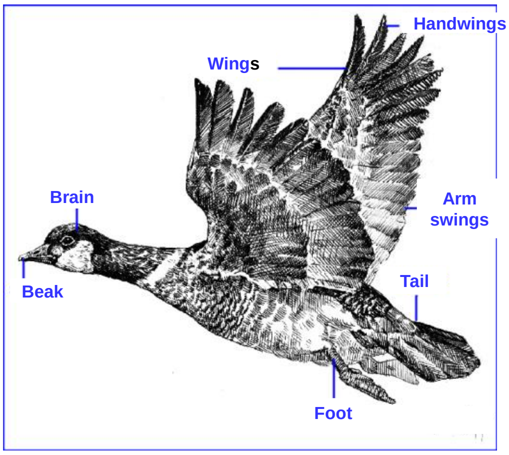
From the picture shown in the reconstruction it is clearly seen, that the Archeo-, pterix with his bird-like skull, his tallons, wings, feathers and his wishbone (Gabelbein) is quite similar to a bird. Apart from birds, no other animal has feathers and whishbones. The structure of the feathers is highly complex; they are optimally suited for their destined structures, i.e. for their aerodynamic functions as well as for heat accumulators.

Fossil records which have been classified as birds, show the relationship with her ancesters, the reptiles. The size of the oldest known fossil bird shown above, was similar to the size of a small pigeon. From this fossil bird, only a single feather and 7 completely or partially conserved imprints have been discovered, all of which descend from the upper Jurassic (between 157 and 145 million years ago).

Birds are found on all Continents of the Earth; they are able to adapt themselves to nearly every living space. Today, aboud 9000 species exist. They are living in apparently uninhabitated deserts or in the Antarctic, in wildwoods, swamps, rock coasts, forests, fields and in cities.

146

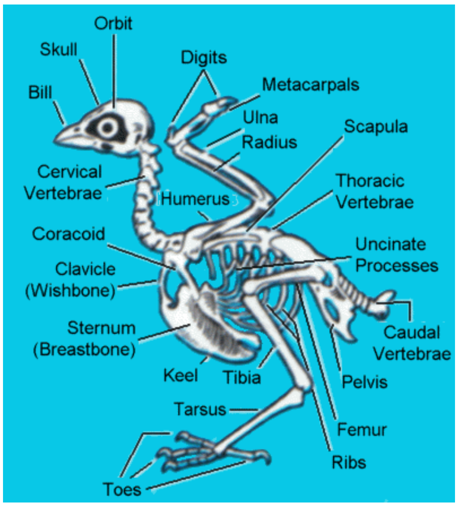
Bird’s Habitus and Skeleton



Habitus of a Bird

The two wings correspond to the two arms of the Bird

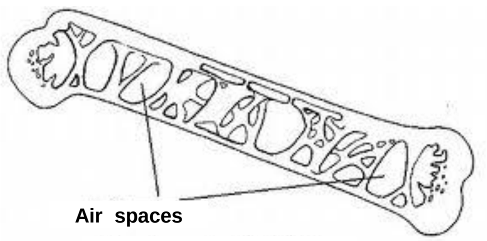
Figur lettering transöated from German To English by P. Brüesch



The skeleton of a typical Bird

147

Physiology of Birds: The Skeleton - Bones



Bone of a Bird
(longitudinal section)

Longitudinal section through the bones of a Bird

In order to achieve the small body-weight nessecary for flying, the bones of birds are to a large extent hollow.

Nethertheless, depending on the group of birds, the degree of pneumatization is developed to a different degree.

Cross section through the bone of a Bird

The trabeculae provide the necessary stability.
The weight of the skeleton is only 6 – 8 % of the total body weight.
(for mammals: 20 – 30 %)

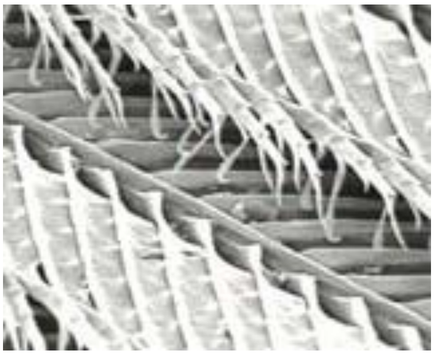
148

Physiology of Birds - The Wings

The wings of birds are movement organs used for flying. They have been developed by a transmutation of the forelimbs. During flying they generate lift and thrust (s. p. 111).

The plumage (feathering) consists of large flight feathers and shorter pinions. For the upper and lower wings, the latter form the wing-covers. The flight feathers are the largest feavers on the wing and are divided into primaries and secondaries. They are forming interlocking tiles. For flightless birds such as ostriches, the flight feavers are usually largly reduced.

As shown in the Figure below, the interconnection of the feathers is very complex.



Microscopic picture
of a bird's feather:

Interconnecting
tiny hooklets, barbs and
barbules are stabilizing
the feather

149

Remarks about the Dynamics of the Flight of Birds

The physical principles underlying the flight technique of airplanes have been discussed in detail in Section 4.1 (pp 109 – 119). The same principles do essentially also apply for the flight of Birds: At a stretched flapping wing (gliding flight) the lift is produced in the same way as for an airfoil which is subjected by an air current acting from the front of the wing.

However, for the case of the flight of a Bird, there is an essential complication due to the dynamics of the wings i.e. due to their flapping motion.

Lift and thrust depend esentially on the wing shape as well as on their upstroke and downstroke motion.

At the upstroke of the wings, the air impinges the wings essentially from above while at the downstroke of the wings, the air impinges the wings essentially from below. The associated forces are small in the vicinity of the wingroots and increase towards the wingtips.

During the downstroke of the wings, the local overall distribution of the lift force is larger than for gliding motion and more shifted towards the wingtip. Due to this batting movement, a thrust force (p. 111) is created along the total length of the wing. The functional principle is similar to a propeller blade having a very large pitch (ascent angle), with the exception that in the case of birds the longitudinal propeller force acts as a lift force.

A similar flight technique exists in principle also for insects. But due to the small size of insects compared to that of birds, there are not only similarities but also some important differences of the flight dynamics (s. Section 4.2).

150

Masters of the Air - Records of the World of Birds

The fastest flyer: The fastest Bird is the falco peregrinus (Wanderfalke) with a maximum air speed of 389 km/h (!) and an average diving speed of about 250 km/h. His average speed lies between 50 – 100 km/h.

Highest flying bird: Most bird species are flying abot 100 to 2000 m above ground.

Migrating birds however, are climbing frequently up to 10’000 m, für example if they are crossing the Himmalaja. The observed record is 11’000 m for the african ruspelli griffen (Sperbergeier). It is astonishing that the animals have the necessary physical strength inspite of the reduced oxygen concentration (Chapter 2, p. 301).

Long distance flyers: Record holder in long distance flights is the Arctic tern (Küs-tenseeschwalbe). From all migrating birds it is the one who is flying the longest distances. The bird is breeding in the Arctis and than migrates to the Antartics where it overwinters. The total travel distance in both directions lies between 30’000 and 50’000 km. This corresponds roughly to the circumference of the Earth (≈ 40’000 km).

Longest staying birds in the air: No bird is staying longer in the air than the alpine swift (Alpensegler): It has been ascertained recently that this bird is able to cover a non-stop flight of 200 days! Another bird who is also able to stay a very long time in the air is the common swift (Mauersegler) (s. Appendix 4-A-3-4).

151

Colorful Birds

The Red tile in flight

The vain Peacock

The coctactoo

The Albatros

The Mandarin duck

The great spotted woodpecker

The Toucan

152

The Anden condor

The Anden condor is a bird species belonging to the New World vultures. Adult mail animals are large and black rapterial birds. The Anden condors are giant, black birds with distinct white to silvery hanwlings. A white ruffle seperates the reddish-blue head from the trunk. They are the largest rapterial birds having a weight up to 15 kg and at the same time, they belong to the few birds with a wing span of more than 3 meters !

153

4.3.3 Gliding of Fishes - 1

Certain saltwater fishes are referred to as «flying» fishes. By means of self-propelling these fishes are able to perform jumps out of the water into the air. With the help of their long wing-like fins they are able to cover large distances over the water by means of gliding flights. This exceptional skill is a natural mechanism of self-defense against predators.

It is often observed how flying fishes are jumping out of the ocean water. Their streamlined torpedo-shaped habitus makes it possible to generate sufficient underwater velocity and together with their large wing-like pectoral fins they become able to fly.

The process of gliding in the air starts with the generation of high speeds close below the water surface, about 60 km/h. Once in the air, they achieve gliding heights up to 1.2 meters and they are able to glide over distanceis as large as about 200 meters.

154

Gliding flight of Fishes - 2

Flying fishes are living in all Oceans, most often in warm, subtropical water. They are usually smaller than 30 cm; the largest of them are up to 45 cm.

Flying fishes are bone fishes; with their wing-shaped fins, they are equally well capable to swim in water as to glide in the air. The rounded profile of the «wings» is comparable to the aerodynamic form of bird wings. But in contrast to birds, they are unable to flap their pectoral fins and for this reason they can not fly actively. With a leap, they rather catapult themselves out of the water and are then able to glide short distances above the water surface.

Flying fishes have extraordinary large pectoral fins which are fixed at the upper part of their boddy. For the subfamily Cypselurinae, also the ventral fins are winglike such that even 4 wings are available for gliding flight.

The largest flight routes are achieved, if these fishes are gliding very close to and parallel to the water surface: If they are gliding in a height of 1.5 meters above the surface, the fishes can stay more than 30 seconds in the air, thereby covering distances of about 50 meters; in extreme cases the gliding distance is even as large as 400 meters !

The excellent flight capabilities of these fishes are due to the fact, that the configuration of their fins are very well suited to achieve aerodynamically favorable characteristis of flight currents.

Occasionally, the fishes are able to reach velocities up to 70 km/h during their gliding flights and achieve flying heights up to 5 meters.

155

Gliding of Sharks

Sharks are cartilaginous (Knorpel-) fishes and therefore lighter than bony fishes. Worldwide, about 500 species are known. Most of the sharks feed on fishes and other marine creatures. Although only about 5 people are dying per year due to shark attacks, sharks are considered to be cold-blooded killers and ogres (Menschenfresser). Within the canivorous and hunting species, the White Shark (Jaws; remember Steven Spielberg) with a maximum length of 7 meters is the largest shark.

Skarks have oil-containing livers which contribute to their lift. In South Africa, the sharks have developed a special technique for seal (Robben) hunting: When seals cross deep water, the sharks, swimming at great depth, dart with great speed towards their victims near the surface. In doing so, they often shoot far beyond their target, i.e. they cross the water surface and are then gliding up to 200 meters across the air. During their gliding motion they admittedly touch the water several times but without immerging into it. The lift necessary for the gliding flight is favored by their oil-containing liver as well as by their light bones. In addition, the movement of their tail contributes to the lift.

156

4.3.4 Gliding flight of Reptiles

Reptiles are a group of animals that have scales (Schuppen), breathe air, and usually lay eggs. The term «Reptile» is loosely defined in everyday English to mean scaly, cold-blooded, egg-laying animals. The two most important features of Reptiles are:

- They are cold-blooded
- They are covered with scales

Being cold-blooded means that their bodies react to the temperature of their surroundings. They prefer warm surroundings but when they get too warm, they moove into the shade or into the water.

Common Reptiles include alligators, crocodiles, lizards (Echsen), snakes, tortoises (Landschildkröten) and turtles (Wasserschildkröten). One of the most remarkable feature of Reptiles are the scales that cover their body.

Some gliding Reptiles:

There are no flying Reptiles, but a few of them are able to glide:

- Gliding Kites (lizard)
- Gliding Geckos
- Gliding snakes

157

Flying Dragons

Flying dragons are a species of the family of lizards (Echsen).

They are living on trees in the rain forests of South-East Asia, in particular on the Islands of the Malayan archipels.

Flying dragons have a size of 20 to 26 cm. They possess flying membranes which are stretched by 5 to 8 extended ribs. Using these membranes as sails, they are able to glide from one tree to the next one. Most often they bridge only a few meters, but they are also able to cover gliding distances of up to 60 meters. The skinny sails as well as the throat sack are often multicolored and in resting position they are laterally back folded to the body.

158

Gliding flight of a Gecko

Geckos are a family of scaled reptiles. They populate the Earth since about 50 million years and during their development they spread out globally.

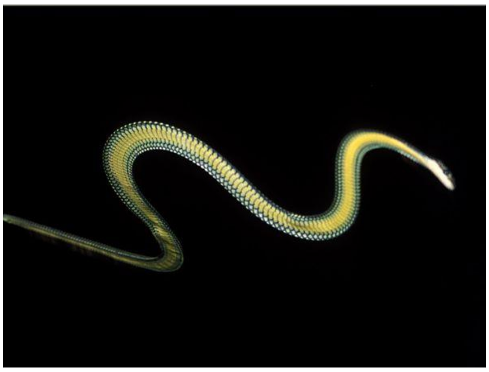
Geckos are small to middle-sized lizards with sizes ranging from 1.6 cm up to almost 40 cm. About 75% are twilight- and nocturnal active animals and correspondingly, their coloration is quite modest.

Flying Gecos have airfoils at the extremities, at the tail and at the the body sides. Geckos are bug hunters. The tinge of the membranes is barklike and hence unobtrusive. In their resting position, these barklike membranes serve as a cover against predators.

Their toes are connected by a tissue. Due to the above mentioned airfoils and the tissue between the toes, they are excellent gliders.

159

Gliding or «Flying Snakes»



Five related colubrid species in Asia are not only crawling across the ground but they are also «flying» through the air!

These «flying snakes» are considered to be biomechanical miracles: They do not possess wings, but nevertheless they are able to «fly». Strictly speaking, they are gliding through the air. For this purpose, they are leaving a tree or a higher object, thereby making their body flat like a sail. Then, they are gliding from one tree to another tree or to the ground. During their gliding motion, the colubrids are able to stay in the air by a wavelike spiral mouvement of their bodies. They are, however, not able to fly actively up to higher altitudes.

«Flying snakes» constitute a small group of tree snakes. Only five known related species belong to this group, all of which are so-called «Golden Tree Snakes». They are living in Southeast Asia and in South Asia. The lengths of the adult reptiles varies between 60 cm and 120 cm. If the diurnal snakes are biting, they excrete a weak poison which is only dangerous for their preys such as Gecko's. frogs, birds and bats.

The reason of why these snakes are gliding is not known. It is presumed that by gliding, the snakes are catching their preys and / or are escaping from their enemies.

160

4.3.5 Gliding Amphibians

Difference between Amphibians and Reptiles

Amphibians are strongly dependent on water. At the beginning of their life they are gill breathers and they always need a humid habitat to prevent drying out.

Reptiles (pp 157 – 160) are, however, pure terrestrial animals. They faver warm and sunny habitats. Their skin consists of a scale layer; some of them even have a protecting shell. During the year they moult themselves several times since their scale layer does not grow back.

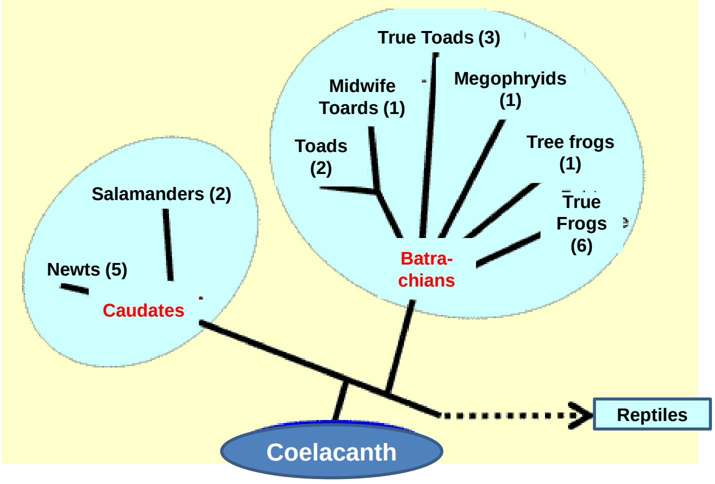
Amphibians: Definition and general facts

The Amphibians are the phylogenetically oldest class of terrestrial vertebrates. Many species are living first in a larval stage in water, and after a metamprphose they change to a terrestrial life. As a consequence of this beaviour they have been named Amphibia which originates from Greek and refers to their two-stage live.

During the course of a year, the adult animals often live in aquatic habitats as well as in terrestrial habitats. The vast majority of species is dependent at least temporarily on freshwater pools. Many Amphibians are living at night, i.e. they are nocturnal animals. This protects them from natural enemies as well as from water loss through their skin.

161

Amphibians: General



In the above representation, the family relations within the Amphibians are illustrated. The 21 native species of Amphibians can be divided into 2 groups: the **Caudates** and the **Batrachians**. The author of this representation has indicated the number of species in paranthesis: for example, there are 5 species of Newts, 2 species of Salamanders, 2 species of Toads, 6 species of True Frogs, etc.

At the following page, the **Tree Frogs** are of particular interest because they are able to glide.

162

Gliding Frogs

It is well-known that frogs are able to jump. What is much less well-known is that some frogs can fly or more precisely can glide. One member of the treefrog family which is found in Malaya can «fly». It flies not for advantage but rather to catch its prey.

Gliding Wallace Treefrog

It is called Wallace's Treefrog and is more equipped to chase flying insects than other frogs.

It has webbed feet with long fingers and toes. When it can catch a particular insect that is flying away, it stretches its fingers and toes wide apart. This increase in surface area allows it to glide downwards for long distances. And during its decent it can catch pray for dinner.

In addition to the Wallace's Treefrog also the Chines frog is able to glide.

163

4.3.6 Flying and Gliding Mammals

164

Flying and Gliding Mammals: Overview

Bats and Flying foxes

Flying Squirrels

Colugos

Flying Lemures

Marsupials

165

4.3.6.1 Bats and flying Foxes

Bats are a group of mammals which together with the «Flying Foxes» constitute the order of bats. Flying vertebrates are divided into two groups: birds and flying mammals. From the latter, only bats and flying foxes can actively fly. Worldwide, there exist about 900 bat species. The bat shown below is the so-called «Greater mouse-eared Bat»; its wingspan is as large as 42 cm! In our latitudes, the maximum wingspan of the animals is, however, only about 8 cm.

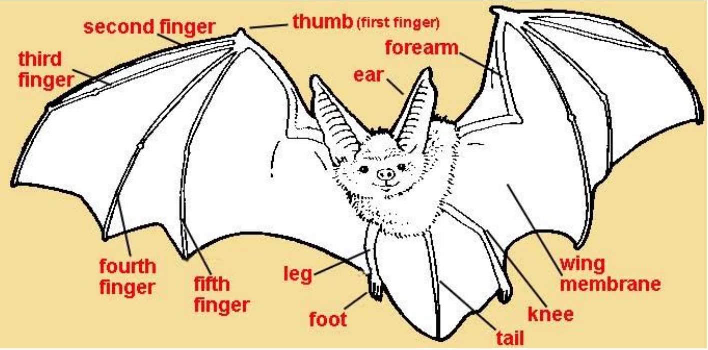
Greater mouse-eared Bat

166

Anatomy of Bats

Strictly speaking, the name «Bats» (Fledermäuse) is not justified because they are by no means related to mices. Bats or «hand-flyers» represent a proper order. Together with «Flying Foxes» they are the only mammels which are capable of flight and are constituting the order of bats.

The principle type of locomotion is flying. This is possible by their flying membranes and other specific adaptations (see Figure below). There exis narrow-winged species as well as broad-winged species. The narrow-winged bats are often rapid flyers which are usually living in open areas. Their travel speed is as high as 50 km/h. On the other hand, the broad-winged bats are slow flyers (about 15 km/h) and they are moving in variegated landscapes.



Anatomy of Bats

167

Aeronautics: Bat in the Wind Channel

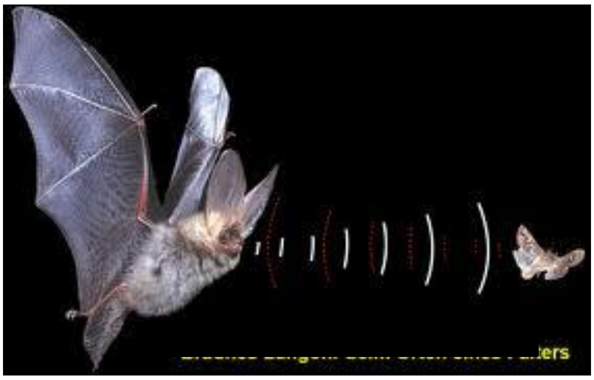
In contrast to birds, bats do not have feathers. They turn their wings to the vertical axis, clap their wings upwards and then flap the flat wings downwards. The skin of the wing tails serves for manoeuvring and deceleration. Scientists of the Swedish University in Lund have studied the resulting air currents as well as how the bats are using these currents very skillfully for flying (see picture below). The secret of the acrobatic fliers can be understood on the basis of their elastic and very flexible membrane wings. The latter are functioning as a hand with skins between their fingers. .

The motion of a bat's wing has been studied by researchers of the Max-Planck Institute (MPI) together with Swedish scientists. They studied the air currents in a wind channel and observed vortices generated by each stroke of wings. The arrows in the left-hand picture indicate the circular air stream; the length of an arrow indicates the velocity of the air molecules at this site. During an up-stroke of the wings, these vortices rotate at the centers of the wings as well as at the wing tips but in opposite directions. The superposition of these two vortices generates a lifting force. The photographic image has been obtained by keeping the bats at a fixed position in the wind channel while the air was flowing over the animals.

168

Echolocation of Bats

With the help of their vocal cords and of their voicebox, bats are producing hoots (inaudibile calls), i.e. ultrasonic louds; this is known as ultrasonic localization. Most bat species produce these hoots by their mouth which propagate through the air as ultrasonic waves. If the sound waves impinge on an obstacle or on a pray insect, they are back reflected and the echo is detected by the bat's sensitive ears. By analizing the echo, i.e. the frequency distribution of the sound, the sound transmitting bat can distinguish whether the reflected sound originates from a house, a tree or a pray insect. From the Doppler effect (increase or decrease of the frequency of the reflected waves), the bats are able to detect the flight direction of the pray insect (see Figure below).



White waves: Ultrasound waves emitted by the bat.

From the located object, a butterfly in the present case, ultrasonic waves are back-reflected to the bat.

169

4.3.6.2 Flying Foxes

Flying foxes are the largest species of bats: The wingspan of the Kalong flying fox can be as large as 170 cm and many species have a snout-vent length up to 40 cm. Many species are, however, smaller; the largest bats are distinctly taller than the smallest flying foxes.

The bodily frame of flying foxes is similar to that of bats. The membrane wings are clamped between the elongated second and fifth fingers (dactyls) and extend down to the ankles .

Flying foxes are widespread in the tropical and subtropical Africa, in southern Asia and Australia as well as in western Oceania. Similar to bats, they are essentially twilight-active and nocturnal. For searching food, they often cover large distances. During the day, they are sleeping. In contrast to bats, flying foxes are often sleeping in a hanging position at the branches of trees (s. p. 171).

In contrast to bats, flying foxes are not able to orient themeselves by echolocation (an exception are the Rosette flying foxes). Flying foxes have well developed eyes as well as an excellent sense of smell. Because of the warm climate in their habitats, they are not sleeping during winter. The taller species are often assembled in large groups (up to 500'000 animals!) while the smaller species are essentially loners (rogues).

170

Orientation and Sleep of Flying Foxes

Orientation: The species of Pteropus of flying foxes orient themeselves optically. Their twilight vision is well developed but ultrasonic location is completely absent. For the search of food, their sense of smell is very well developed.
The flying foxes belonging to the species «Rousettus» are not only able to orient themeselves optically but also by ultrasonic localization. Depending on the circumstances, both, optical and acoustical orientations are used. With increasing darkness, the optical orientation is replaced by acoustical orientation.

How do flying foxes sleep? During the day, they gather in large groups as sleeping colonies in high trees. There, they are hanging head over heels and envelop themeselves into their leathering wings. Even the copulation of these animals takes place upside down!

171

Little Red Flying Foxes

PHOTO: Little Red Flying Foxes have transparent wings and red flurry bodies

Little Red Flying Foxes are tree-dwelling bats. In daytime they can be seen roosting in giant camps that may include as many as a million individuals. The bats are indeed efficient fliers, as their name suggests, but time in the trees has also made them excellent climbers.

Despite the old «blind as a bar» axiom, these and other flying foxes have excellent sense of both, sight and smell, which enables them to find plenty of their favored foods.

172

4.3.6.3 Flying Squirrels

Between the forelegs and the hind legs a gliding membrane is spanned up which acts as a paraglider; this inables the animal to jump from one tree branch to the other. Although squirrels are not able to fly but are rather gliding, they are referred to as «flying» squirrels.

The tail is always long, broad and bushy and serves as a flight controle. Under favorable conditions, the so-called giant squirrels are able to glide over distances as large as 50 m.

In order to land at a perpendicular tree trunk below the crown, the squirrel raises the arms and the tail and is then able to tilt their body nearly perpendicularly in the air. This strongly slows down the gliding speed. In this way, the squirrel can perform a soft landing with the head upwards.

Squirrel at a tree trunk

Gliding squirrel

173

4.3.6.4 Gliding Lemurs

Flying Lemurs are not really flying but they are rather gliding through the forest over distances as large as 130 m. If they are climbing up a tree trunk, their flight membranes are foldet together; this is a handicapp which makes climbing particularly tedious. After having arrived at the top of the tree, they are gliding down to a branch or to another tree and the tedious ascent starts again.

Gliding Lemurs are principally nocturnal; their acrobatic flights would attract to much attention to their hunters during the day.

For female Lemurs, gliding is particularly tedious since during the flight their offsprings are hanging on the mother.

Remark: Gliding Lemurs should not be confused with Colugo's (Riesengleiter: s. p. 4-A-3-5)

A Lemur climbing at a tree trunk

174

A gliding Lemur

4.4 Gliding and Flying of Men

175

4.4.1 The Dream and Myth of Flying

In antiquity, flying was often considered as an attribute of privilege of the Gods. Also in cases where the Gods or the supernatural beings are not pictured with wings, their ability of flying belongs to their property. In indian myth, there are pictures of flying divine chariots (Vimanas), as are known from the Epos of Ramayana.

One of the earliest considerations of the dream of flying of humans is found in the Legend about the chinese Emperor Shun (2258 – 2208 BC). In this Legend, the Emporer learned to fly as a bird in order to escape from his imprisonment.

Emperor Shun

Icarus and Daedalus (Greek mythology)

Icarus and Daedalus

Daedalus fashioned two pairs of wings out of wax and feathers for himself and his son Icarus. Deadalus tried his wings first, but before taking off from the island, warned his sun not to fly too close to the sun. Overcome by the giddiness that flying lent him, Icarus soared through the sky curiosly, but in the process he came too close to the Sun which melted the wax. Icarus kept flapping his wings but soon realized that he had no feathers left and that he was only flapping his bare arms, and so Icarus fell into the Sea in the area which today bears his name, the Icarian Sea near Icaria, an island southwest of Samos.

The Flight of Icarus

176

Berblinger: The Tailer of Ulm

Albrecht Ludwig Berblinger (1770 – 1829), known as «The Tailer of Ulm», was a German inventor and flight pioneer. He became well-known by the construction of an airworthy hang glider, with which he intendet to fly over the Danube. However, the gliding flight from the «Adlerbastei» of Ulm at 1811 misslang and he crashed into the Danube.

Before his fatal attempt, he was the first human beeing who was able to accomplish short gliding flights. Unfortunatly, his first public flight 200 years ago failed miserably. In the mean time it is evident that the daring aviation pioneer just startet from an awkward place.

It was only in the last century that Berblinger has been rehabilitated: Experts investigated the thermal conditions at the «Adlerbastei». It was found that even at the warmest weather conditions a descending air current exists over the cold water of the river. Because of the perpendicular town wall, the headwind does not develop to an upwind but rather to a whirlwind. These unfavorable wind conditions were resposible for his disaster.

177

Flight Pioneer Otto Lilienthal

Karl Wilhelm Otto Lilienthal (1848 – 1896) was a German engineer and flight pioneer. According to current knowledge, he was the first men who was able to complete successful and reproducible gliding flights by using hang-gliders and he was able to leverage the flight principle «heavier than air». By his experimental work he established the physical principles of airfoils which are still valid today. The production of the «Normal Glider» in his engineering works in Berlin can be regarded as the first serial production of an airplane. His principle of flying corresponds to that of the present hang-glider. This hang-glider has been further developed by the Brothers Wright to the airplane of today.

Otto Lilienthal

The Brothers Otto and Gustav Lilienthal have recognized that the wing form is of primary importance: They realized that slightly elevated airfoils produce a larger lift than flat airfoils. The characteristic form of the wings of birds did not slip the attention of other aerodynamic engineers too, but the Lilienthal's have related this fact by means of exact measurements. For the evaluation of the lift they used the relation (4.1.15) quoted on our page 119.
The sensetional photographic pictures of flight have been reproduced in scientific and popular publications in many countries.

Ready for take-off

178

Lilienthal: «From Step to Jump, from Jump to Flight»

His brother Gustav did not participate anymore at the actual gliding flights. For this reason, the first gliding flight of a man is exclusively credited to Otto Lilienthal. It should, however, bee realized that his brother actively contributed to the construction.

Original glider in the «National Air and Space Museum» in Washington

Fotos and gliding flights of Otto Lilienthal with gliding distances up to 250 meters.

Lilienthal constructed at least 21 gliding machines and carried out more than 2'000 flight experiments.

At August 9, 1896 he crashed from a hight of 15 meters near Stöllin at the Gollenberg in Germany. Due to awkward thermal conditions, Lilienthal's glide pitched forward heading down quickly. One reason for his accident is probably also related to the fact that he always tried to increase the flight distance. He died either from a cervical fracture or from a brain bleeding.

The damaged glider

179

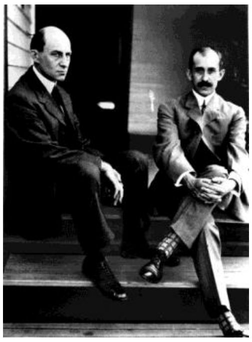
4.4.2 The first gliding and flying machines

The brothers Wright, Wilbur Wright (1867–1912) and Orville Wright (1871–1948) from Dayton, Ohio, were american pioneers of aviation. At the beginning of the 20. century, they performed first flights with gliders and then they started flights with motor-controlled airplanes.

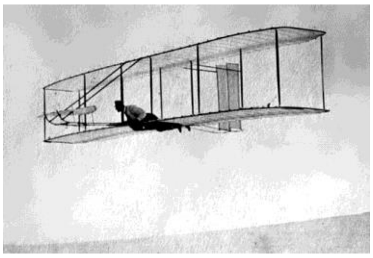
Following Lilienthal, the brothers Wright used the lift relation (in this work: eqation 4.1.15, p. 119) but with a modified coefficient C_A. They also recognized that Lilienthal's crash was due to inadequate flight control (steering capability).

At 1899 the brothers Wright started with the construction of the first flying machine, a biplane gliding flyer (see photphraph). It contains already a very important feature, namely the wing-warping airfoils, with which the horizontal position of the flight apparatus could be controlled.

Between 1901 and 1903, many unmanned and manned gliding flights have benn performed. During the year 1902 a large number (more than 1'000) gliding flights with the biplane glider were carried out, the longest distance was s=189.7 m with a flight duration of t=26 s, i.e. the mean velocity was v =s/t ≈ 7.3 m/s = 26.2 km/h.



The bruthrs Wright:
Wilhelm (left) -- Orville (right)



Biplane glider: 1902

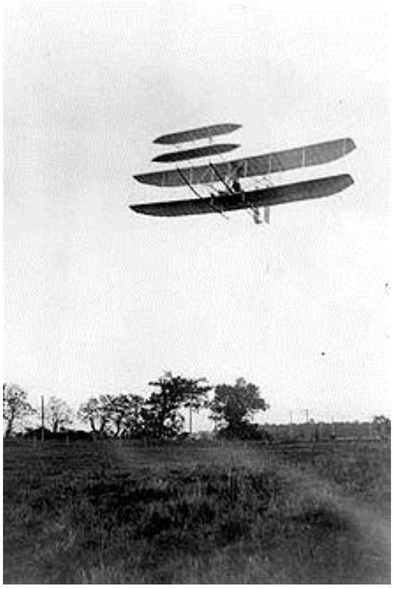
180

Double decker motorized Airplane

At Decenber 17, 1903 Orville and Wilbur Wright started their «Flyer». It was a fragile looking Double decker motorized airplane built from wood, wire and textile.

The brothers cut a propeller having a high efficiency and gave order to manufacture a suitible propulsion unit, namely a water-cooled four-cylinder four-stroke gasoline engine having a mass of 81 kg which delivered 12 PS. For momentum compensation, the airplane was equipped with two opposite air-screws having a suitable mechanical drive.

The motorized airplane was 12 seconds in the air and covered a distance of 37 meters, corres-ponding to a an average velocity of 11.1 km/h. The velocity could be increased to 16 km/h. The airplane had a wingspan of 12.3 m; its length was 6.4 m and its height was 2.8 m. The flight mass was 340 kg and the pilot was laying quitely at the lower airfoil.



The brothers Wright :
Power Flyer 1905

181

Charles Lindbergh : Alone over the Atlantic

Charles Lindbergh (1902 – 1974) was an US pilot and winner of the «Medal of Honor». Between March 19 to 21 he was able to achieve the first Solo Flight over the Atlantic, starting in New York and landing in Paris. The covered distance was 5'805.5 km, for which he needed a flight time of 33.5 hours. His airplane had only one single motor with a power of 223 PS. The average speed was 173 km/h, and the maximum speed was 220 km/h.

In the benefit of a maximum fuel load, Lindbergh did not carry with hîm neither a radio equipment nor a sextant. He was only equipped with a wristwatch and a compass. The most severe problem was a heavy snow storm in New-foundland which he passed between New York and Nova Scotia. Another severe problem was to over-come his fatigue during his flight between Southern Island and Southern England. Hovewer, his navigation worked very well: when he atteined the shore of Ireland, he was only 5 km off from his target. He than flew along the coast of England, passed the English Channel and arrived in France. In Paris he was received by a jubilant crowed.

Charles Lindbergh, 1927

Lindbergh with his Airplane
«Spirit of St. Louis»

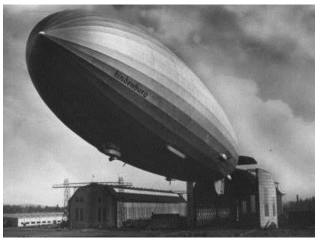
182

4.4.3 The Airship of Count Ferdinand Von Zeppelin

The principle of the Airship is simple: It is filled with a gas which is lighter than air thereby gaining a lift and is gliding forward, powered by motor-driven propellars.

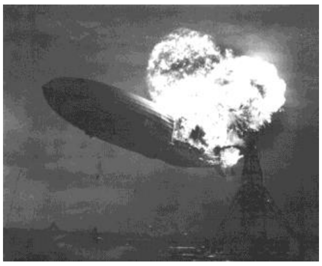
Last Photograph of Count Ferdinand Von Zeppelin (1838 – 1917)

The largest Zeppelin which has ever been built was the giant Airship LZ 129 «Hindenburg». Its length was 245 m(!), its maximum diameter was 41.2 m and it was filled with 200'000 m^3 Hydrogen. Instead of hydrogen it is also possible to use the inert Helium gas. The LZ 129 was equipped with 4 Diesel engines (total power 4'200 PS, maximum velocity 130 km/h, travelling time from Frankfurt to New York: 2 ½ - 3 days). Its last flight took place in May1937. During landing at Lakehurst near New York, the Hindengurg caught fire and birst into flames within seconds. At the time of this Hindenburg disaster, 97 persons were on board, but 62 of them survived the catastrophe.



Ascent of Zeppelin «Hindenburg» LZ 129 in Friedrichshafen

Tragic flight of Zeppelin «Hindenburg» from Friedrichshafen (Germany) to Lakehurst (near New York)



The catastrophe of Zeppelin «Hindenburg» (6. Mai 1937)

183

4.4.4 The Sailplane

A sailplane is an aicraft which is constructed for gliding with a small loss of altitude. In the upwind it even rises. In order to be able to fly, it must transform height (potential energy) into forward speed (kinetic energy). A sailplane must be started appropriately. Starting can be achieved by using an aircraft tractor (s. left-hand Figure below). The sailpane is raised into the air by means of a motorized aircraft. The height at which the sailplane is released is usually between 500 m und 1500 m. There exist also other starting principles (s. Reference R.4.4.7).

Modern sailplanes have a gliding ratio between 1:30 and 1:60. This means that in quiete air they can fly 30 to 60 km with a loss of height of only 1 km. In order to achieve good gliding properties, a sailplane must be constructed with a very low drag.

Aircraft tractor starting a sailpane

A sailplane in gliding flight: a high - performance two-seater.

184

4.4.5 Jet engines of Airplanes

The propulsion of a Jet Aircraft (e.g. Boeing 747) depends on the <u>reaction propulsion:</u> A rapid ejection of a combustion gas creates a recoil in the opposite direction. Therefore, if a jet engine ejects a jet blast in the backward direction, a <u>recoil</u> in the forward direction is created. As a consequence, the whole Jet aircraft is accelerated in the forward direction.

[As we have discussed at p. 4-A-2-3, Octopus are using the same principle, the <u>principle of conservation of momentum</u> to escape the water and to glide through the air.]

Boeing 747 – 81 (in operation since 2012)

Some Data of Boeing 747 - 81

Length	76.30 m
Wingspan	68.50 m
Airfoil area	534 m^2
Span width	22.17 m
Hight	19.40 m
Fuselage height (Rumpfhöhe)	7.85 m
Cabin width (internal)	6.1 m
Cabine height	2.54 m
Flying range	14'815 km
Speed at an altitude of about 10'700 m	913 km/h
Take-off speed	~ 300 km/h (*)
Maximum take-off mass	447'700 kg
Maximum number of seats	605
Average number of seats	467
Crew (Cockpit)	2
Aircraft delivery	2013 - 2015
Number of orders at 2013:	~ 33

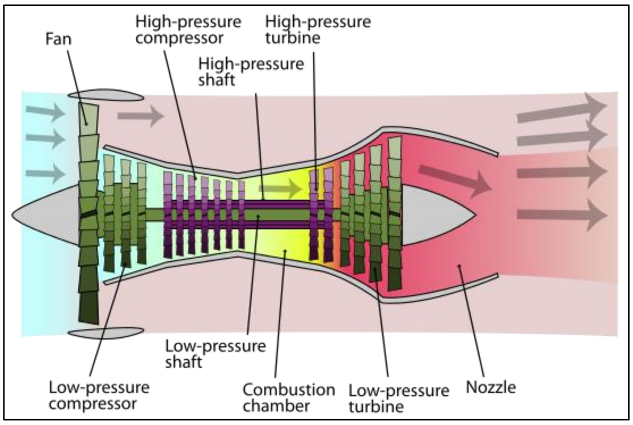
(*) depending on take-off weight, height of runway and wheather.

185

Airbreathing Jet Engine

The airbreathing engine suckes in the ambient air and increases its pressure in a compressor. In the adjacent combustion chamber, the fuel (Kerosine) is injected and the mixture is combusted. The combustion increases the temperatureand and the flow speed of the gas. This flow energy is partially transormed into rotating motion of the turbine and the gas is further expanded (thus the turbine extracts energy).

The turbine powers the compressor, the fan and other aggregates. The gas expands in the thrust nozzle behind the turbine and acquires nearly ambient temperatur while the flow speed is further increased. The gas escaping through the thrust nozzle generates the propulsion (recoil) in the opposite direction. (For more information see Appendix 4-A-4-1).



Major components of an Airbreathing Jet Engine

Propulsion (recoil)

186

Estimate of take-off speed of Boeing 747 - 81

From equation (4.1.15) at p. 119, the lift force is given by $F_{at} = (1/2)\, C_A\, A\, \rho\, u^2$ and solving for the velocity u gives

$$u = [2\, F_{at} / (C_A\, A\, \rho)]^{1/2} \qquad (4.4.1)$$

For lift, the force F_{at} must be equal to or larger than the weight M g of the airplane (M = mass of the airplane with Kerosine, passengers and cargo, g = 9.81 m/s² = gravitational acceleration). In this case, $u \approx u_{take\text{-}off}$ is the take-off speed of the airplane:

$$u_{take\text{-}off} \approx [2\, M\, g / (C_A\, A\, \rho)]^{(1/2)} \qquad (4.4.2)$$

For Boeing 747–81 we put M ≈ 400’000 kg (with Kerosine and passengers, s. p. 185). The coefficient of lift C_A (s. p. 119) depends on the angle of attack α (p. 117).

According to Ref. (R.4.4.10 a) we write $C_A = 2\pi\alpha_r$, where α_r is the angle of attack (s. p. 117) in radians, $\alpha_r = (\pi/180)*\alpha_d$, α_d = angle in degrees (º). The above expression for C_A is an approximation for $\alpha_d \leq 13^0$ as discussed in Ref. R.4.4.10 a). We put $\alpha_d = 13^o$ i.e. $\alpha_r = 0.227$ and obtain $C_A = 1.426$. For the Boeing 747 – 81, the total airfoil is A = 534 m² (s. p. 185). At 20⁰C, the density of air is ρ = 1.204 kg/m³ at sea level. From equation (4.4.2) we then obtain: $u_{take\text{-}off} \approx$ 92.5 m/s = 333 km/h. This take-off speed corresponds within 11% to the approximate speed of 300 km/h for the Boeing 747 – 81 aircraft (s. p. 185).

Take-off of Boeing 747 - 81

187

4.4.6 The Helicopter - General

Swiss Helicopter during landing

Swiss Helicopter during flight

A Helicopter is a vertically starting and landing aircraft. It transfers motor force to one ore several rotors for generation of lift and thrust. These rotors are rotating wings; for this reason, Helicopters are rotating-wing aircrafts.

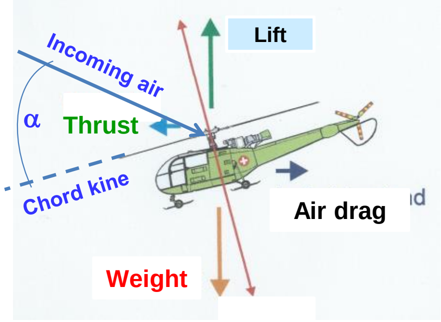
The splitting of the incoming air at the rotor blades gives rise to a pressure difference and a corresponding dynamical lift (see pp 114, 117 for fixed wings). As for the case of airplanes, the lift depends on the profile of the wing, on the angle of attack and on the flow speed of the air.

The basic physical flight principles are therefore the same as for a fixed-wing airplane. For a Helicopter, however, the wings are rotating around the rotor shaft. As a consequence, a Helicopter is more flexible than an airplane, it can even hovering at a fixed position.

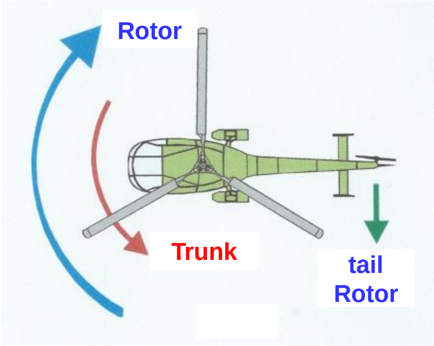
The flying of an airplane can be explained by the recoil principle: The dynamics of the air around an airfoil results in a lift force. For a Helicopter, a lift force exits even if the wings are rotating at a fixed position.

188

About the Physics of Helicopters



The spinning rotor blades of a Helicopter accelerate the air from top to bottom. This increases the angle of attack α. (The angle of attack is the angle between the relative diretion of air flow and the chord line of the rotor blade). In analogy to a fan, the air is blown downward, the lift is increased and the Helicopter starts to ascend. In order that the Helicopter is moving forward, the rotor plane must be tilted forward; in this way, the airstream is blown backward by the rotor blades.
(See also the similarities and differences with the flight characteristics of Dragonflies (pp 138, 139).



According to the law of action and reaction, the trunk of the Helicopter is turned in the opposite direction to that of the rotor. In order to prevent this, most Helicopters are equipped with a perpendicularly oriented rotor, the so-called tail rotor, which balances this torque. With the help of this tail rotor, the Helicopter can also be navigated around its vertical axis in the case of a hovering flight.
Helicopters with two main rotors spinning in opposite directions, do not generate a resulting torque but the lift is then reduced.

189

Appendix - Chapter 4

4-A-0

Basic Equations of Aerodynamics

Navier – Stokes Equations

The Navier–Stokes equations are the fundamental relations for viscous heat-conducting fluids (gases, liquids). They consist of a system of coupled non-linear differential equations, which have been derived by applying Newton's equations of motion to a fluid-element. These equations are very complex and can only be solved numerically.

Euler's – Equations

The Euler-equations are a system of partial differential equations of first order which is a special case of the Navier-Stokes equations if frictional forces (viscosity) and heat conduction can be neglected. Euler's equations are usually also solved numerically.

The Bernoulli Equation

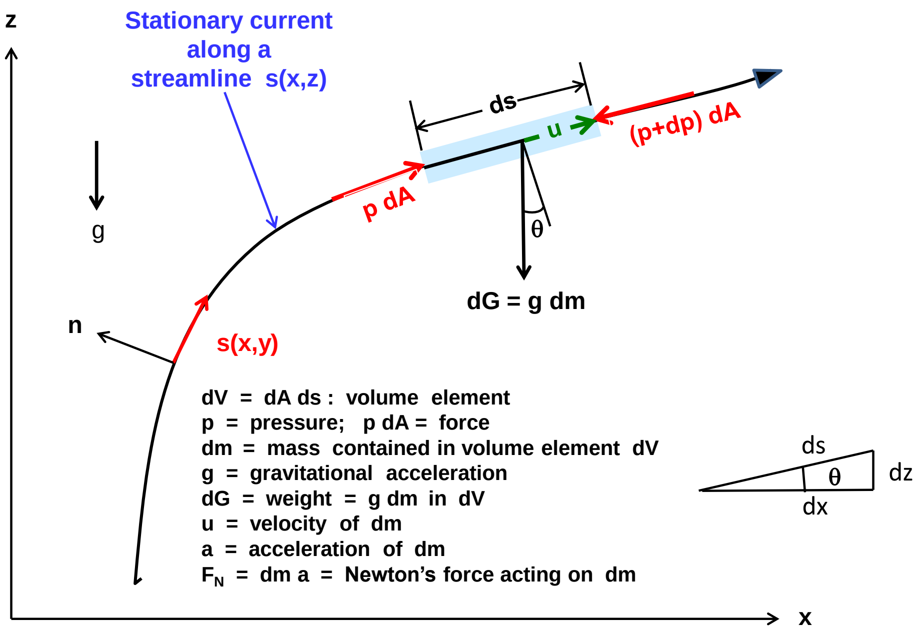
For the case of stationary flows, Euler's equations can be spationally integrated and one obtains the Bernoulli-equation which is valid for the entire fluid current. In the special case of incompressible homogeneous fluids with constant density ρ and if only the graviational force is acting, one obtains:

$$p + \rho\, g\, z + (1/2)\, \rho\, u^2 = p_0 = \text{const.}$$

Here, p is the hydrostatic pressure, p_0 the total pressure, ρ the density of the fluid (air), u the velocity of the moving object or of the fluid. The term $(1/2)*\rho*u^2$ is the hydrodynamic pressure, g is the gravitational acceleration and z is a reference level with constant geodetic altitude (pp 4-A-1-3, 4-A-1-4).

4-A-1-1

Forces acting on a fluid particle along a streamline



4-A-1-2

Derivation of Bernoulli's equation

Let dm be the mass in the volume element dV = dA ds of the streamline considered (s. Figure, p. 4-A-1-2). If u(s) = ds/dt is the velocity of dm , the acceleration a of dm is given by

$$a = du/dt = (du/ds)\,(ds/dt = u\,(du/ds) \qquad (1)$$

and Newton's force is

$$F_N = dm\, a = dm\, u\, (du/ds)\ . \qquad (2)$$

Let dV = dA ds be the volume element considered and ρ = dm/dV the density of the fluid at the position s. For an isothermal fluid with negligible frictiom, the external forces F_{ext} are composed on the pressure forces and the weight force dG: From the Figure on p. 4-A-1-2 it follows:

$$F_{ext} = p\, dA - (p + dp)\, dA - dG \sin(\theta). \quad \text{With } F_{ext} = F_N \text{ we obtain}$$

$$p\, dA - (p + dp)\, dA - dG \sin(\theta) = dm\, u\, (du/ds) \qquad (3)$$

Using dG = g dm, dm = ρ dV = ρ dA ds and with sin(θ) = dz/ds it follows

$$dG \sin(\theta) = \rho\, g\, dA\, ds\, (dz/ds) \qquad (4)$$

Substituting eq. (4) into eq. (3) and using u du = (1/2) d(u^2) one obtains after simplifying

$$dp + (1/2)\, \rho\, d(u^2) + \rho\, g\, dz = 0 \qquad (5)$$

If ρ is independent on p (incompressible fluid), one obtains after integration Bernoulli's equation:

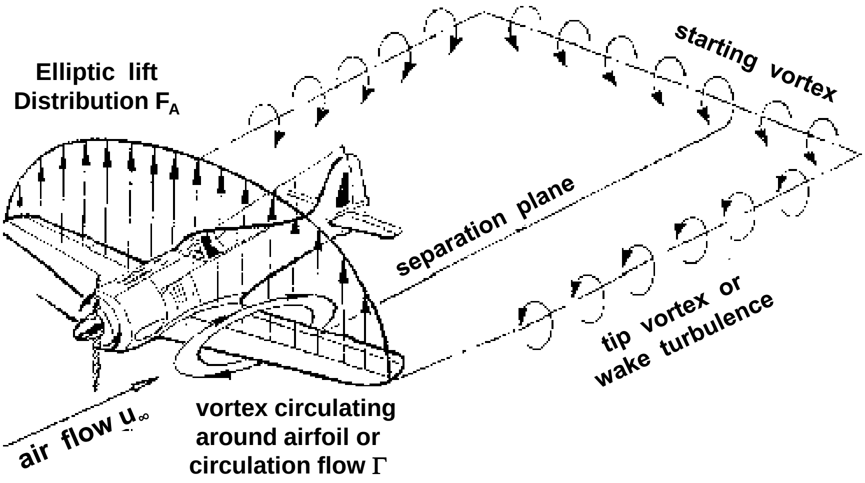
$$\boxed{p + (1/2)\, \rho\, u^2 + \rho\, g\, z = \text{const.}} \qquad (6)$$

or

$$\boxed{p_1 + (1/2)\, \rho\, u_1^2 + \rho\, g\, z_1 = p_2 + (1/2)\, \rho\, u_2^2 + \rho\, g\, z_2} \qquad (6a)$$

4-A-1-3

Vortex system of an airplane



Due to a superposition of the starting vortex, the circulation vortex Γ around the wings and the air stream u_∞, the airfoil streaming is established and as a consequence, the dynamic lift starts to operate. According to the conservation of angular momentum, the circulation flow Γ and the starting vortex cancel each other; the same holds for the tip vortices of the two wings. Note also the elliptic distribution of the dynamic lift F_A across the two wings.

4-A-1-4

Heuristic Derivation of the Reynolds – Number Re

We consider an object immersed in a one-dimensional flow with flow velocity u in the flow direction x. The Reynolds-Number Re (s. p. 127) is the ratio of the force of inertia F_T and the frictional force F_R acting on the object in the direction opposit to F_T:

$$Re = F_T / F_R \qquad \text{(a)}$$

Force of inertia: $F_T = m\, b = m\, (du/dt) = (\rho\, V)\, (du/dt) = (\rho\, L^3)\, (du/dt)$ (b)

(m = mass , ρ = density of fluid , $V \approx L^3$, L = characteristic length of the object)

Frictonal force: $F_R = [\rho\, \nu\, (du/dz)]\, A = [\rho\, \nu\, (du/dz)]\, L^2$ (c)

(ν = kinematic viscosity, $[\nu] = m^2/s]$; du/dz = change of u in z-direction due to friction)

It follows: $F_T/F_R = [(\rho\, L^3)\, (du/dt)] / [(\rho\, \nu\,)\, (du/dz)]\, L^2] = (\, L/\nu)\, (dz/dt)$ (d)

Using $dz/dt = (dz/dx)\, (dx/dt) = (dz/dx)\, u$ one obtains (e)

$$F_T/F_R = (L / \nu)\, u\, (dz/dx) \qquad \text{(f)}$$

Since dz/dx is only a ratio of two lengths, we put $dz/dx \sim L/L = 1$ for geometrically similar flows; then

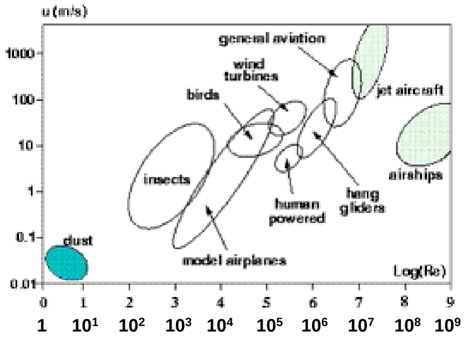
$$Re = F_T/F_R = (u\, L) / \nu \qquad \text{(g)}$$

Introducing the dynamical viscosity $\eta = \rho\, \nu$ $[[\eta] = N\, s/m^2 = kg/(m\, s)]$ one obtains from equation (g) the following expression for Re:

$$Re = (\rho / \eta)\, L\, u \qquad \text{(h)}$$

4-A-2-1

Examples of Reynolds numbers of flying animals and in Technique



The diagram shows the Reynolds numbers Re of several classes (insects, birds, model aircrafts, wind turbines, etc.) as a function of the velocity u. Note that the Reynolds numbers of the smallest insects, such as the fairyflies are not shown in the diagram. (The corresponding numerus scale of the logarithme of Re has also been added by P. Brüesch).

While bats and birds are flying with Re- numbers between 10^4 and 10^6, most of the insects are flying with Re- numbers of about 10^4 down to numbers in the teens.

Re ≈ 10^4: Larger insects such as dragonflies and hawk moths are flying with Re- numbers of ≈ 10^4.

Re between 10^4 and 10^2: Most of the medium-sized insects are flying in this range.

Re smaller than 10^2: The great army of small insects who are weighing only a few milligrams are flying with Re- numbers in the teens (not shown in the diagram). The flight of these animals is dominated by viscous resistance forces. W. Nachtigall, a pioneer of animal flight has formulated the situation of these tiny little things vividly as follows: «For these tiny insects the air behaves as a tenacious honey in which they are floundering about as water flies».

Example: Fairyflies are the smallest insects known; the males of the species «Dicopomorpha echmepterygis» have a length of only 0.14 mm. With their paddle shaped reduced forewings they are not good fliers but are rather carried by the wind. In the following we assume that they are flying in completely still air and we estimate their Reynolds number Re (s. p. 127). We put L = 0.2 mm (female); ρ = 1.204 kg/m^3 (density of air at 20^{0}C); $\eta = 18 \times 10^{-6}$ kg m^{-1} s^{-1}; u ≈ 1 cm/s = 0.01 m/s. It then follows: Re ≈ 1.

4-A-2-2

Gliding Octopuses - Calmaries and Common Octopuses

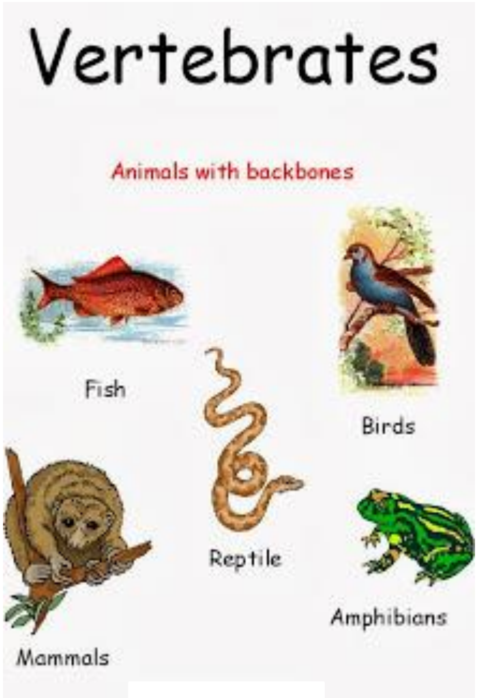
Octopuses belong to invertebrate molluses; they are cephatopods with 8 to 10 arms. Without exception they are predators (Räuber) and most of them are very fast swimmers. Calamaries and Common Octopuses are subgroups of Octopuses; Calamaries and Common Octopuses (Kraken) have 10 and 8 arms, respectively. On the run in water, they employ the principle of recoil: they press out the water from their mantle cavity through a sinkhole and escape by the principle of recoil.

Based on this propulsion technology, some species are able to escape from the water and are then able to glide 30 to 50 meters in the air above the water surface. Based on the jet propulsion, they are able to achieve velocities up to 11.2 meters per second ! The Figure shows that during the gliding, the Octopuses are adopting an aerodynamically efficient shape. They use gliding while hunting crustaceans or gastropods or to escape predators.

Octopus in water

Gliding Octopus (schematic)

4-A-2-3



The five classes of Vertebrates

4-A-3-1

Bird Migration

Bird migration is referred to as the annual flight of magrating birds from their breeding area to their winter quarter and back again to their breeding area.

The ecological orgin lies in the extreme seasonal variations of the food availability in the breeding grounds. As insect eaters, they do not find insects and as a consequence, large bird populations would die during winter due to lack of food.

Genetic and physiological origins: Whether a bird migrates, where it migrates and when it migrates is determined genetically. Both, the direction of flight as well as the flight duration are inheherent.

Orientation: The internal compass is presumably due to the existance of magnetic field recorders in the eye, which enables the birds to determine the tilt angle of the Earth's magnetic field. In addition, birds are able to guide themselves with the help of the starry sky. The birds can also determine the position of the Sun in the case of a cloudy sky by detecting the UV radiation emitted by the Sun.

Bird migration metabolism: Nutrition is saved before migrating. They even resort to the proteins of their internal organs.

4-A-3-2

Migrating birds: Starlings in Flight to their Winter Habitats

4-A-3-3

Alpine swift - World record in endurance Flight

Alpine swift

Common swift

From time to time, even birds must land for feeding and for recovering. One exception are swifts who are perfectly adapted to the life in the air. They feed by catching insects in flight. It has long been suspected, that they do not sleep at night, but rather stay in the air all night long. The best indication for these uninterrupted flights have been obtained from Radar Images of the Common swift in large altitudes (right-hand picture) .

Recently, scientists of the Swiss Ornitological Station in Sempach, Switzerland, have demonstrated that the closely related Alpine swift (left-hand picture) is able to remain more than 6 months continuously in the air. In 2011, researchers of this Institution have equiped Alpine swifts with «Geolocators». This has been done in collaboration with the University of Applied Science in Burgdorf (Bern). The Geolocator is a technical masterpiece having a weight of only 1 g. All year round, this Instrument measures and stores the brightness in the vicinity of the bird. From these data it is then possible to measure the day length from which the geographical position of the bird can be determined. The Instrument is also able to give information regarding the dynamics of the wings (durations of flapping and gliding motions, respectively).

With the Geolocator mounted on the back of the Alpine swifts, the birds flew into their winter quarters (usually in Africa) where they spent the cold season, and in spring they returned to Switzerland. The unique Instrument demonstrated that the birds remained non-stop in the air all the time of flight to Africa, as well as during the time spent in their winter habitats.

4-A-3-4

Colugo's (Riesengleiter)

Colugo's have about the size of a cat but they are built distinctly lighter. Depending on the species, their total length is 56 to 69 cm and their snout-vent length varies between 34 and 42 cm. Mass: 1 to 1.74 kg; wingspan: 70 to 120 cm. Colugo's are living in Southeast Asia.

The gliding animal has a flying membrane which covers almost the whole body and extends down to the spyky claws. By spreading the forelimbs and the hindlimbs, the animal is able to open the thin flying membrane similar to a parachute. But the membrane is immobile and for this reason, the Colugo is not an active flyer but rather a glider.

Colugo's are essentially nocturnal tree-dwellers and descend seldomly to the ground. During the day, they are living in tree holes or on tree branches as well as on tree trunks and are found at heights between 25 and 50 meters above ground. It is only after the beginning of darkness when they start to be active. Their gliding flight varies between 50 and 70 meters, in exceptional cases up to 136 meters.

Colugo hanging on a tree trunk

Colugo in gliding flight to the next tree

4-A-3-5

Alfred Hitchcock - The Birds

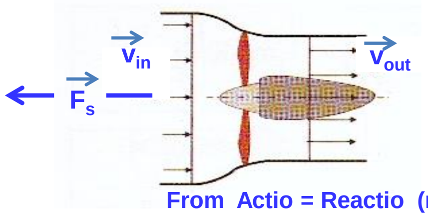
The overriding question is why are birds attacking? The reason is humanitie's long history of killing birds and other animals. Therefore, humans are now suddenly the victims of bird attack.

«The Birds» implies that the avian assaults are nature's revenge on complacent and willfully ignorant humanity.

4-A-3-6

Airbreathing Jet Engines (schematic)

Airscrew thrust F_S



F_S : recoil force in N

$F_S \approx -(dm/dt)\,(v_{out} - v_{in})$;

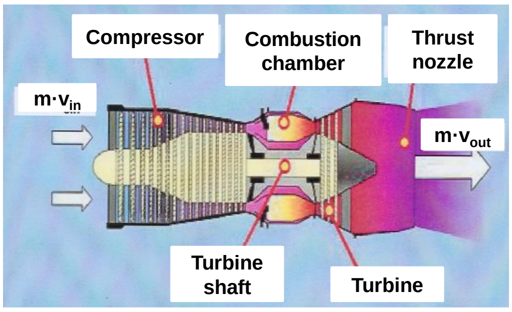
dm/dt = air flow rate in kg/s

v_{in} : inflow velocity in m/s

v_{out} : exit velocity; $v_{out} >> v_{in}$

From Actio = Reactio (recoil) F_s is antiparallel to v_{in} and v_{out}

Airbreathing engine



- The sucking in of air takes place in the part where the air of mass m and velocity v_{in} streams into the engine. $m \cdot v_{in}$ is the momentum of inflowing air.
- The air is compressed by a compressor, which is driven by the turbine.
- Combustion is achieved by adding a fuel (Kerosine) into the combustion chamber.
- The discharged air with velocity v_{out} takes place in the turbine compartment and in the thrust nozzle. Note that $v_{out} >> v_{in}$. $m \cdot v_{out}$ is the momentum of the outfowing air.

4-A-4-1

For more detailed information see Ref. R.A.4.1.

Referenzen: Kapitel 4

R-4-0

4.0 Flying - Overview

R.4.0.1 p. 107 : Flying and Gliding: Overvies; (collected by P. Brüesch)

R.4.0.2 p. 108 Flying and Gliding of Birds and Airplanes:

a) Flying (Fliegen (Fortbewegung): http://de.wikipedia.org/wiki/Fliegen:(Fortbewegung)
b) Flight: From Wikipedia, the free encyclopedia - http://en.wikipedia.org/wiki/Flight
c) Flying White Stork and Boeing 747 - 100
- Flying White Stork: Text from: Whight stork - Pictures from «Google Images
http://wikipedia.org/wiki/Wei%C3%9Fstorch
- Airplane: Boeing – 747-100: Picture from Google Images: Boeing – 747; Text from: Boeing 747
http://www.airlines-inform.com/commercial-aircraft/Boeing-747-100.html
http://de.wikipedia.org/wiki/Boeing:747

4.1 Physical Basis

R.4.1.1 p. 110: Physics of Flying - Aerodynamics

a) Overview about Navier-Stokes – Euler – Bernoulli – and Kutta-Joukowski –equations (P. Brüesch)
b) Navier-Stokes-Equations - From Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiîki/Navier%E2%80%93Stokes-equations
c) An Introduction to Fluid Dynamics - G.K. Bachelor - Cambridge University Press /2000)
d) Die physikalischen Grundlagen der Luftfahrt - Lena Michaela Altherr
Johannes Gutenberg-Universität Mainz - Institut für Physik
www.zq.uni-mainz.de/.../Die_physikalischen_Grundlagen_der_Luftfahrt

R.4.1.2 p. 111: Air flow acting on an airfoil

a) Aerodynamics - http://en.wikipedia.org/wiki/Aerodynamics (contains Figure of airfoil)
b) Lift (force) - http://wikipedia.org/wiki/Lift_(force)
c) The Basics of Flight - http://www.aviastar.org/theory/basics_of_flight
d) Airfoil - http://en.wikiprdia.org/wiki/Airfoil
e) Thrust - http://en.wikipedia.org/wiki/Thrust
f) Flying of Birds – The Flying Birds – Animal Wallpaper
(found under «Flying of Birds» - Forces on a wing added by P. Brüesch)

R-4-1

R.4.1.3 Euler – Equation

a) Euler equation (fluid dynamics) - http://en.wikipedia.org/wiki/Euler_equations_(fluid_dynamics)
b) Euler Gleichungen - http://de.wikipedia.org/wiki/Euler-Gleichungen

R.4.1.4 Theorem of Kutta-Joukowski

a) Kutta-Joukowski theorem - http://en.wikipedia.org/wiki/Kutta%E2%80%93Joukowski_theorem
b) Introduction to Hydrodynamics - Hardy Peter and Rolf Schllichenmaier
Vorlesungen an der Universität Freiburg (2004 / 2005); written in English
www3.kis.uni-Freiburg.de/~schliche/…/hydro.pdf
c) Satz von Kutta-Joukowski - http://de.wikipedia.org/wiki/Satz_von_Kutta_Joukowski
d) Das Gesetz von Kutta-Joukowski
http://www.physik.uni-würzburg.de/video2/alpha/kap5/Tips/Tio01/Tip01:ct.htm

R.4.1.5 Bernoulli equation and Theorem of Kutta-Joukowsky

a) Lift: Why can airplains fly ? ([PDF[: Chapter 5)
Hardi Peter und Rolf Schlichtenberger : Introduction to Hydrodynamics
www3.kis.uni-freiburg.de/~peter/hydro05.pdf
b) Die physikalischen Grundlagen der Luftfahrt (Physical principles of Aeronautics)
www.eg.uni-mainz.de/.../Die_physikalischen_Grundlagen_der_Luftfahrt, Lena Michaela Altherr
pp 171 – 173: Herleitung der Bernoulli-Theorie bei Altherr (s. hier: Anhang 4-A-1-2, 4-A-1-3)
c) Fliegen und Luftfahrt (Flying and Aeronautics)
[PDF] Script : www.kphys.uni-heidelberg.de/.../huefner/V075-p---
d) Wie erklärt man das Fliegen eines Flugzeugs ?
(How can the flying of an aircraft be explained?)
Rita Wodzinski ; serienblogs.de/diaxs…/warum-ein-flugzeug-fliegt… PLIS LUCIS (Fachdidaktik) pp 18 – 22
e) Wie erklärt man den Auftrieb nach Kutta-Joukowsli ?
(How can the lift be explained on the basis of Kutta Joukowsky?)
Heuristische Herleitung der Kutta-Joukowski Gleichung aus der Bernoulli-Gleichung
(for thin planar plates) – Heuristic derivation of Kutta Joukowsky from, Bernoulli's equation)
http://www.physik.uni-würzburg.de/video/alöha/kap5/Tips/Tip0/Tip01_ct.html

R-4-2

R.4.1.6 p. 112: The Bernoulli equation

a) Derivation and Interpretation of Bernoulli's equation - Lesson 61: Physics – Trinity Valley School
Dr. Mitch Hoselton; Physics: An Incremental Development, John H. Saxon, Jr.
faculty-trinityvalleyschool.org/…/Lesson%2061…
b) p. 4-A-1-3, p. 112: Bernoulli's principle - http://en.wikipedia.org/wiki/Bernoulli's_principle
c) Bernoulli-Gleichung; Druckerhaltung und Energieerhaltung
[PDF] Bernoulli-Gleichung - www.delta-q.de/export/…/bernoulligleichung.pdf-
d) Physik: Ein Lehrbuch von Wilhelm Westphal - Achtzehnte und neunzehnte Auflage
Springer. Verlag; Berlin – Göttingen – Heidelberg (1956)
Diskussion der Bernoulli-Gleichung: p. 173 im Besonderen für horizontale Strömung
e) p. 112: Derivation and discussion of the Bernoulli-Equation
This equation can be derived from Energy conservation or directly from Newton's second Law.
The derivation given in the Appendix (pp 4-A-1-2 and 4-A-1-3) is based on Newton's Law
(linear momentum equation of Fluid Dynamics)
highered.mcgraw-hill.com/…/Simple_Chapter.pdf- ; Chapter 12
f) Bernoulli's or Newton's Laws? - http://hyperphysics.phys-astr.gsn.edu/hbase/fluids/airfoik.html
(contains a Section about «Airfoil Terminology»)

R.4.1.7 p. 113: Air flow around Airfoil - 1:

a) First and third Figure from: «Das Gesetz von Kutta-Joukowsky»
http://www.physik.uni-wuerzburg.de/video2/alpha/FluidDynamik/node25ct.html
b) Second Figure from: BoundVortex - http://www.boundwortex.com/Read/Article.aspx?ArticleID=53
c) Airfoil: http://en.wikipedia.org/wiki/Airfoil

R.4.1.8 p. 114: Air flow around Airfoil - 2:

a) Airfoil – http://en.wikipedia.org/wiki/Airfoil
b) Airfoils and Airflow: http://www.av8n.com/how/htm/airfoils.hrm
(Conclusion: Bernoulli's principle is an excellent approximation under a wide range of conditions)
c) Air Foil: How An Airfoil works - http:///web.mit.edu/2.972/www/reports/airfoil.html
(Contains a discussion of the applicability of Bernoulli's equation – pro and contra)
d) Tragflächen «Airfoil» - http://www.shtym.lb/schule-bw.de/unterricht/faecher/ph/stroemungsphysik/tragfluegel.html
(contains the Figure showing the «Potential flow», the «circulation» and the «resulting streamlines»
e) see also References R.4.1.1 d) quoted on p. R-4-1

R-4-3

R.4.1.9 p. 115: Qualitative explanation of lift

a) References R.4.1.2 b); R.4.1.4; R.4.1.5; Ref. R.4.1.6
b) in: Lexikon der Physik: Auftrieb – Spektrum der Wissenschaften: www.spektrum.de/labo/lexikon(physik/970

R.4.1.10 p. 116: Lift and Kutta – Joukowski

a) Kutta-Joukowski Theorem: http://en.wikipedia.org/wiki/Kutta%E2%89%93Joukowski:theore,
b) see Reference R.4.1.4
c) Strömungslehre 2: Peter Junglas: http://www.peter-junglas.de/th/vorlesungen/.../stroemungslehre2.pdf

R.4.1.11 p. 117: Kutta-Joukowski: Heuristic Model – 1

Figure of airfoil: Google - «Tragflächen» - «Airfoil»; Figure adapted by P. Brüesch
Text from P. Brüesch : based on different References

R.4.1.12 p. 118: Kutta-Joukowsk: Heuristic Model – 2

a) Basic relations from Reference R.4.1.4
b) Simplifications proposed by P. Brpesch

R.4.1.13 p. 119: Technical Equations for Lift and comparision with Kutta.Joukowski

a) Lift coefficient:
http://en.wikipedia.org(wiki/Lift_coefficient
b) The Lift Coefficient http://www.grc.nasa.gov/WWW/k-12/airplane/liftco.html
c) 2. Gasphysik: Zweidimensionale Strömung; 3. Tragflügel endlicher Spannweite
[PDF] – MBS : www,mbsroegner.bizland,com/FLUWIIB.pdf
d) p. 119: Praktische Aerodynamik; Bild 13
Dieter Thomas : Vortrag im Rahmen der Fluglehrerweiterbildung 1992 in Frankfurt
www.thomas-flight-test.de/.../Aerodynamik_Bilde...
e) pp. 4-A-1-2, 4-A-1-3, Derivation and discussion of Bernoulli's equation
The derivation contained in Appenices 4-A-1-2 and 4-A-1-3 is based on Newton's Law
(Linear Impuls-equation of Fluid Mechanics): highered.mcgraw-hill.com/…/Simple_Chapter.pdf- ; Chapter 12

R-4-4

4.2 Flying and gliding Invertebrates

4.2.1 Invertebrates and Vertebrates

R.4.2.1 p. 121: General Remarks
Flying and gliding animals - http://en,wikipedia.org/wiki/Flying_and_gliding_animals

R.4.2.2 p. 122: Flying in the geological time scale

a) Geological Time Scale
http://www.ucmp.berkeley.edu/education/explorations/tours/geotime/guide/geologictimescale.html
b) Geologische Zeitskala - http://de.wikipedia.org.wiki/Geologische_Zeitskala
(contains Table of biological – geological time scale)

R.4.2.3 p. 123: The Planet of Insects

a) Invertebrates - http://en.wikipedia.org.wiki/Unvertebrate
b) Insect - http://en.wikipedia.org/wiki/Insect
c) Insect morphology - http://en.wikipedia,org/wiki/Insect_morphology
d) Planet der Insekten - http://www.schmetterlingspark.de/insekten.htm
(The Figure has been adapted to English by P, Brüesch)
e) Mosquito - http://en.wikipedia,org/wiki/Mosquito

4.2.2 Flying and Gliding Invertebrates: Insects

R.4.2.4 p. 124 Flying and Gliding Invertebrates (Title)

R.4.2.5 p. 125: Definition: What are Insects ?

a) see References R.4.2.3
b) Insekten - http://de.wikipedia,org/wiki/Onsekten
c) Fllightless insects: a test case for historical relationships of African mountains
http://onlinepibrary.wiley.com/de/10.1046/j.1365-2699.1997.00073.x/abstract

R-4-5

R,4.2.6 p. 126: Insects: Bugs, Butterflies, Flyes, Mosquitos and Hymenoptera

a) Insect - http://en.wilipedia.org/wili/Insect
b) Planet der Insekten – Reference R.4.2.3 d)
http://www.schmetterlingspark.de/Insekten.htm - (Text translated from German to Englisch by P. Brüesch)

R.4.2.7 p. 127: The largest and smallest Insects of the Earth

a) List of largest Insects - http://en.wikipefda.org/List_of_largest_Insects
b) Birdwing - http://en.wikipedia.org/wiki/Birdwing - (contains Queen Alexandrea Butterfly)
c) Queen Alexandra's birdwing - http://en.wikipedia.org/wiki/Queen_Alexandra's_birdwing
(Picture of Femaile and Male)
d) Königin-Alexandra-Vogelfalter - aus Wikipedia, der freien Enzykloprdia - Grösstes Insekt der Welt
http://de.wikpedia.org/wiki/K%C3%B6nigin.Alexandra-Vogelfalter
e) Die kleinsten Insekten der Welt
Die Zwergwespe Dicopomopha echmepterygis
Nur das Weibchen ist flugfähig
f) http://en.wikipedia.org/Dicopomorpha_echmepterygis
g) http://de.wikipedia.org/wiki/Dicopomorpa_echmepterygis
h) http://en.wikpedia.org/wiki/Fairfly
http://de.wikpedia.org.wiki/Zwergwespen
The author is indepted to Mister Peter Etter for his Information about the Dicopomorpha echmepterygis

R.4.2.8 p. 128:: Morphology of Insects

a) The Fascinating World of Insects (BrainFood Learning & TV)
http://www.amazon.com/The-Fascinating-World--Insects/dp/B005ZV54Z0
b) Faszinierende Welt der Insekten - http://www.hoppsala.de/index.php?!menueID=261&contentID=1955

R.4.2.9 p. 129: Internal Anatomy of a Bee - A flying Bee
a) Honey – bee – 68 – 69 - http://www.untiredwithloving.org/honey_bee_68_69.html
b) Wer kann schneller fliegen: eine Wespe oder eine (Honig) Biene? (contains Photo of a flying Bee)
http://www.cosmiq.de/ka/show/464586/Wer-kann-schneller-fliegen-eine-Wespe-oder-eine-Honigbiene?

R-4-6

R.4.2.10 p. 130: Die fliegenden Insektenstaaten: Bienen – Ameisen – Termiten
a) Swarming (honey bee) -- http://en,wikipedia.org/wiki/Swarming_(honey_bee)
(Picture of Bee swarm on the tree branch)
b) Reporting a Swarm of Honey Bees - http://www.sembabees.org/toplevelpages/swarm,html
c) Ant - http://en.wikipedia.org/wiki/Ant
(Flying coloney of ants: http://www.tiere-umwelt.de/fliegende-Ameisen)
d) Termite - http://en.wikipedia.oth/wiki/Termite
e) TERMITE SWARM - http://www.orkin.com/termites/termite-swarm.why-termotes-swarm/
(Picture of flying termites: http://de.wikipedia.org/wiki/Termiten)
f) The Truth about Termites - http://www.orkin.com/termites/termite-swarm.why-termotes-swarm/
g) Flying Termites - http://www.orkin.com/termites/flying-termites
h) Termiten - http://de.wikipedia.org/wiki/Termiten

4.2.3 Butterflies

R.4.2.11 p. 131: Butterfly

a) http://en.wikipedoa.org/wiki/Butterfly
b) Schmetterlinge - http://de.wikipedia.org/wiki/Schmetterlinge

R.4.2.12 p. 132: Development stages of a Butterfly

a) Butterfly Life Cycle - http://www.ansp.org/explore/online-exhibits/butterflies/lifecycle/
b) Butterfly school – Metamorphosis - http://www.butterflyschool.org/new/meta.html
c) Butterfly Life Cycle / Butterfly Metamorphosis
http://www.thebutterflysite.com/life-cycle.shtml
d) Lebenszyklus der Schmetterlinge
Picture from: http://www.telfs.com/noafl/schmetterlinspage/frames(Lebenszyklus.htm
(Labeling of the Figure translated from German to English by P. Brüesch)

R.4-2.13 p. 133: Wings and Flight Characteristics of Butterflies

a) Butterfly Wing Anatomy
http://www.enchantedlearning.com/subjects/butterflies/anatomy/Wings.shtml
b) Flight Behavior: How To Estimate The Altitude of Migrating Butterflies
http://www.erin.utoronto.ca/~w3gibo/Hpw%20to%20do%20field%20studies/flight_behavior_i.htm

R-4-7

R.4-2.13 (cont.) p. 133: Wings and Flight Characteristics of Butterflies

c) Flight Behavior II: Type of Flight – Characteristics of Flapping, Gliding, and Soaring Flight
http://www.erin.utoronto.ca/~w3gibo/Hpw%20to%20do%20field%20studies/flight _behavior_ii.htm
d) Flight Behavior III: Flight Path in the Horizontal Plane
Characteristics of Straight, Circling, Variable and Erratic Flight Paths
http://www.erin.utoronto.ca/~w3gibo/Hpw%20to%20do%20field%20studies/flight _behavior_iii.htm
e) Flight Behavior IV: Flight Path in the Vertical Plane
Characteristics of Level, Climbing, and Descending Flight Paths
http://www.erin.utoronto.ca/~w3gibo/Hpw%20to%20do%20field%20studies/flight _behavior_iv.htm
f) How Do Butterflies Fly ? - http://www.ehow.com/how-does_4570140_butterflies-fly.html
g) Schmetterlingsflügel und Schuppen (Text und Bild)
http://www.hydro-kosmos.deklforsch/schuppen.htm
h) Schmetterlinge - Flügel und Flugverhalten - http://wikipedia.org/wiki/Schmetterlinge

R.4.2.14 p. 134: Pictures of some Butterflies: A small collection of Butterflies
www.ausgabe.natur/lexikon.com/schmetterlinge-php
(The names of the Butterflies have been translated from German to English by P. Btüesch)

4.2.4 Flies and Gnats

R.4.2.15 p. 135: Flight of Flies and Gnats

a) Scientists Study Amazing Flight of Flies - http://abcnews.gp.com/Technoöogy/story?id=97651
b) Fly like a Flie - By Rafal Zbikowski (1. Nov, 2005)
http://spectrum.ieee.prg/computing/hardware/fly-loke-a-fly
c) Wie fliegen Fliegen ? - http://www.mpg.de/3648523/Wie_Fliegen_fliegen
d) Taufliege kann mit Augen auf Fühlern sehen - p. 135: oberes Bild: Taufliege im Gleitflug
http://www.krone.at/Wissen&Taufliege:kann:mit:Augen_aif_Fuehlern_sehen-Hilfe:fuer_Blinde-Story-105499
e) Frankfurter Allgemeine: Wissen - DIe Taufliege in der Identitätskrise
p. 134: Bild unten: Die aktiv fliegende Taufliege
http://m.faz/aktuell/wissen/natur/taxonomie-die-taufliege-in-der-identitätsktise-11008050.html
f) Tsetsefliegen - http://de,wikipedia.org/wiki/Tsetsefliegen

R-4-8

4.2.4 Flies and Gnats

R.4.2.16 p. 136: Mosquitos

a) Mosquitos - http://en.wilipedia,org/wiki/Mosquito
b) Malaria - http://simple.wikipedia.org/wiki/Malaria
c) Mosquito.Born Diseases - http://www.mosquito.org/mosquito.borne.diseases
d) Mücken - http://de.wikipedia.org/wiki/M%C3%BCcken
e) Stechmücken -- http://de.wikipedia.9rg.wiki/Stechm%C3%BCcken

4.2.5 Hymenoptera (Hautflügler)

R.4.2.17 p. 137: Hymenoptera (Hautflügler)

a) Hymenoptera - http://en,wikipedia.org/wiki/hymenoptera
b) Hymenoptera - http://www.cals.ncsu.edu/course/ent425/library/compendium/hymenopters.htm
c) Hautflügler - «Wespen im Jahr 1970»; Heuschrecken, Käfer und Wespen - Text and picture to the left
http://www.aktion-wespenschutz.de/Zeitreuse/1970/History%201970.htm
d) Hautflügler - http://de.wikipedia.org/wiki/Haut%C3%BCgler
e) Xyelidas: http://de.wikipedua.org/wiki/Xyelidae - Picture - right

4.2.6 Dragonflies

R.4.2.18 p. 138: Dragonflies

a) Dragonfly - http://en.wikipedia.org/wiki/Dragonfly
b) 10 - Fascinating Facts About Dragonflies
http://insects.about.com/od/dragonfliesand damselflies/a/10.Cool-Facts-About-Dragonflies.htm
c) Libellenflug - Flugtechnik der Libellen - http://www.libellen.li/flugverhalten.html
d) Libellen - http://de,wikipedia.org/wili/Libell)
e) Fliegen Libellen anders als andere Insekten ? - wissen,de
http://www.wissen.de/bikdwh/fkiegen-libellen-anders-als-andere-Insekten

R-4-9

R.4.2.19 p. 139: Dragonflies and Helicopters

a) Helicopters and Dragonflies
cetministries.files.wordpress.com/…/sep-oct-2011-copying-the crator-helicopters-and.dragonflies.pdf
b) Was the dragonfly the inspiration for the helicopter ?
http://www.answers.com/Q/Was_the_dragonfly_the_inspiration_for_the_helicopter
c) Symbolism / Meaning of a Dragonfly
http://www.dragonfly-slte.com/meaning-symbolize.htmk
d) Vergleich von Libelle mit Hubschrauber (Helikopter)
Ingo Rechenberg: Vorbild aus der Natur: « Wie aus der Libelle ein Hubschrauber wurde»
in: DIE WELT (24. 95 10 – Vorbild Natur - www.welt,de>Wissen-
e) Senkrechtstarter und – Landung - http://de.wikipedia.org/wiki/Senkrechtstarter_ud_landung

4.3 Flying and Gliding Vertebrates (p. 140)

4.3.1 Pterosaurs (p. 141)

R.4.3.1 Pterosaur: http://en,wikioedia.org/wiki/Pterisaur

R.4.3.2 Pterosaurs: Flight in the Age of Dinosaurs
http://www.amnh,org/exhibitions/current-exhibitions/pterosaurs-flight-in-the-age-of-dinosaurs

R.4.3.3 p. 142: The earliest flying animals were Probably gliders - Picture of Pterosaurus
http://www.lookandlearn.com/blog/19871/the_earliest-flying-animals-probably-gliders/

R.4.3.4 pp 143, 144: Pterosaurus
Picture of p. 143 (Skeleton); Picture of p. 144 (Pterosaurus): http://de.wikipedia.org/wiki/Flugsaurier

R.4.3.5 p. 144: Characterization of Pterosaurs

a) Quetzalcoatlus - Text to p. 144 (Transated from German to Englisch by P. Brüesch)
http://de.wilioedia/wiki/Quetzalcoates
b) SCINEXX: Plerosaurier waren Langsamflieger - http://www.scineaxx-de/wissen-aktuell-12606-11-24.html

R.4.3.6 p. 144: Pterosaurier Facts - Right hand picture - http://someinterestingfacts,net/pterosaur.facts

R-4-10

4.3.2 Birds: Physiology, History – Flight Dynamics and Examples

R.4.3.7 p. 146: Birds: History, Masters of the Air – Examples

a) Bird: http://en.wikipedia.org/wiki/Bird
b) Bird flight - http://wikipedia.rg/wiki/Bird:flight

R.4.3.8: p. 146: Referat: Evolution der Vögel
http://www.pausenhof.de/referat/biologie.evolution-der-voegel/9092
Text zu p. 146 (Translated from German to English by P. Brüesch)

R.4.3.9 p. 147: Habitus and Skeleton of a Bird

a) Skelett, Körperbau und Organe eines Vogels (left-hand picture)
http://www.medienwerkstatt.online.de/lws_wissen/vorlagen/showcard.php?id=5194
b) The Skeleton of a Typical Bird (right-hand picture)
http://www.robinsonlibrary.com/science/zoology/birds/general/skeleton.htm

R.4.3.10 p. 148: Physiology of Birds: Sceleton - Physiologie der Vögel: Skelett

a) Longitudinal section: from www.google.ch/search - Bilder
b) Cross section: Faszination Fliegen – Modell Vogel
http://its.mv.fh-duesseldorf.de/Vorlesung/alt_iplom_schueler_etc/facharbeiten/quirimus/CD_facharbeit_Tragfluegel

R.4.3.11 p. 149: Physiology of Birds - The wings

a) Feather - http://en.wikipedia.org/wiki/Feather
b) Bird Feather Types, Anatomy, Growth, Color, and Molting
http://peteduction.com/article.cfm?c=15+18298&aid=2776
c) Feather Structure - http://www.birds.cornell.edu/All/AboutBirrds/studyinf/heathers/feathers
d Bird Feather Identification -
e) Die Vogelfeder - Aufbau der Vogelfeder - http://www.natwiss.ph-karsruhe.de/BIO/medien/feder/aufbau,html
f) Wie fliegt ein Vogel ? - http://129.143.230.62/faecher/biologie/klasse06/vogelflug/vogelflug.htm
(contains microscopic picture of feathers)
g) Flügel (Vögel) - http://de.wikipedia.org/wiki/F1%C3%BCgel Vogel
h) Vogelflügel - http://universal:lexikon.deacademoc.com/316312/Vogelfl%C3%BCgel

R-4-11

R.4.3.12 p. 150: Dynamics of the Flying of Birds

a) Bird flight - http://en.wikipedia.org/wiki/Bird_flight
b) [PDF] How Do Birds Fly ? - files.dnr.state.mn.us/publications/volunteer/you
c) Schlagflug: http://de.wikipedia.org/wiki/Schlagflug
c) Wie fliegt ein Vogel?
http://www.goethe.lb.bw.schule.de/faecher/biologie/biologie/klasse06/vogelflug/vogelflug-htm
d) Das Flugprinzip der Ornithopter - http://www.ornithopter.de/ptinzip.htm

R.4.3.13 p. 151: Records of Bird Migration

a) Bird - http://en.wikipedia.org/wiki/Bird
b) List of birds by flight speed - http://en.wikipedia.org/wiki/List_of_birds_byflight_speed
c) List of High Flying Birds - http://animals.pawnation.com/list-high-flying-birds-9333.html
d) Alpine swift - http://en.wikipedia.org/wiki/Bird_nigration
e) Bird migration - http://en.wikiiedia.org/wiki/Bird_migration
f) Swift Record ! - http://www.livescjence.com/40268-alpine-swifts-fly-nonstop.html
g) Meister der Lüfte – Rekorde aus der Vogelwelt
http//www.planet-wissen.de/natur_technik/tierisches/tierische_flieger/meister:der_luefte.jsp
h) Der Alpensegler: Weltrekord im Dauerfliegen - Dr. Felix Liechti (Schweizerische Vogelwarte Sempach)
http://www.xn-vgel-5qa.c/weltrekord-im-dauerfliegen.html

R.4.3.14 p. 152: Examples of colorful Birds - from Wikipedia - Images

R.4.3.15 p. 153: Anden condor

a) Andean condor - http://en.wikipedia.org/wiki/Andean:condor
b) Andean Condor - http://animals.nationalgeographic.com/animals/birds/andean-condor/
c) Andenkondor - http://de.wikipedia.org/wiki/Andenkondor
Bild: unter www.google.ch «Vogelflug» : Aktivitäten 2002 – uzwil.birdlife.ch

R-4-12

4.3.3 Gliding Fishes

R.4.3.16 pp 154, 155: Gliding fishes

a) Flying fish: http://en.wilipedia.org/wiki/Flying_fish
Picture for p. 154 unter Images; www.google.ch/search - (File: Pink-wing flying fish.jpg-Wikipedia)
b) Flying Fish: http://animals.nationalgeographic.com/animals/fish/flying-fish/
c) Gleitende Fische - http://de.wikipedia.org/wiki/Fliegende_Fische

R.4.3.17 p. 156: Sharks and flying flights of Sharks (Pictures from Google – Images)

a) Shark - http://en.wikipedia.org/wiki/Shark
b) Photographing Africa's «Flying Sharks»
http://news.nationalgeographic.com/news/2003/11/1124_flyingsharks.html
c) Flying Great White Sharks
http://www.divediscovery.com/shark-diving/divetours/flying-great-white-south-africa.php
d) Haie: http://de.wilipedia.org/wiki/Haie
e) Die fliegenden Haie von Seal Island
http://dokumonster.de/sehen/4440-die-fliegenden-Haie-von.seal-island.n24-doku/

4.3.4 Gliding flights of Reptiles

R.4.3.18 p. 157: Reptiles

a) Reptile: http://en./wilipedia.org/wiki/Reptile
b) Reptile Printouts - http://www.enchantedlearning.com/subjects/reptiles/printouts_shtml
c) Reptiles: Lizards, Snakes, anf Others - http://www.kidport.com/reflib/science/animals/reptiles.htm
d) Animals / REPTILES - http://animals.sandiegozoo.org/content/reptiles
e) Reptilien - http://de.wikipedia.org/wiki/Reptilien
f) Gleitflug von Reptilien - http://de.wikipedia.org/wiki/Reptilien

R.4.3.19 p. 158: Flying Dragons

a) Draco (genus) - http://en.wikipedia.org/wiki/Drago_(genus
Flying Dragon: Lizards: Animal Olanet
Picture from: www.google.ch/search - Images : Flying Dragon: Lizards: Animal Olanet
b) Flugdrachen: http://de.wikipedia.org/wiki/Flugdrachen

R-4-13

R.4.3.20 p. 159: Gliding Flight of Geckos

a) Picture of Gecko - SCIENCE PHOTO LIBRARY
Flying Gecko - http://www,sciencephoto.com/media/379134/view
b) Facts about the Flying Gecko's Natural Habitat
http://www.examiner.com/article/facts-about-the-flying-gecko-s-natural-habitat
c) Geckos: http://de.wikipedia.org/wiki/Geckos
d) Von Baum zu Baum segeln - Wirbeltiere lernen fliegen - Fluggeckos
http://www.daserste.de/infotmation/wissen-kultur/w-wie-wissen/specialsvon-baum-zu-baum-segeln-100.htm
e) Gleitflug bei Tieren
http://www.wissen.dethema/gleitflug-bei-tiefen?chunk-gleitflug-bei-amphibien-und-reptilien

R.4.3.21 p. 160: Gliding Snakes

a) Fliegende (gleitende) Schlangen
http://www.focus.de/wissen/natur/biologie-fliegende-schlangen_aid_574578.html
b) s. auch Ref. R.4.3.20 c)

4.3.5 Gliding Amphibians

R.4.3.22 p. 161: Amphibians - Gliding Amphibians

a) Amphibians - http://en.eikipedua.org/wiki/Amphibian
b) Amphibien - http://de.wikipedia.org.(wiki/Amphibien

R.4.3.23 p. 162: Amphibia (Lurche)

Die 21 mitteleuropäischen Amphibien und ihre wesentlichen Bestimmungsmerkmale – BioNetworX.de
http://www.bionetworx.de/biomemorix/uebersicht.html
Contains Diagram of «Amphibia (Lurche)
(Names of Amphibia in Diagram and Text translated from German to English by P. Brüesch)

R-4-14

R.4.3.24 p. 163: Gliding Frogs

a) Flying and gliding animals - http://en.wikipedia/org/wiki/Flying_and_gliding_animals
b) The Caudal Lure - http://thecaudallure.blogspot.ch/2011/08/malaysian-rainforest-gliders.html
c) Wallace's flying frog - http://en.wikipedia.org/Wallace's_flyingfrog
d) Biomes Blog - http://biomesblog.tyoeoad.com/the_biomes:bkig/2007/03/
e) Picture and Text found under: «Flying frogs» – Images
Collection & Selection: Earth Facts to visit page - Flying frog : Wallace's Treefrog
f) Vergleichende Tierphysiologie – Vol. 1, p. 627
Gerhard Heldmaier, und Gerhard Neuweiler – 2003 - Science
books.google.ch/books?isbn=3540442839
http://books.google.ch/books?id-rKx-RKYoxeMC&pg=PA627&dq=Sprungweite+von+Fr%C3%B6schen

4.3.6 Flying and Gliding Mammals

R.4.3.25 pp 164, 165: Flying and Gliding Mammals - Overview
Bats - Flying Foxes - Colugos - Marsupials - Lemures - Flying Squirrels - Information from different sources

R.4.3.26 p. 166: 4.3..6.1 : Bats and flying Foxes

R.4.3.27 pp 166 - 169: Bats

a) Bat - http://en.wikipedia,org/wiki/Bat
b) Bats In Flight Reveal Unexpected Aerodynamics
http://www.freerepublic.com/focus/f-news/1771906/posts
c)) Bats In Flight Reveal Unexpected Aerodynamics
http://www.brown.edu/Administration/News_Bureau/2006-07/06-082.html
d) Bat Flight Generates Complex Aerodynamic Tracks
http://viterbi.usc,edu/news/2007/bat-flight-generates.htm
e) What Does A Bat Look Like ? - http://www.bats4kids.org/look.html
http://sciencev1.orf.at/science/news/148077.html
f) Bats are Mammels - http://www.kidzone.ws/animals/bats/

R-4-15

R.4.3.28 pp. 166 – 167: Fledermäuse (Bads)

a) p. 166: Arbeitsgemeinschaft für Fledermäuse – Fulda e.V.
http://www,fledermausschutz-fulda.de/fleder.html - Figur; Grosses Mausohr – Greater mouse-eared Bat
b) p. 167: Oekokosmos: Fledermäuse - http://www.oekosmos.de/artikel/details/fledermeuse/
Figure from Reference R.4.3.27 e)

R.4.3.29 pp 167- 168: Flugtechnik : Fledermaus im Windkanal

a) Fledermäuse schiessen im Flug schnell nach oben – ORF ON Science
http://sciencev1.orf.at/science/news/148077.html
b) p. 168: Fliegen wie der Teufel - http://www.zeit.de/online/2007/20/fledermaus-flug-galerie
c) p. 168: [PDF] Fledermäuse sorgen für Wirbel
Figur: Momentaufnahme der Luftströmung um eine Fledermaus im Windkanal
Figure: Photograph of air stream with vortices produced by a bat in the Wind Channel
www.mpg.de/933912/S007_Blickpunkt:092.pdf

R.4.3.30 p. 169: Landfachausschuss für Fledermausschutz und Forschung: Fledermäuse hören ihre Umgebung
http://www.lfa-fledermausschutzmv.de/Echoortung.19.0.html (s. auch Ref. R.4.3.26, p. 166
Contains Figure of «Braunes Langohr beim Orten eines Falters»
i.e. Figure of «Echolocation of Bats»

R.4.3.31 p. 170 - 172: Flying Foxes - Flughunde

a) Pteropus - Flying foxes - http://en.wikipedia.org/wiki/Pteopus
b) Black flying fox - http://en.wilipedia.org/wiki/Black_flying_fox
c) Flughunde - http://de.wikipedia.org/wiki/Flughunde
d) Eigentliche Flughunde - http://de.wikipedia.org/wiki/Eigentliche:Flughunde

R.4.3.32 p. 171: Orientation and sleep of flying foxes

a) Large Flying Fox - http://en.wikipedia.org/wiki/Large_flying_fox
b) Grey-headed flying fox - http://en.wikipedia/org/wiki/Grey-headed_flying_fox
c) Über die Orientierung der Flughunde (Chiroptera – Pteropopidae)
http://link.springer.com/articke/10.1007%2FBF00338621?L1=true

R-4-16

R.4.3.32 (cont.) d) Flughunde fliegen nach der Karte
http://www.sckenceticker.info/2011/08/15/flughinde-fliegen-nach-der-Karte
e) Flughunde orientieren sich nach interner Landkarte
http://www.focus.de/wissen/natur/wissenschaft-flughunde-orientieren-sich-nach-interner-Landkarte-aid_656004.html
f) Bild zu «Schlafende Flughunde»
www.google.ch : Images – unter: «Wie schlafen Flughunde ?»

R.4.3.33 p. 172: Little Red Flying Fox

a) Little Red Flying Fox - http://animals.nationalgeographic.com(animals/mammals(little-red-flying-fox/
b) Flying foxes make unusual sojourn to the Barkly
www.abc.net.au/news/2012-10-12/.../flying-foxes-at.../4310686
By Ruby Jones - contains PHOTO of «Little Flying Foxes»
c) Little red flying fox - http://en.wikipedia.org/wiki/Little_red_flying_fox
d) Roter Flughund - http://de..wikipedia/org/wiki/Roter_Flughund

R.4.3.34 p. 173: 4.3.6.3 - Flyng squirrel (Gleithörnchen)

a) Flying squirrel - http://en.wikipedia.org/wiki/Flying_squirrel
b) Japanese giant flying squirrel - http://en.wikipedia.org/wiki/Japanese_giant_flying_squirrel
c) Gleithörnchen - http://de.wikipedia.org/wiki/Gleith%C3%B6rnchen
d) Gewöhnliche Gleithörnchen - http://en.wikipedia.org/wiki/Colugo

R.4.3.35 p. 174: 4.3.6.4 - Gliding Lemures

a) Lemur - http://en.wikipedia.org/wiki/Lemur
b) Why do flying lemors glide ?
http://blogs.discovermagazine.com/notrocketscience/2011/07/28/why-do-flying-lemurs-glide/
c) Sunda flying lemur - http://encwikipedia.org/wiki/Sunda_flying_lemur
d) Lemuren - http://de.wikipedia.org/wiki/Lemuren
e) Fliegende Lemuren - http://www.aeroman.org/html/DE/fliegende_lemuren.html

R-4-17

4.4 Flight Attempts and the Flying of Men

R.4.4.1 p. 176: The Dream and Myth of Flying

a) History of Aviation - http://en.wikipedia/org/wiki/History_of_aviation
b) Geschichte der Luftfahrt - http://wikipedia.org/wiki/Geschichte_der_Luftfahrt
c) Geschichte des Fliegens – Die Anfänge bis zum ersten Weltkrieg
http://www.luftrettung-hamburg.de/html/pioniere.html
d) A History of Aeronautics
Author: E. Charles Vivian - http://www,gutenberg.org/files/874/874-h/874-h.htm
e) Chinese Emperor Shun in 2200 BC - https://av8rblog.wordpress.com/tag/emperor-shun/
f) Ancient Flying Myths and Legends - http://www.century-of.flight.net/new%20site/frames/myths:frame.htm
g) Shun (Kaiser) - http://de.wikipedia.org/wiki/Shun_(Kaiser)
h) Schwerelos . Kai König - http://www.heise.de/ix/artikel/Schwererlos_506840.html
i) Icarus: http://en.wikipedia.org/wiki/Icarus
k) Daidalos - http://de.wikipedia.org/wiki/Daidalos
l) Daedalus and Icarus - (with right-hand picture below)
http://owlnet.overlake.org/Academics/Faculty/jrothfels/Latin%2011%20Ovid%202007/hades/index.html
m) Ikarus - http://de.wikipedia.org/wiki/Ikarus

R.4.4.2 p. 177: Albrecht Ludwig Berblinger – Der Schneider von Ulm und der Flugpionier - The Tailer of Ulm

a) Albrecht Berblinger - http://en.wikipwdia.org/wiki/Albrecht_Berblinger
b) 200 Jahre Gleitflug: Schneiderlein im Sturzflug - (with picture above)
http://www.spiegel.de/wissenschaft/technik/200-jahre-gleitflug-schneiderlein-im-sturzwind-a-765672.html
c) Berblinger, Albrecht Ludwig - http://de.metapedia.org/wiki/Berlinger,_Albrecht_Ludwig - (with picture below) .
d) Albrecht Ludwig Berblinger - http://de./wikipedia.org/wiki/Albrecht_Ludwig_Berblinger

R.4.4.3 pp 178 – 179: Otto Lilienthal

a) Otto Lilienthal - http://en.wikipedia.org/wiki/Otto_Lilienthal
b) Otto Lilienthal - http://www.britanica.com/EBchecked.com/EBchecked/topic/340975/Otto-Lilienthal
c) Lililenthal's Fatal Glider Crash in 1896: Evidence Regarding the Case of Death
Victor Harsch, Benny Bardrum, and Peter Illig
Aviation, Space, and Environmental Medicine - Vol. 79, No. 10, October 2008
d) Otto Lilienthal - http://de.wikipedia.org/wiki/Otto_Lilienthal

R-4-18

R.4.4.4 pp 180 – 181: Wright brothers

a) The brothers Wright - http://en.wikipedia.org/wiki/Wright:brothers
b) Die Brüder Wright - http://de.wikipedia.org/wiki/Br%C3%BCder_Wright
Remark to p. 180: «Biplane gliding machine»: There is an error in the German version:
The indicated distance of 622.5 m should be replaced by 622.5 ft = 189.7 m; (1 ft = 0.3048 m).
[The corresponding distances in the English version a) are correct].

R.4.4.5 p. 182: Der Transatlantikflug von Lindbergh - Bilder aus: www.google.ch/

a) Charles Lindbergh - http://en/wikipedia.org/wiki/Cjarles_Lindbergh
b) Transatlantic flihgt - http://en.wikipedia.org/wiki/Transatlantic_flight
c) Charles Lindbergh - http://de.wikipedia.org/wiki/Charles_Lindbergh
(Lindbergh geriet in den USA wegen seiner Nazi-freundlichen und Juden-feindlichen Einstellung stark unter Beschuss, nicht zuletzt von Präsident Roosewelt. Erst viel später, im Jahre 1957, als er seine Autobiografie schrieb, entsetzte er sich über die NS-Konzentrationslager und die Vernichtung der Juden).
d) Spirit of St. Louis - http://de.wikipedia.org/wiki/Spirit_of_St._Louis
e) Planet Wissen Startseite - Navigationspfad – Luftfahrt
http://www.planet-wissen.de/wissen_interaktiv/html-versionen/luftfahrt/index.jsp

R.4.4.6 p. 183: Der Zeppelin – Die Katastrophe der «Hindenburg» (1937)

a) Zeppelin - From Wikipedia, the free encyclopedia - http://en.wikipedia.org/wiki/Zeppelin
b) Last Photograph of Count Ferdinand Von Zeppelin, Inventor of the Zeppelin Airship
http://www.aööposters.de/~sp/Last-Photogograph-of-Count-Ferdonand-og-Zeppelin-Airship-Poste...
c) Zeppelin - http://de.wikipedia.org/wiki/Zeppelin
d) Infos zum Thema «Zeppeline» - Die Luftschiffe von Ferdinand Graf von Zeppelin
http://www.zeppelinfan.de/html-seiten/deutsch/liftschiff_zeppelin.htm
e) AKTUELLER / ARTIKEL - Der Zeppelin fliegt wieder
http://www.wasistwas.de/aktuelles/artikel/link/435866c988/article/der-zeppelin-fliegt-wieder.html

R.4.4.7 p. 184: Sailplanes

a) Glider (sailplane) - http://en.wikipedia.0th/wiki/Glider_(sailplane)
b) Segelelflugzeug - http://de.wikipedia.org/wiki/Segelflugzeug

R-4-19

R.4.4.8 p. 185: Jet aircraft

a) Jet aircraft - http://en.wikipedia.org/wik//Jet_aircraft
b) Jet airliner - http://en.wikipedia.org/wiki/Jet_airliner
c) Momentum conservation of a Jet plane: A Textbook of Applied Mechanics - Google Book . R.K. Rajput
Books.google .ch/books?isbn=8131809056
d) Boeing 747 - http://en.wikipedia.org/wiki/Boeing_747
e) Boeing 747 - http://de.wikipedia.org.wiki/Boeing_747
f) Flugzeug - http://de.wikipedia.org/wiki/Flugzeug
g) Rückstossantrieb (= Recoil drive) - http://re-flugzeuge-info/rueckstossantrieb.php
h) Flugzeugtriebwerke – Basiswissen Schule Physik
http://m.schuelerlexikon.de/mobile_physik/Flugzeugtriebwerke.htm
i) Rückstoss - http://de.wikipedia.org/wiki/R%C3%BCckstoss%C3%9F

R.4.4.9 p. 186: Jet engine of a jet airliner

a) Airbreathing jet engine - http://en.wikipedia.org/wiki/Airbreathing_jet_engine
b) Jet engine - http://www.daviddarling.info/encyclopedia/J/jet_engine.html
c) AIR-Breathing ENGINES - http://settlement.arc.nasa.gov/Nowicki/SPBI1AB.HTM
e) Strahltriebwerk - http://de.enc.tfode.com/Strahlantrieb
(Zur klaren Darstellung wurde die Figur vom Autor retouchiert)
d) Strahltriebwerk - http://de.wilipedia.org/wiki/Strahtriebwerk

R.4.4.10 p. 187: Take-off of Boeing 747 . 81

a) Lift Coefficient & Thin Airfoul Theory
http://(www.aerospaceweb.org/question/aerodynamics/q0136.shtml
b) Modern Lift Equation - http://wright.nasa.gov/airplane/lifteq.html
c) John S. Denker: See How It Flies
(A new spin on the perceptions, procedures and principles of flight)
Published by McGraw – Hill Companies - Copyright @1996 – 2008 jsd
see especially Chapters 2 and 13:
Chapter 2: Section 2.4: «Angle of Attack Awareness and Angle of Attack Management»
Chapter 13: Takeoff; Section 13.1: «Simplest Takeoff»: - http://en.wikipedia.org/wiki/Helicopter

R-4-20

d) Flying Lessons - Lesson 4: Slow Flight - Definition and Illustrations for the «Angles of Attack»
http://krepelka.com/fsweb/lessons/student/studentlessins04.htm
e) Airliner Takeoff Speeds - http://www.aerospaceweb.org/question/performance/q0088.shtml

R.4.4.11 p 188: Helicopters

a) Helicopter - http://en.wikipedia.org/wiki/Helicopter
Fotos von Hubschrauber: www.googl,ch/seaech- Helikopters
b) Principle of Helicopter Flight - http://www,thaitechnics.com/helicopter/heli_principle.html
c) How helicopters fly and are controlled - http://www-re-airplane-world.com/how-helicopters-fly.html
d) Hubschrauber - http://de.wikipedia.org/wiki/Hubschrauber
e) Physikalische Grundlagen zum Hubschrauber - http://wiki.re-heli-fan.org/index.php/Physikalische_Grundlagen
f) Fotos von Hubschrauber: www.googl,ch/seaech- Helikopters

R.4.4.12 p. 189: About the Physics of Helicopters

a) Helicopter Aerodynamics - http://www.copters.com/helo:aero.html
b) Helicopter - http://www,britanica.com/EBchecked/topic/259992/helicopter
c) How can a helicopter fly up the sky? Why does it need an upright tail motor?
http://www.hk-phys.org/kg/helicopter/helicopter_e.html
d) Physics of Helicopters - http://wiki/aerodynamics.com/index.php?/title=Physics_of_Helicopters
e) Hubschrauber - www.grider.de/.../Aerodynamik%20Der%20Hubschrauber(cont
(contains pictures of forces acting on Helicopters and tail rotor; Figures adapted to English by P. Brüesch)
f) Flugdynamik und Aerodynamik des Hubschraubers - http://www,heliport.de/lexoka/hubschrauber-ühysiklexikon
http://www,heliport.de/lexoka/hubschrauber-ühysiklexikon/

R-4-21

Appendix – Chapter 4

R.A.1.1 p. 4-A-1-1: Basic Equations of Aerodynamics
Chapter 2: Basic Aerodynamic Principles and Applications - PDF
www.ohio.edu/people/uijtdeha/chapter-2...basic-aerodanam.pdf

R.A.1.2 p. 4-A-1.2: Graph: Forces on fluid particles along a streamline
according to Reference R.4.1.8 - http://www.butterflyschool.org/new/meta.html

R.A.1.3 p. 4-A-1-3 Derivation of Bernoulli Equation
from Reference R.4.1.8; pp 471 – 474; R.4.1.10, R.4.1.11

4-A-1-4 Appendix 4-A-1-4: Vortex System of an Airplane: http://www,toeging/net/flieger/profil/aerodyn.html
Bild des Wirbelsystems am Flugzeug - Figure adapted from German to Englisch by P. Brüesch.

R.A.1.5 p. 4-A-1-5 : Physik Experiment : Warum fliegen Flugzeuge ?
http://experimentis.de/PhysikExperimente/Versuch/314Fliegen.html

R.A.2.1 p. 4-A-2-1: ¨Zur Herleitung der Reynolds Zahl (Derivation of Raynolds Number)

a) Intuitive Derivation of Reynolds Number
Randall D. Peters and Loren Summer - http://physics.mercer.edu/hpage/friction/ajp/reynolds.html
Die heuristische Herleitung beruht nicht auf Trägheits- und Reibungskräften. sondern auf Leistungen,
d.h. auf der Aenderungsrate der kinetischen Energie und dem Leistungsverlust durch Reibung des Fluids
b) Low Reynolds number flows - www.hitech-projects.com/…/Low%20Reynolds%20
c) Hocine Oumeraci - Leichtweiss – Institut für Wasserbau ; Technische Universität Braunschweig
Vorlesungsdruck für das Grundfach «Hydrodynamik»
Kapitel 11: Laminare und turbulente Strömung
Abschnitt 11.5,2 , p. 202 ; Heuristische Herleitung der Reynolds-Zahl auf der Basis der Trägheitskraft
und der Reibungskraft eines sich durch ein Fluid (Wasser oder Luft) bewegenden Objektes
http://www.tu-braunschweig.de/Medien.../skript-hydromechanik.pdf

R.A.2.2 p. 4-A-2-2: Gliding Octopuses (i.e. Calmaries and Common Octopuses (Kalmare))

a) Octopus - http://en.wilipedia.org/wiki/Octopus
b) Tintenfische - http://de.wikipedia.org/wiki/Tintenfische

R-4-22

R-A-2-3 Octopuses (i.e. Calmaries and Common Octopuses (Kalmare))

a) Octopus - http://en.wilipedia.org/wiki/Octopus
b) Tintenfische - http://de.wikipedia.org/wiki/Tintenfische
c) Fliegende Meerestiere: Tintenfische übertreffen Sprint – Weltrekord
www.spiegel.de/.../fliegende-meerestiere-tintenfische-uebertreffen-sprint-
(d) Kalmare: http://de.wikipedia.org/wiki/Kalmare
e) Kraken: http://de.wikipedia.org/wiki/Kraken
f) PDF] Tintenfisch: www.fischinfo.de/pdf/TINTENFISCH.pdf
g) Pictures from: www,google.ch - Images // Tintenfisch / Octopus

R.A.3.1 p. 4-A-3-1: The 5 Classes of Vertebrates

a) Vertebrates: http://mrsmoyerfog4.wikispaces.com/Vertebrates
b) Vertebrates: http://bio.edu.ee/animals/selgro.htm

R.A:3.2 p. 4-A-3-2: Bird Migration

a) Bird migration - http://en.wikipedia.org/wiki/Bird_nigration
b) Text : http://de.wikipedia.org/wiki/Vogelzug
c) Image of Bord migration from - http://uzwik.birdlife.ch/aktivitäten02.html

R.4.3.3 p. 4-A-3-3: Migrating Birds (Zugvögel) Stare auf Flug ins Winterquartier
Sabina Galbiati: Der Sonntag, Nr. 9, 3. März 2013

R.A.3.4 p. 4-A-3-4: Weltrekord im Dauerfliegen (08.10.2013) - World Record in long-distance flight

a) Alpine Swift (Alpensegler) - http://en,wikipedia.org/wiki/Swift
b) Common Swift - http://en.wikipedia.org/wiki/Common_swift
c) Dr. Felix Liechti (Schweizerische Vogelwarte Sempach)
Zum Alpensegler - http://www.vogelwarte.ch/weltrekord-im-dauerfliegen.htm
d) Mauersegler - Apus apus - http://www,vogelwarte.ch/mauersegler.hrml

R-4-23

R-A-3-5 p. 4-A-3-5 - Coligo's (Riesngleiter)

a) Colugo - http://en.wikipedia.org/wiki/Colugo
b) Riesengleiter (Colugo's) - http://de.wikipedia.org/wiki/Riesengleiter
c) Riesngleiter (Pelzflatterer) - http://bethge.freepage.de/riesengleiter2.htm
d) Was haben Affen mit Riesengleitern zu tun ?
http://www.wissenschaft.de/wissenschaft/hintergrund/285029.html

R-A-3-6 p. 4-A-3-6 - Theological Reflections on Alfred Hitchcok's «The Birds»
By Michael J. Bayly - http://www.cpinternet.com/~mbayly/filmandtheology3.htm

R.A.4.1. p. 4-A-4-1: Airbreathing jet engines (schematic)

a) See References a), b), c), d), e) of R.4.4.9, p. 186
b) [DOC] Die historische Entwicklung von Flugzeugantrieben - homo.arcor.de/p4nty/txt/Facharbeit.doc
(Figuren - Texte von P. Brüesch neu geschrieben)

R-4-24

5. Air Pollution: Toxic gases, Particulates and Radioactive Fallout

190

5.1 General Aspects

191

Air Pollution: Definition and Examples

Air pollution is a partial aspect of environmental pollution. Air pollution is present if a deviation from the natural composition of air is present (s. p. 16), especially by smoke, particulates, soot, aerosoles, vapours or odourants. These substances are also referred to as pollutants. In most industrial countries, the local pollution has been strongly reduced in the last decades. In contrast, the emission of greenhouse gases such as carbon dioxide (CO_2) has, however, strongly increased all over the world.

In the Third World countries and in other imerging countries as well as in Russia and China, the local air pollution is still a very severe problem (see picture below: air pollution in Beijing - contamination by particulates !).

Beijing

The Air Quality Index (AQI) is an index for reporting daily air quality. The Environmental Protection Agency (EPA) calculates the AQI for 5 major pollutants: Partical Polution (also known as Particulate Matter (PM)), Carbon monoxide (CO), ground level Ozone (O_3), Sulfur dioxide (SO_2), and Nitrogen dioxide (NO_2).

In Beijing, pollution by PM's are particularly severe. On Saturday 12. 1. 2013 at 8 p.m., the concentration of fine particles in the air was extremely large, reaching an AQI-value of as large as 755, exceeding the upper limit of the «Hazardous» category by some 255 points ! (see p. 5-A-1-2)

192

Forms and Sources of Air Pollution

Forms of Air Pollutants

Pollutants can be divided into two groups:

a) Primary pollutants: emitted directly from a natural source or from human action.

b Secondary pollutants: form when primary pollutants react chemically in the atmos-phere.

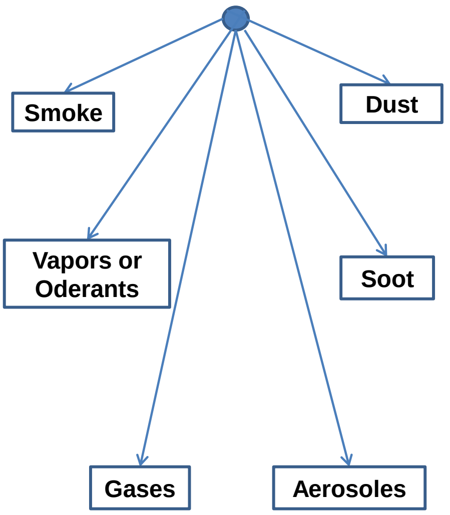
Sources of Air Pollutants

a) Pollutants from traffic: Gases and par-ticles released fom vehicles.

b) Stationary sources: Combustion of fossile fuels such as coal, oil, in power plants and households.

c) Other sources: Forest fires, biomass combustion (dead organisms, volcanic eruptions, etc).

Changes of Natural Composition of Air



193

Origin and Sources of Pollutants

Primary Pollutants	Sources - Origin
Carbondioxide (CO_2)	Volcanic activity, Hot springs, Combustion processes, Cars, Power plants
Carbonmonoxide (CO)	Oxygen deficent combustion processes, wood, coal, fuel (also from cars)
Nitrogen oxides (NO_x, NO_2)	Combustion of fuels in cars and industrial processes
Methane (CH_4)	Color- and odorless, combustible, reacts with O_2 to highly explosive mixtures
Sulfuric oxides (SO_x, SO_2)	By combustion of coal and oil
Ammonia (NH_3)	Pungent smelling and toxic gas; for fertilization of crop plants, etc.
Volatile org. Compounds (VOC's)	From vehicle exhausts, detergents, furniture polish, fabrig softener
Asbestos (mineral silicates)	Fibres penetrate into the lungs → cytotoxic effects
Radioactive noble gases	Unhealthy noble gases, e.g. Radon (Rn) from natural decay of Uranium
Lead (Pb)	Occurring naturally, from lead smettings, e.g. in pipings
Persistent org. pollutants (POP's, e.g. PCB's)	Produced by industrial processes and waste incineration Man-made synthetic chemicals; are irreverisble
Secondary Pollutants	**Sources**
Particulate matter	Fine particles, originating from compounds such as sulfates and nitrates; Produced by man or by natural processes
Ozone (O_3)	Produced by chemical reactions in the presence of solar radiation

194

5.2 Primary Pollutants

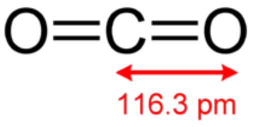
<u>Primary pollutants</u> are emitted directly from a source. They can be released from natural ways or human action.

For <u>Secondary Pollutants</u>:
s. Section 5.5 (pp 238 – 244)

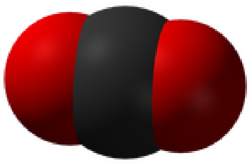
Carbon Dioxide - CO_2: General Properties

Carbon Dioxide is a chemical compound containing carbon and oxygen and the molecucar formula is CO_2. CO_2 is an incombustible, colorless and odourless acid gas, which is well soluble in water.
CO_2 is an important greenhouse gas (a heat-trapping gas) and it is a natural constituent of air where its mean concentration is 0.039% in volume (390 ppm). CO_2 is either formed by complete combustion of carbon-containing substances in the presence of sufficient oxygen concentrations as well as in living organisms as by-products of cell breathing.
The total mass of CO_2 in the atmosphere is 3'000 Gigatons, corresponding to about 800 Gigatons of carbon (the ratio of the molar masses of CO_2 and C is 11/3 (molar mass of CO_2 = 12+32 = 44, molar mas of C is 12). The concentration of CO_2 varies seasonally and locally, especially near the ground. In urbane regions, the CO_2-concentration is in general higher than in rural areas.

1 picometer =
1 pm = 10^{-12} m
= 0.01 Å = 0.001 nm



Lewis-structure of CO_2

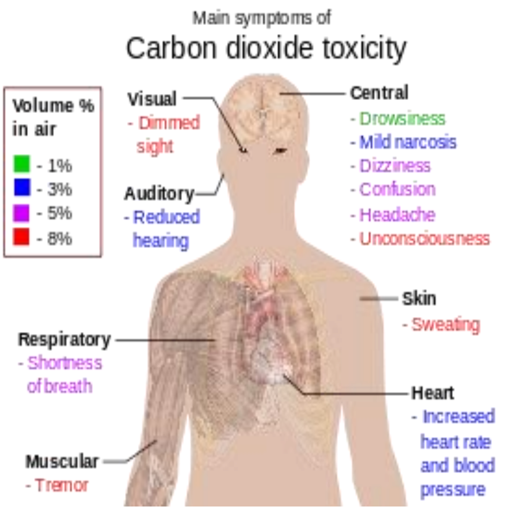


Space-filling model of CO_2

The CO_2- molecule is linear: all 3 atoms are on a straight line and the molecule has no dipole moment. The 2 C=O double bonds are covalent with 2 electron pairs from each O- atom. The 2 C=O bonds are polar but cancel each other and the C=O distance is 116.32 pm.

Carbon Dioxide - CO_2: Physiological effects and dangers

The adverse effects of CO_2 to animals and humans is not only due to the displacement of O_2 in the air. Depending on the CO_2- concentration of air, the room air is divided into 4 quality grades: For values below 800 ppm, the indoor quality is considered to be good. Values between 800 and 1'400 ppm (0.08 to 0.14 Vol.-%) are of average to medium quality. For higher concentrations, CO_2 can have toxic effects: for values larger than 1'400 ppm, the indoor quality of the air is considered to be bad. For a CO_2- concentration of 1.5%, the total lung ventilation per minute (minute ventilation) increases by more than 40%. The presence of elevated CO_2-levels in the blood is the stimulant that the respiratory center responds to in order to signal the respiratory muscles to breathe.



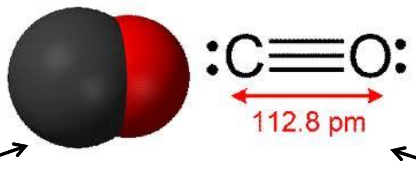
Inspired air containing about 5% CO_2 gives rise to headaches and vertigo. For still higher concentrations, the heart beat and the blood pressure increse. This can lead to breathlessnes and unconsciousness. High CO_2- concentrations in fodder silos, cesspools and wells repeatedly give rise to serious accidents.

197

Carbon monoxide - CO: Physical and Chemical Properties

Carbon monoxide is a chemical compound with the molecular formula CO. CO is a colourless, odourless, tasteless and non-perceptible toxic gas. Among others, it is produced during incomplete combustion.

CO is combustible and it burns with a blue flame to CO_2. As a component of a city gas, it has been used in Germany as a fuel gas and illuminating gas until mid-20th century. In chemical industry, H_2 and CO are used to synthesize Methanol (CH_4O or CH_3OH) as well as of other basic chemicals.



1 pm = 10^{-12} m
112.8 pm = 1.128 Å

Space-filling model of the CO- molecule

Lewis-structure of the CO- molecule

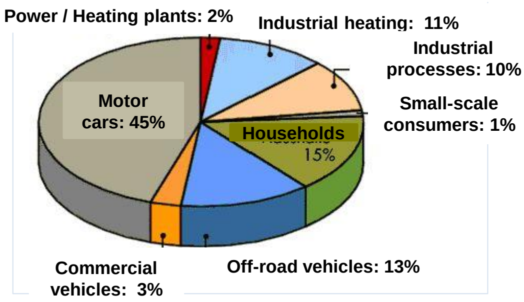
The formation of CO is favoured by high temperatures or by oxygen deficiency according to $CO_2 + C \rightleftarrows 2\ CO$. At temperatures of 1'000 °C, the equilibrium concentration of CO in this reaction is only about 1%. Pure CO can then be obtained by rapid cooling to room temperature and a stable chemical compound is obtained. CO is weakly polar with a dipolar moment of 0.122 D (1 D = 1 Debye ≈ 3.336 10^{-30} C m; 1 C = 1 Coulomb = 1 Ampere x s). World-wide, most CO is produced by photo-chemical reaction in the Troposphere (about 5 x 10^{12} kg per year). Other natural sources are volcanos, forest fires, chimneys and other combustion processes.

198

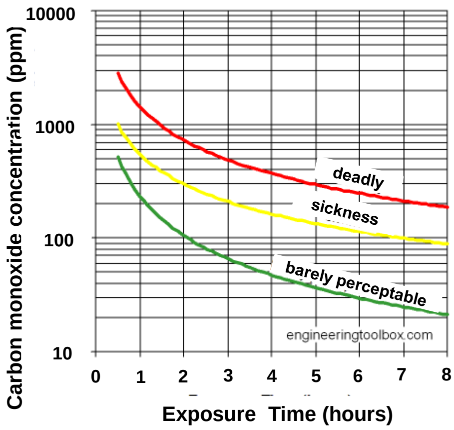
Carbon monoxide - CO : Toxicity

CO is a dangerous respiratoy poison. If it passes the lungs and enters the blood circulation, it disables the oxygen transport in the blood. This can cause death by suffocation. Light intoxination causes headache and dizziness while higher doses are very harmful for the central nervous system and the heart. This can also lead to serious complications of the development of foetuses. Since CO is colourless, odourless and tasteless, it is hardly discerned. On average, pollutants higher than 100 ppm are hazardous. The maximum allowable concentration at a workplace is 30 ppm. CO is also a poison for photosynthesis and therefore it affects the Chlorophyll of plants.

CO - Emissionen in Germany 1998: 5'800 kt/yr



Percentages of CO - Emissions

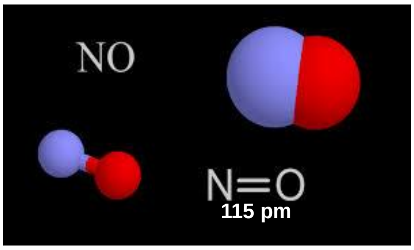


Nitrogen oxides: NO_x

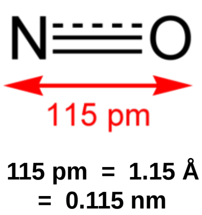
«Nitrogen oxides» is a collective term for gaseous oxides of nitrogen. They are also abbreviated as NO_x becaus there exist many oxidation states of nitrogen. Examples are NO (Nitrogen monoxide), NO_2 (Nitrogen dioxide), N_4O, N_2O, N_4O_2, N_2O_3, N_4O_6, N_2O_4 and N_2O_5.

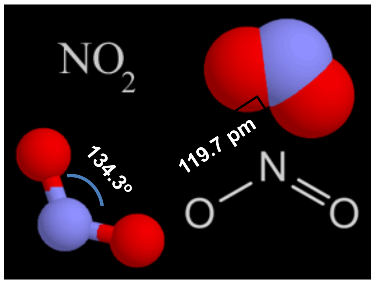
Without exceptions, nitrogen oxides are endothermic compounds, i.e. they are formed from their elements only at external constraints (energy input). With the exception of N_2O (nitrous oxide or laughing gas) they react with water to form an acid. Because of this acidification (on the mucosae) they have an irritating and poisonous effect. In the one hand, laughing gas has medical and industrial applications. In the other hand, it is emitted unintentionally into the atmosphere during technical and agricultural processes. There, it acts as a greenhouse gas and as an ozone killer (see Chapter 2).

NO and NO_2 are produced nearly exclusively by combustion reactions in technical facilities and by motors and is emitted mainly as NO. In the presence of air, NO is oxidized to NO_2.



Nitrogen monoxide: NO



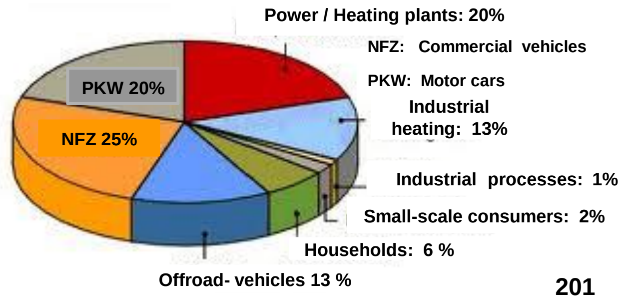


Nitrogen dioxide: NO_2

NO_x, Nitrogen monoxide NO and Nitrous dioxide NO_2

NO and NO_2 develop at high temperatures (> 600–800 °C) as a result of combustion processes, especially from road traffic heating systems. 90 to 95% are emitted as NO and in the atmosphere they are chemically transferred to the more poisonous NO_2. The major portion stems from traffic (passangers cars, utility cars, Off-road vehicles). The concentrations of NO and NO_2 have an early cycle: the highest values are measured in winter half years.
In the denitrification plant (DENOX), the nitrogen oxides are chemically decomposed into nitrogen and water and the Dioxins (p. 213) are decomposed. The purified flue gases leaving the chimney, consist mainly on water vapour.
Primarily, nitrogen oxides are naturaly generated by lightnings. Electrical discharges in air occur at temperatures as high as 30’000 °C thereby oxidizing N_2. In additon, nitrogen oxides are generated by forest fires (about 40 t/Jahr) as well as by fertile soils. Microorganisms in the soils are emitting about 6’600 t/year into the atmosphere.

NO_x - Emissions in Germany 1998: 1’670 kt/yr

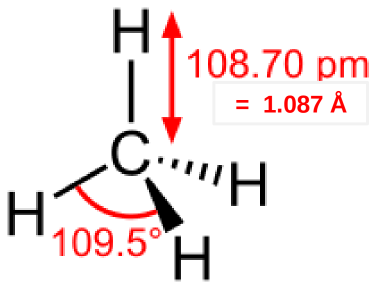


- Nitrogen oxides are present in tobaco smoke !
- Experiments suggest the unique role of vegetation as a sink of NO_2.
- Inhalation of NO_2 is poisoness. Because of the penetrating smell, inhalation can normally be prevented.

201

Methane: CH_4

Methane is a hydrorarbon and the simplest Alkane. It is a colourless and odorless gas. As a main component of natural gas, it is of greatest importance as a heating gas for chemical industry and as starting product for technical systems.
CH_4 appears at diverse conditions and is permanently reformed, for example by biological and chemical processes. On the Earth, approximately 60 million tons of CH_4 are emitted each year.
The density ρ of Methane is smaller than that of air (at 0 °C, 1 bar: $\rho(CH_4)$ = 0.708 kg/m³, ρ(air) = 1.292 kg/m³); therefore, CH_4 ascends to higher layers of the Earth’s atmosphere. It is more effective than CO_2 by a factor of 20 to 30, however, its concentration is much smaller than that of CO_2. There, it reacts with O_2 to form CO_2 and water (chemical half time ≈ 14 Jahre; [$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$].



Methane is generated at high temperatures and pressures in the deeper underground below the surface of the Earth. In most cases, it is released by volcanic activities. It is the main component of natural gas (85 – 98 %), which appears primarily in conjunction with fossil oil. [Natural gas is a combustible gas which often appears together with fossil oil and consists mainly on highly-inflammable methane].

The Figure shows the methane molecule CH_4: The carbon atom C is located at the centre of the tetrahedron which is formed by 4 hydrogen atoms H. 1 pm = 10^{-12} m.

202

Methane CH_4: Handling, Dangers and Safety

At a volume fraction between 4.4 and 16.5% in the air, methane forms explosive mixtures i.e. dangerous explosive atmospheres. The unnoticed escape of natural gas repeatedly leads to fatal gas explosions. In addition, the greatly feared mining explosions in coal mines (fire damps) are due to methane-air mixtures. Methane is highly flammable. The flash point is at – 188 ^{o}C and the ignition temperature is at 600 ^{o}C.

Methane is nontoxic. The inhalation of methane can, however, cause increased breathing frequency (hyperventilation) and increased heart beat. In addition, it can cause low blood pressure, numbness in the extremities, sleepiness, mental confusion and loss of memory (amnesia). All these symptoms are due to the lack of oxygen. However, methane does not cause permanent damages .

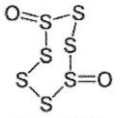
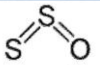
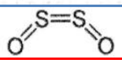
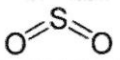
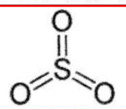
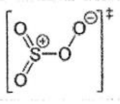
Rice production by «Wet Rice Agriculture»

- Due to the worldwide rice agriculture, 50 to 100 tons methane are produced per year. This kind of methane production is probably the highest man-made generation of methane.
- Rice is produced worldwide and the quantity of methane production depends strongly on the actual location. Among other things, it depends on the average temperature, the water depth and period of time during which the rice is exposed to water.
- As a consequence of the increase in global population and the associated increase of rice cultivation, the concentration of methane increases.

203

Sulfur oxides: General

Sulfur oxides (chemical formula: S_xO_y) are oxides of the chemical element sulfur (S). Since sulfur can exist in several different oxidation states, several sulfur oxides exist:

Chemical formula	Oxidation state	Structural formula
S_7O_2	0, +II	
S_2O	0, +II	
SO	+II	S=O
S_2O_2	+II	
$\boxed{SO_2}$	+IV	
$\boxed{SO_3}$	+VI	
SO_4	+VI	

Sulfur oxides are formed by combustion of sulfur and sulfur-containing combustibles (coal, petrol, fuel oil, Diesel fuel), but also by natural processes such as by volcanic eruptions.

As a result of combustion processes, sulfur reacts mainly to the two following oxides:

- Sulfur dioxide: SO_2 and
- Sulfur trioxide: SO_3 (in small quantities)

In aqueous solutions, both sulfur oxides. react to acids. SO_2 reacts to the unstable sulfurous acid H_2SO_3(aq) and SO_3 reacts to the very important sulfuriq acid H_2SO_4. Both acids play an important role for the acidification of lakes due to acid rains. These acids are also poisonous in the gases state.

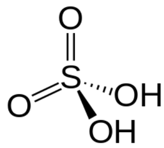
204

Sulfur dioxide - SO_2 and Sulfuric acid

Sulfur dioxide is the anhydrate of the sulfuric acid H_2SO_3. SO_2 is a colorless and poisonous gas with a pungent odor and an irritating taste. It is well water-soluble and in contact with water it partially reacts to sulfurous acid.

Lewis – Structure of SO_2

Space-filling model of SO_2



Sulfuric acid (H_2SO_4)

SO_2 is primarily formed by combustion of sulfurous fossil fuels such as coal or petroleum products which contain up to 4% sulfur. Thereby, it contributes to an essential degree to air pollution. It is at the origin of acid rain; here, SO_2 is first oxidized to SO_3 and by reacting with water it is converted to sulfuric acid (H_2SO_4). (The H_2SO_4-molecule has a tetrahedral structure, see above).

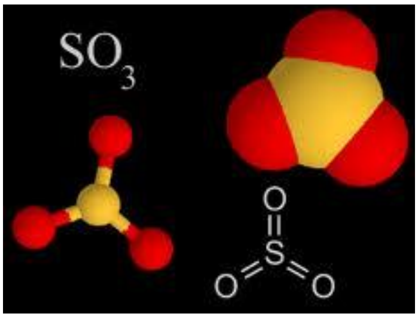
There are two sources of how SO_2 can rase into the atmosphere: The first one has a natural origin, namely by volcanic eruptions; these eruptions can eject 2 to 20 million tons per year. The second source is man-made, i.e. by fossile fuels such as coal and oil.

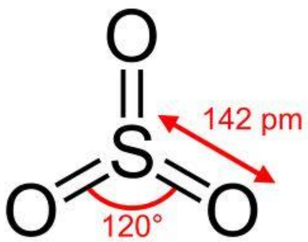
In high concentrations, SO_2 causes harm to man, animals and plants. The acid rain is harmful for the ecosystem such as woodland and lakes. The largest contribution of emission into the air is due to ship traffic.

205

Sulfur trioxide - SO_3

Sulfur trioxide, SO_3, is an anhydrate of sulfuric acid, H_2SO_4. At normal conditions, it is colourless and forms needle-shaped crystals which are extremely hygroscopic and which react violently (explosive) with water. Gaseous sulfur trioxide is a monomer (monomers are reactive and low molecular molecules, which among others can form molecular chains, nets or branched polymers). The SO_3 – molecule is planar (all 4 atoms are in the same plane) and have a trigonal symmetry (three 120^0 - angles) and it contains three double bonds of equal lengths (s. picture below).





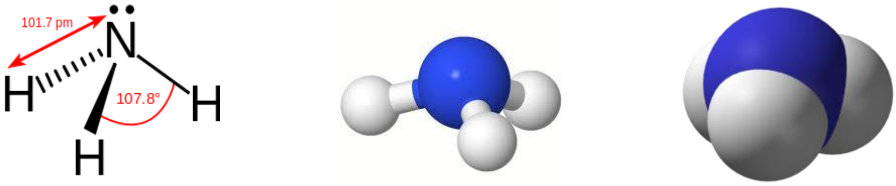
Inhalation of vapour causes irritations and in the lungs, sulfuric acid is formed. This can provoke a life-endangering pulmonary oedema. Since SO_3 is strongly corrosive and hygroscopic, inhalation or incorporation causes serious injuries. Therefore, SO_3 should be treated with extreme caution. With water, it reacts violently and converts into highly corrosive sulfuric acid.

206

Ammonia - NH_3: General Properties

Ammonia is a chemical compound of nitrogen (N) and hydrogen (H) atoms with the chemical formula NH_3. Since ammonia reacts easily with acid compounds, gaseous ammonia appears only in small quantities on Earth. It is formed by decomposition of dead plants and animal faeces. Ammonia is also formed by humification, in which nitrogen-containing compounds of biomass are decomposed by microrganisms.

The Ammonia molecule: different representations



At room temperature, ammonia is a colourless diamagnetic and pungent-smelling gas. Below – 33^{0}C, it liquifies.

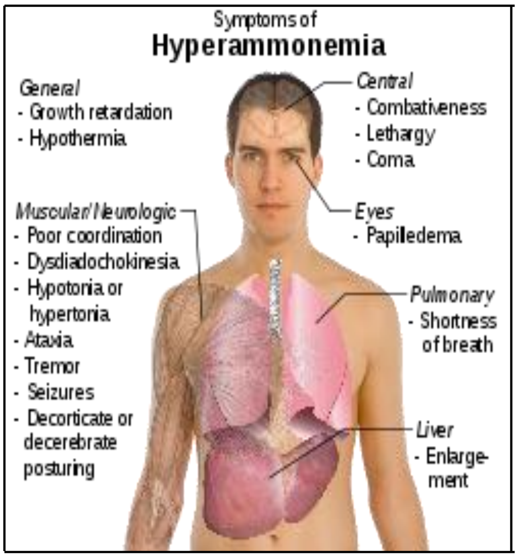
Ammonia is built up from separate NH_3- molecules. The molecule is not planar but rather forms a three-sided pyramid. The N- atom is at the top of the pyramid while the tree H- atoms form the base of the pyramid. The H-N-H angle is 107.3 ^{0}C, slightly smaller than the ideal tetrhedron angle of 109.5^0.

Important sources for ammonia emission are volcanic eruptions, the cattle ranching, the cattle fattering as well as the traffic.

207

Ammonia - NH_3 : Toxicology

The unpleasant odor of ammonia which is already perceivable at low concentrations, is a warning and therefore, cases of injuries and poisoning are very seldom.



Hyperammonemia is a metabolic disturbance characterised by an excess of ammonia (NH_3) in the blood. It is a dangerous condition that may lead to encephalopathy and death,

Gaseous NH_3 reaches the lung primarily by respiration. By reaction with wet air, NH_3 is strongly pungent to the mucosae. In addition, the eyes are also strongly damaged by NH_3. In the case of inhalation of concentrations higher than about 1'700 ppm, mortal danger exists because of damages in the respiratory passages (laryngeal oedema, laryngospasm, pulmonary oedema. pneumonitis and respiratory arrest). By transfer of substantial quantities of NH_3 into the blood, the blood level of NH_4^+ ions increases above 35 μmol. This leads to central nervous phenomena such as hand tremor, language disorder, vision disorder and mental disorder. In extreme cases of poisoning it can cause comas and death.

In addition to respiration, acute poisoning by NH_3 can also occur as a consequence of liver failure (hepatic faiiure).

208

5.3 Toxic Organic Gases

209

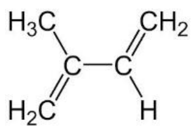
Volatile Organic Compounds - General

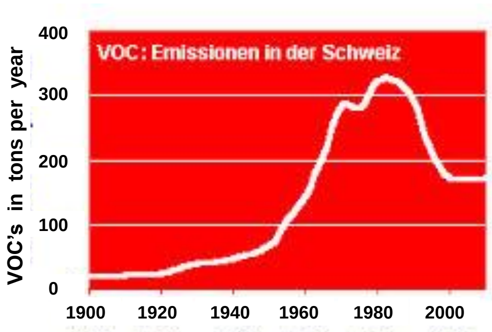
Volatile Organic Compounds (VOC's) is the general term for organic, i.e. carbon-containg compounds, which evaporate easily (are volatile). They exist already at low temperatures (i.e. at room temperature) in the gaseous form. In the case of NMVOC's (Non Methane Volatile Organic Compounds), Methane gas, CH_4 (pp 203, 204), is excluded from the group of VOC's.

VOC's are emitted into the environment by a plethora of biogenic and anthropogenic processes. Plants, animals, soils and Seas are natural, biogenic sources; the most important anthropogenic sources are industrial applications of solvents and traffic.

Biologically generated VOC's

All living beeings (humans, animals, plants and microorganisms) are emitting organic compounds into the environment. Many plants are emitting terpenes and other organic compounds. The simplest terpene is the isoprene shown at the right hand side.





Time cours of VOC – weights in Switzerland

Anthropogenic sources

The release of volatile organic compunds by humans is dominated by applications of solvents and by the traffic. If the emission of methane caused by rice cultivation is considered as an anthropogeneous source, a significant contribution is added to the VOC's.

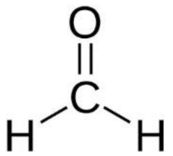
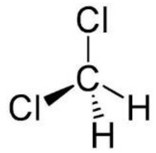
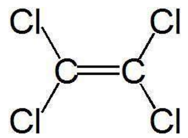
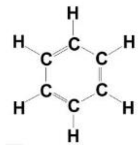
In addition to atmospheric VOC's in the atmosphere, volatile organic compounds are also present in the indoor air. For the latter VPC's, there are different sources such as plastics, construction materials, furnitures, carpets, detergents and tobacco smoke.

210

Volatile Organig Compounds (VOC's): Toxicity

Pollution with VOC's by indoor air: Persons can suffer long-term illnesses. Children and older persons are affected most often. Symptoms such as headaches, allergies, tiredness, degradation of performance, drowsiness and irritations of the respiratory tract are summarized under the term «Sick-Building Syndrom». This cluster of syndroms is internationally used and defined by WHO («World Health Organization»).

Properties and Toxicity of vapours of four VOC's

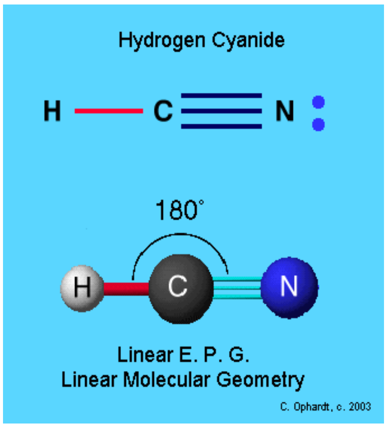
			
Formaldehyde: CH_2O	Dichlormethane: CH_2Cl_2	Tetrachlorethane: C_2Cl_4	Benzene: C_6H_6
Melting point: - 117 ^{0}C	- 94.92 ^{0}C	- 22 ^{0}C	5.5 ^{0}C
Present in blood of mammals, by photo-oxidation in the atmosphere, by incomplete combustion, etc.	Applications: Dichlormethane (DCM) is a good solvent for many compounds.	Properties: C_2Cl_4 is a colourless and volatile liquid, the vapors of which are heavier than air.	Properties: volatile organic compound having an aromatic smell.
Toxicity: Allergies, irritatations of skin, respiratory pasages and eyes. Acute danger of life for higher concentrations (pulmonary oedema, pneumonia; carcinogenic !	Toxicity of DCM is due to the harmful effect of metabolic effective carbonmonoxide (CO). Inhalation can be fatal. For animals: breast cancer, lung cancer and liver cancer.	Toxicity: widely applied in trade and industry. → Contamination of ground waters ! C_2Cl_4 is a carcinogenic dangerous substance!	Toxicity: poisonous by inhalation. Both, the toxic effect as well as the carcinogenic effect is due to the development of a cancerous metametabolite.

211

Hydrogen cyanide (HCN) in the Atmosphere

HCN is one of the strongest poisons known. In very smaii concentrations it is also present in the atmosphere. It has been shown, that HCN present in the troposphere and in the lower stratosphere is produced by combustion of biomass from the Earth. The lifetime of HCN observed in the atmosphere is only a few months. It is believed that this limited lifetime is due to the absorption of HCN by the oceans.

As an example we consider the concentration of HCN in combustion gases. Today, about 5'000 poisonous components are present in these gases. For the acute medication, the following noxes(*) are relevant: Carbon monoxide (CO), Hydrogen cyanide (HCN), and different lung irritants.



Hydrogen cyanade molecule: HCN

Among others. HCN is produced by combustion of wools, silk, Nylon, upholstered furnatures, curtains, carpets, cars, airplanes and paper. In addition, HCN is also contained in tobacco smoke. The smoke of an average cigarette contains 400 to 500 µg HCN.

Properties of HCN:

Molar Mass: 27.03 g/mol; Density: 0.68 g/cm^3;
Melting pointt: - 13 ^{0}C; Boiling point: 26 ^{0}C;
Vapour pressur at 20 ^{0}C: 816 hPa = 0.816 bar = 0.805 atm

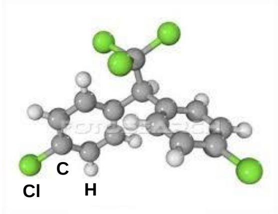
An other name for HCN is Zyklon B; Zyklon B is extremely poisonous: already 1 - 2 mg per kg body weight is deadly! In World War II. Zyklon B has been used for mass poisoning of humans (s. p. 5-A-3-2).

[(*) noxes: see Ref. R.5.3.4 - f)]

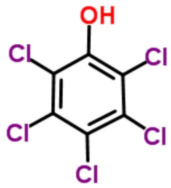
212

Persistent Organic Pollutants (POP's)

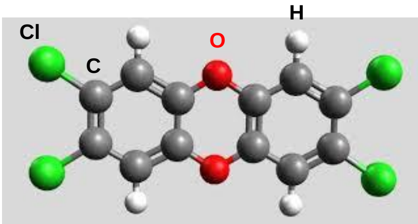
Persistent Organic Pollutants (POP's) are organic compounds which are decomposed only very slowly in the environment (persistent orcanic compounds). Typically, the notion is used for organochlorine insecticides of the «first class» (examples are chlordane, DDT, Dieldrin, Toxaphene), for some industrially manufactured chemicals (PCB) as well as for some byproducts of combustion processes (Dioxin).



DDT – molecule
$C_{14}H_9Cl_5$



PCB – molecule
C_6Cl_5 - OH



Dioxin:
$C_{12}H_4Cl_4O_2$

POP's are «semi-volatile»: they can exist in the gaseous phase as well as bound to dust particles. For this reason they are mobile in the environment, at least to a certain extent, and by mechanisms of long-distance transport, they can be distributed globaly. Persistent organic compounds are relatively resistant with respect to chemical, biological, and photolytic processes of degradation. In many cases, they are composed on chlorine and carbon atoms: The Cl-C bond is very resistant against hydrolysis. POP's are difficult to desolve in water but they are easily soluble in fat. They can be accumulated in the fatty tissue of animals and humans.

213

Defolation of Virgin Forests in Vietnam by «Agent Orange»

The Vietnam War (1965 – 1973) of the Americans against Northern-Vietnam has been conducted in an extremely inhuman and cruel manner and at the same time, it was also extremely detrimental to the environment. Among others, the Americans used the dioxinated defoliant «Agent Orange» (Dioxin: s. p. 213). Their goal was a defoliation of the trees and finally a complete destruction of the forests. The resistance fighters used the forests as military camouflage and as channels of supply. In order to eliminate the basic food resources, the farming land was also destroied. In case of poisoning with «Agent Orange», no method of detoxification is known.

For identification, the barrels in which the active agent containing the Doixin has been transported have been provided with a an oranged-colored strip; hence the name «Agent Orange».

Depending on the sources, 72 to 90 million liters of chemicals have been sprayed !

Dioxin from the air: An airplane investigates a virgin forest in Vietnam (1970)

By using Agent Orange, the Americans defoliated the trees of forests.

214

Cruelest mutilation of newborns from exposure to «Agent Orange» (Dioxin) in Vietnam

According to the Vietnamese Red Cross, more than 3 millions of Vietnamese have been impared by «Agent Orange» and almost 500’000 children suffered from most cruel birth defects. About 4.8 millions Vietnamese have been exposed to the poison «Agent Orange»; they died or have been mutilated.
«Agent Orange», a Dioxin-containing chemical defoliant, has beeb introduced by John F. Kennedy in 1963 and has been further used as a weapon by Lyndon B Johnson !
In the areas which have been contaminated by «Agent Orange», children suffered from diverse healf problems such as cleft palate, serious mental disabilities, hernia (protrusion of intestines through hernial orifices), as well as the formation of additional fingers and toes. In the years after 1970, high concentrations of Dioxin have been detetected in mother’s milk of women from South Vietnam.

Photo of dead Vietnames babies, stillborn and deformed as a result of prenatal dioxine exposure from Agent Orange

Agent Orange – Medical preparation of malformed children

215

Seveso - Disaster with Dioxin - 1

At July 10, 1976 an explosion occured in the Chemical Laboratory ICMESA in Seveso, a small city in Northern Italy. A very large quantity of TCDD (Dioxin) has been released. As a consequence, a deadly cloud of the highly toxic chemical hovered over the city and its 8’000 inhabitants. Ten days past until the population has been informed by the management about the possible severe hazards originating from this toxic gas ! For this reason, the protective measures for the population started much too late.

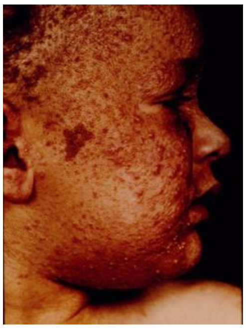
Although the responsible managers of ICMESA knew already at the day of the accident that Dioxin has been released, they announced it officielly only 8 days after the catastrophe. The partner Company Roche in Switzerland has internally been informed already on July 12 about the accident and the released Dioxin but it neither went public.

The Chemical Laboratory ICMEA – Roche after the explosion releasing the deadly Dioxin

It was only a weak after the accident that ICMESA informed the authorities aboit the diaster !

216

The consequences of the Dioxin catastrophe in Seveso - 2



Chloracne - victim

A deadly cloud howered for days over the area of Seveso and its environment.

More than 200 persons suffered from burns and acute symptoms of poisoning and had to be hospitalized. Most of these victimes suffered from Chloracne, a severe skin disease, which is directly related to Dioxin.

In the case of unborn children, severe deformities had to be expected. For this reason, many pregnant women performed an abortion. It is estimated that more than 37'000 persons were affected by the accident.

Widespread deahs of sheeps, 2 months aster the catastrophe

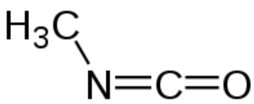
An area of more than 320 hectares populated by about 5'000 persons, has been contaminated. Five days after the accident, widespread dying of animals started, mainly birds, rabbits and sheeps. In the following days, leaves of trees and bushes started to withering. 3'300 carcasses have been found.

The large number of carcasses is due to the fact that the animals ate from the pastures and from other contaminated feed found in nature,.

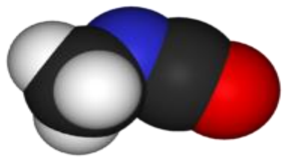
217

The Bhopal – Catastrophe - 1

The catastrophe of Bhopal occured at December 3, 1984 in the Indian city of Bhopal, the Capital of the Indian State Madhya Pradesh. It happened in an industrial plant of the US Chemical Company Union Carbide Corporation (UCC) [after 2001: the Chemical giant Dow Chemical Company (DCC)]. As a result of technical failures caused by an unvorgivable greed for profit and negligence, a very large quantity of highly toxic gases escaped into the Atmosphere. It is one of the worst chemical catastrophs and environmental disasters of history. Thousends of humans died at the direct impacts of this terrible accident.



Methyl isocyanate: $H_3C(NCO)$ is extremely poisonous !



In Bhopal, the pesticide Sevin was produced. As an intermediate, the highly toxic Methyl-Iso-Cyanat (MIC), $H_3C(NCO)$ (s. Figure) was used. At the time of the accident, no production was carried out because of overcapacities of Sevin. Only inspection work and cleaning work were carried out. By an unfortunate and unusual chain of events as well as due to severe omissions of the maintenance of the system, water penetrated into one of the tanks containig MIC. An exothermal reaction occured which produced a huge amount of CO_2 thereby increasing strongly the internal tank pressure. As a consequence, about 25 to 40 tons of MIC and other reactive gases escaped through the overpressure valve into the Atmosphere. The entire contents of the tank evaporated in less than two hours.

218

Bhopal : Consequences of the chemical catastrophe

<u>Left-hand picture:</u> This is the place at which the most terrible Industry-Catastrophe started: Ruins of the pesticide factory in Bhopal.
<u>Right-hand Photos</u>: Warren Anderson (1921 - 2014), CEO of UCC is one of the primarily responsible persons of the catastrophe. Upper Photo: Anderson at the time of the accident; lower Photo: at the age of about 90. At 1986 he flied to the US! It took more than 25 years until 8 executing indian employes have been convicted.

It is not realy known how many humans died by poisoning. It can, however, be assumed that within the first 72 hours after the accident, about 10'000 people died a horrible death ! Up to today about 15'000 persons died by long-term effects. Human Right Organisations believe that altogether about 30'000 humans died. At least 100'000 people became chronically ill.

219

The Apocalypse of Bhopal

Apokalypse - Widespread death !

Life-long severely damaged people

220

5.4 Particulate Matter (PM's) in the Atmosphere: Formation and Dynamics

A distinction is made between Primary Particles and Secondary Particles:

<u>Primary Particles</u> are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks of fires.
(see Analogy with Primary Pullutants, Section 5.2)

<u>Secondary Particles</u> make up most of the fine particles. They form in complicated reactions in the atmosphere of chemicals such as sulfur dioxides and nitrogen oxides that are emitted from power plants, industries and autompbiles.
(see Analogy with Secondary Pollutants, Section 5.5)

221

Particulates: General Remarks

«Particulates» are a part of suspended dust, also called «Particulate Matter» (PM's).
Let D_P be the diameter of the PM's; depending on D_p the following PM's are distinguished:

PM10: Particle P with 2.5 μm < D_P < 10 μm – inhalable suspended dust; (1 μm = 10^{-6} m)

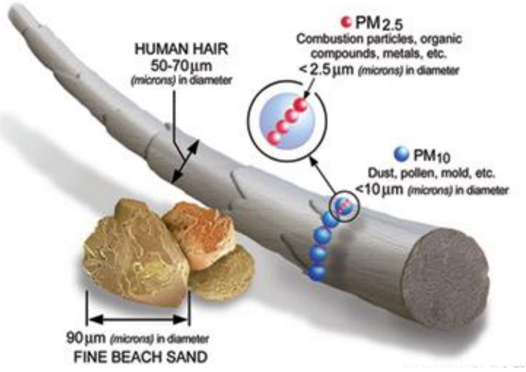
PM2.5: Particle P with 0.1 μm < D_P < 2.5 μm – respirable suspended dust

PMUP: Ultrafine Particles P with D_p < 0.1 μm = 100 nm (1 nm = 10^{-9} m = 0.001 μm)

PM's are very small solid or liquid particles in the atmosphere of the Earth. They are suspended as <u>atmospheric aerosols</u>. PM's can have a <u>natural origin</u> or they can be <u>anthropogenic</u> (produced by humans). PM's can be harmful for human health. In addition, they may have adverse impacts on the climate and on precipitations.

<u>Examples and origin of natural PM's:</u>
- Plants (polls)
- Volcanic eruptions
- Sea salt from foam
- Forest fires
- Sahara dust
- by erosion of rocks
- Particle formation from precursers in the atmosphere

<u>Examples of anthropogenous PM's:</u>
- Economy: Industry, industrial combustion, bulk handling
- Traffic: Road traffic, rail traffic, other traffic
- Private housholds and small-scale consumers
- Electricity and district heating plants
- Agriculture



PM2.5 and PM10 compared with Human Hair and Fine Beach Sand

222

Fine Particulates: Categorization of Suspended Particulete Matter

Suspended Particulates
Collective term for all solid suspended particles

Soot in the Air:
Carbon particles; from incomplete combustion processes

Smoke in the Air:
Fine, solid particles; from mechanical processes or from resuspension

Smoke in the Air:
Fine distributed particles from chemical or thermal processes

Subdivision according to

Inhalable fine particulates:
PM10: $D_P < 10\ \mu m$

Course dust
(sedimented particles)
$D_P > 10\ \mu m$

Respirable particulates: PM2.5
$D_P < 2.5\ \mu m$

Ultrafine particulates: PMUP
$D_P < 0.1\ \mu m$

D_P = Diameter,
$r_P = D_P/2$ = radius of particle P

PM: Particulate Matter
UP: Ultrafine Particles

Subdivision according to dust species :

House dust
- Rock dust
- Skin scales
- Foodstuffs
- Abrasive material
- Fungals spores
- Bacteria

Fine Fibres
- Inorganic fibres, e.g. (Asbestos, Glass wool)
- Organic fibres (e.g. Cotton dust)

Mineral dust
- Silicates (sand)
- Loess

«Dust bonnies»

«Black dwellings»

Pollen
- Farina

223

Particle size D_P and Knudsen – Number Kn

The particle size (Diameter D_P for a spherical particle) plays a decisive role. The same applies for the so-called Knudsen-Number Kn. If λ_A is the mean free path of the air molecules, Kn is defined as:

$$\boxed{Kn = \lambda_A / D_P} \qquad (5.1)$$

In the following, let λ_A = 68 nm = 0.068 μm be the mean free path of air molecules at Standard Conditions (25⁰C and 1 bar). Depending on the range of values for D_P, the following three regions are distinguished::

A) Continuum region: $D_P >> \lambda_L$

$0.2\ \mu m < D_P < 100\ \mu m \rightarrow 0.00068 < Kn < 0.34 \quad (Kn < 1)$

B) Kinetic region: $D_P << \lambda_L$

$0.001\ \mu m < D_P < 0.01\ \mu m \rightarrow 6.8 < Kn < 68 \quad (Kn > 1)$

In this case, the particles behave as free molecules.

C) Transition region:

$0.01\ \mu m < D_P < 0.2\ \mu m \rightarrow 0.34 < Kn < 6.8$

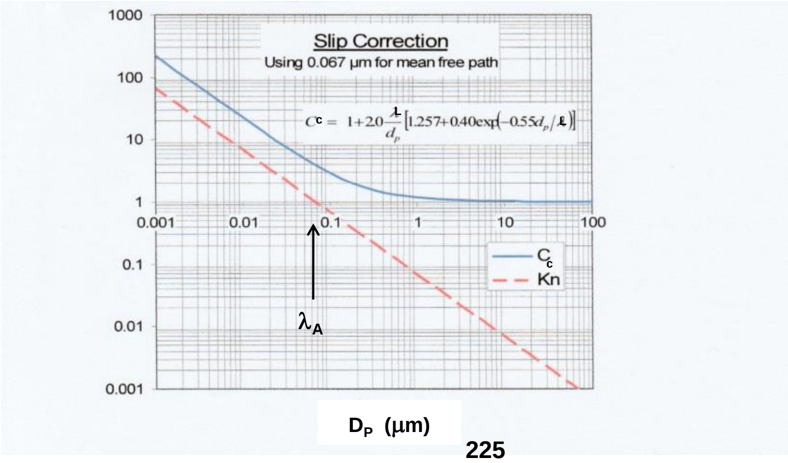
224

Knudsen-Number Kn and Cunningham Correction-Factor C_C

For Stoke's theorem (p. 227) and for the rate of descent of a falling particle as a function of time (p. 228) we need the so-called Cunningham correction factpr C_c. This factor is important if the diameter D_p of the falling particle is comparable to or smaller than the mean free path λ_A of the molecules of the air. In this case, the particles are moving almost freely, i.e. without collisions with the molecules of air. The Cunningham factor C_C is written in the form

$$C_c(\lambda_A/D_P) = 1 + 2\,Kn*[A_1 + A_2*\exp(-A_3/Kn)] \qquad (5.2)$$

where $Kn = \lambda_A/D_P$ is the Knudsen number as defined in eq. (5.1). The constants A_1, A_2, and A_3 are: $A_1 = 1.257$, $A_2 = 0.400$, $A_3 = 0.55$. The Figure shows the functions $Kn(D_P)$ and $C_c(D_P)$ for 20^0C and 1 atm with $\lambda_A = 6.6*10^{-8}$ m = 0.06 μm.



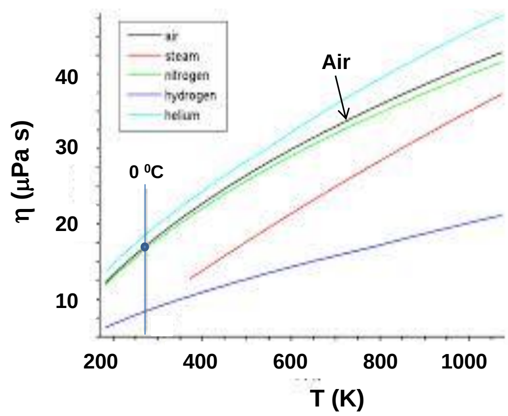
225

Viscosity and mean free path for some gases

The viscosity η is a measure of the tenacity of a fluid (liquid or gas). The larger η, the smaller is the fluidity, and the smaller η, the larger is the fluidity. The unit of η is Pa s; for gases, the unit μPa s = 10^{-6} Pa s is used.

For the dynamic viscosity of gases, η is given by: $\eta = (1/3)\, n\, m\, v\, \lambda$, where n is the number density, m the (average) mass of the gas particles, v the average velocity of the particles, and λ the mean free path of the particles.

For relatively small pressures P (0.1 < P < 10 bar), the viscosity is essentially independent on P. η depends, however, on temperature T. Since the average velocity v increases with T [v is proportional to $T^{1/2}$], η increases with increasing temperature T (see Figure).



The Figure shows $\eta(T)$ for some gases in the temperature range between 200 K to 1000 K (- 73 ^{0}C to + 727 ^{0}C).

For dry air, $\eta_A(0\ ^0C)$ = 17.1 μPa s, and $\eta_A(20\ ^0C)$ = 18.6 μPa s. Since air contains about 80% Nitrogen, $\eta(N_2)$ is similar to η(air).

[Note: For liquids, η decreases with increasing T: $\eta(T) \approx \eta_0*\exp(E_A / R\,T)$].

[The viscosity of air will be used for the fricton force of a particle falling in air (pp 227- 231)].

226

Theorem of Stokes with Cunningham-Correction

We first consider the Theorem of Stokes, which describes the friction force F_{RS} of a spherical particle P falling with constant velocity v_{PS} in a fluid F (Liquid or Gas). Let η_F be the viscosity of the fluid and R_P the radius of the particle. For non-spherical particles, the radius is approximated by half of an appropriate equivalent diameter. The friction force of Stokes is then given by:

$$F_{RS} = 6\,\pi\, R_P\, \eta_F\, v_{PS} \;=\; 3\,\pi\, D_P\, \eta_F\, v_{PS} \;; \qquad (D_P = \text{Diameter of spherical particle}) \qquad (5.3)$$

If the sphere sinking in a gas is so small, that it is comparable or smaller than the mean free path λ_F of the molecules of the gas, the number of collisions and hence F_{RS} will be reduced. This reduction is described by the Cunnigham-Correction factor C_C (p. 225) and for particles falling in Air ($\eta_F = \eta_A$), the following Stokes-Cunningham factor F_{RSC} is obtained:

$$F_{RSC} = 3\,\pi\, D_P\, \eta_A\, v_{PSC} \,/\, C_C \;. \qquad (C_C \;\geq 1) \qquad (5.4)$$

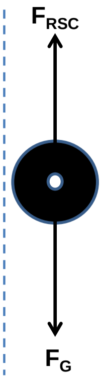
The Stokesche-Cunningham relation is the basis for the evaluation of the sedimentation velocity v_{PSC} of the spherical particle in a fluid (liquid, oil, gas, etc). If F_G is the weight, F_{RSC} the friction force, and F_A the buoyant force, we have: $F_G = F_{RSC} + F_A$. Using $F_G = M_P\, g = (4\pi/3)\, R_P^3\, \rho_P\, g$ and $F_A = (4\pi/3)\, R_P^3\, \rho_A\, g$ [ρ_P, ρ_A : densities of particle and air, respectively], the stationary Stokes-Cunningham sedimentation velocity v_{PSC} of the particle P is given by :

$$v_{PSC} \approx (2/9\, \eta_A)^*R_P^2\, g\, \rho_P\, C_C = (1/18\, \eta_A)^*(D_P^2\, g\, \rho_P\, C_C \qquad (5.5\text{ a})$$

(since $\rho_A << \rho_P$ we have neglected ρ_A).

$$v_{PS} \approx (1/18\, \eta_A)^*D_P^2\, g\, \rho_P \;\; (\text{Stokes-velocity}) \qquad (5.5\text{ b})$$

It follows: $v_{PS}(D_{P1}) = (D_{p1}/D_{p2})^2\, v_{PS}(D_{p2})$



Examplel:
Root particles

D_P = 100 nm

ρ_P = 2 g/cm³

$\eta_A = 1.8\; 10^{-5}$ kg/(ms)

$C_C \approx$ 2.9

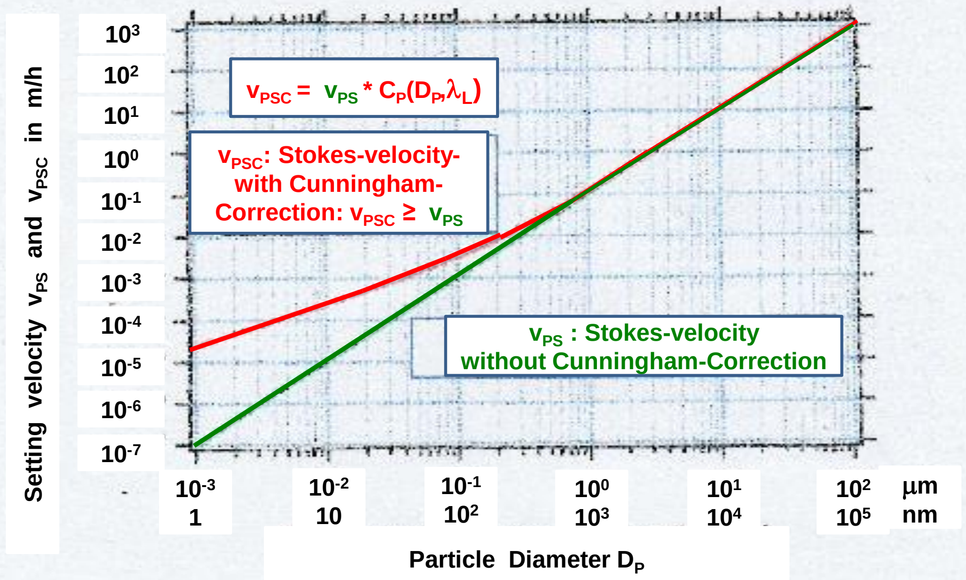
g = 9.81 m/s²

→ $v_{PSC} \approx$ 6.1 mm/h

= 6.1 * 10^{-3} m/h

227

Setting velocity of dust particles P with and without Cunningham-Correction C_C; Density ρ_P = 1g/cm³ ; ($\rho_L << \rho_P$)



228

Velocity of fall v(t) and Acceleration a(t) of particles falling in Air

For the veliocity of fall v(t) of a particle P with mass m_P and characteristic diameter D_P in still air of viscosity η_A the following differential equation must be solved:

$$m_P\,(dv/dt) = m_P\,g - (3\,\pi\,\eta_A\,D_P\,/\,C_P)\,v(t) \qquad (5.6)$$

Here, $g = 9.81\ m/s^2$ is the gravitational acceleration and C_P is the Cunningham Correction factor. With the initial condition $v(t = 0) = 0$ and the stationary velocity $v_0 = g{*}\tau$ one obtains the following solution:

$$v(t) = v_{PSC}\,[1 - \exp(-\,t/\tau)] \ . \qquad (5.7)$$

τ Is a characteristic relaxation time: $\tau = m_P\,C_C\,/\,(3\,\pi\,\eta_A\,D_P)$.

For a spherical particle with density ρ_P the mass is $m_P = (\pi/6)\,\rho_P\,D_P^3$, hence

$$\tau = (1/18\,\eta_A)\,\rho_P\,D_P^2\,C_C \quad \text{and} \quad v_{PSC} = g\,\tau = (1/18\,\eta_A)\,\rho_P\,g\,D_P^2\,C_C \ . \qquad (5.8)$$

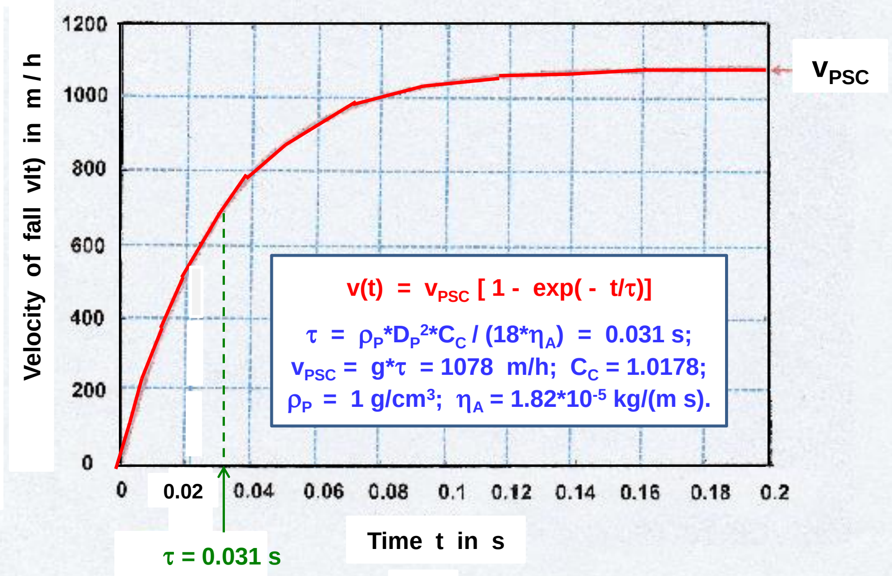
The acceleration is given by $a(t) = dv(t)\,/\,dt$:

$$a(t) = g\,\exp(-\,t\,/\,\tau) \ . \qquad (5.9)$$

<u>Example:</u> $D_p = 100\ \mu m = 10^{-4}\ m$; $\rho_P = 1\ g/cm^3 = 10^3\ kg/m^3$; $\eta_A = 18.2 \times 10^6\ kg/(m\ s)$; $\lambda_A = 68\ nm = 6.8 \times 10^{-8}\ m$ and $C_c = 1.0178$ (value for 298 K and 1 atm). At sea level one obtains: $v_{PSC} = 1078\ m/h = 0.2994\ m/s$; $\tau = v_{PSC}/g = 0.0305\ s$ and $a(t{=}0) = g$. For an altitude h = 10 km and the corresponding parameters from Literature one obtains the following values: $v_{PSC} = 1350\ m/h = 0.375\ m/s$ and $\tau \approx 0.038\ s$ (calculated by P. Brüesch).

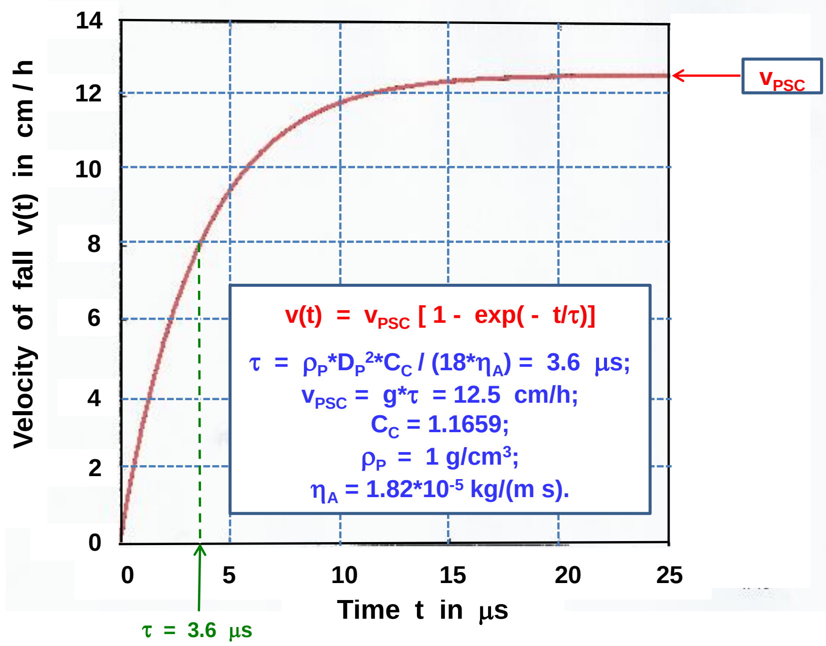
229

Velocity of fall v(t) for a particle with diameter $D_p = 100\ \mu m = 10^{-4}\ m$



230

Velocity of fall v(t) for a particle with diameter $D_P = 1\ \mu m = 10^{-6}$ m



231

Asbestos Minerals - Morphology

White Asbestos or Chrysotile, also known as fibrous serpentine, is a member of the mineral family of serpentines. The composition of the sheet silicate is

$Mg_3\,Si_2\,O_5\,(OH)_4$.

Ribeckite or Crocidolite has essentially a blue colour and is therefore also referred to as «Blue Asbestos» (Blaueisenstein). It has a fibrous crystal structure and its chemical composition is

$Na_2[Fe_3^{2+}\,Fe_2^{3+}]\,Si_3\,O_{22}\,(OH)_2$

White Asbestos or Chrysotile takes its name from its golden brown colour

Fibrous Ribeckite or Crocidolite

232

Asbestos: Properties, early Applications and Problems

Asbestos is a collective term for various, naturally occurring fibrous silicate minerals. There are different minerals belonging to Asbestos. One important modification is Chrysotile, also called «White Asbestos». Chrysotile was used most extensively for technical applications, to a large part for concrete reinforcement fibres in Asbestos cement.
Asbestos has been called the «miraculous fibre». The reason for this name is its great mechanical strength, its heat- and acid resistance, its excellent thermal insulation and the fact that it can be interwoven.

Due to these properties, Asbestos could also be used in the shipbuilding industry for navigation, for heat insulation in construction industry and for car-tyre industry. In the mean time, however, the severe health risks originating from working with Asbestos have been clearly recognized and since 1990, Asbestos is forbidden in many countries, for example in the EU and in Switzerland. Today, Asbestos is a severe disposal problem.

Fibre length : 5 μm
Fibre diameter: < 3 μm
Density : 2.53 – 2.65 g/cm^3
Tensile strength : larger than steel wire
Chemical resistance: very good

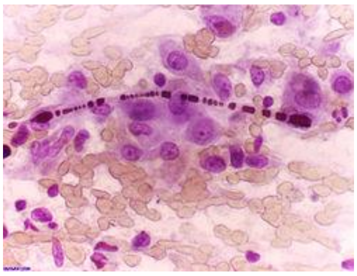
233

Asbestos – related diseases: Asbestosis - Lung cancer

Asbestosis is a lung disease and belongs to the so-called Pneumoconiosis (Silicosis). It is caused by inhaled asbestos dust and for this reason, the utilization of Asbestos is forbidden in Austria and Switzerland since 1990, in Germany since 1993 and in the EU since 2005.

Pathophysiology

Fibrosis: Depending on the duration of exposition and concentration of the Asbestos fibres and on personal disposition, inhaled asbestos dust gives rise to fibrosis and lung parenchyma after a delay of 15 to 20 years.
Lung cancer: After a latency period of 25 – 40 years, Asbestosis can lead to lung cancer. Cancer of visceral pleura: Development of a Mesothelioma, a malignant tumour of the pleura (about 20 to 40 years after exposition).



Asbestos fibres and lung carcinoma; medical inspection by Cytodiagnostics

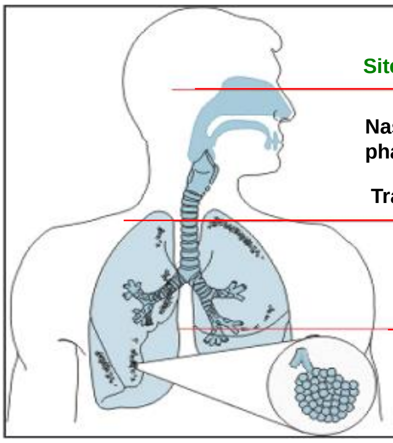
Asbestos removal of a slated roof.

234

Nanoparticles pollutants

Ultrafine Particles (UP) are smaller than 0.1 µm, i.e. smaller than 100 nm. The particle size is decisive of whether a dust particle can be enhaled and where the deposition takes place in the respiratory tract.

Particles with a size of 10 µm (PM10, pp 223, 224) are deposited to about 50 % in the bronchia. With dereasing size of the particles, the ratio of particles which reaches the pulmonary alveoli increases. There exist indications that particles of 1 µm and ultrafine particles smaller than 0.1 µm (100 nm) are penetrating through the Alveoli blisters and are reaching the blood.



Sites of attack	Particle diameter D_p
Nasal area and pharyngeal space	5 – 10 µm
Trachea	3 - 5 µm
Bronchia	2 - 3 µm
Bronchioles	1 – 2 µm
Pulmonary alveoli	0.1 – 1 µm (100 - 1000 nm)

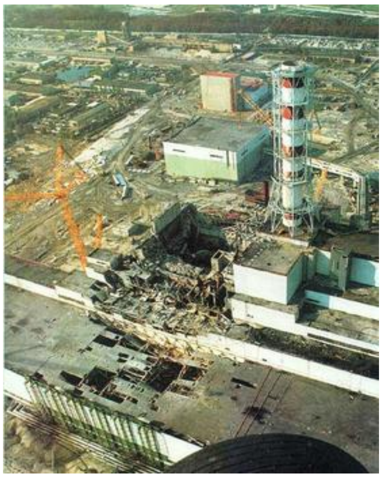
Deposition of particulate matter in the human respiratoty tract

235

The Chernobyl Disaster of the Nuclear Reactor

The Chernobyl disaster was a catastrophic nuclear accident that occurred on 26 April 1986 at the Chernobyl Nuclear Power Plant in Ukraine. An explosion and fire released large quantities of radioactive particles into the atmosphere, which spread over much of the western USSR and Europe. The Chernobyl disaster was one of the worst nuclear power plant accident in history in terms of causalities and cost, and it is one of only two classified as a lebel 7 event (the maximum classification). (The other being the Fukushima nuclear disaster in 2011).

The disaster began during a systems test on Saturday, 26 April 1986 at reactor number 4 of the Chernobyl plant, which is near the city of Pripyat. There was a sudden and unexpected power surge, and when an emergency shutdown was attempted, this led to rupture of the reactor vessel and to a series of steam explosions. The resulting fire sent a plume of highly radioactive fallout into the atmosphere and over an extensive geographical area including Pripyat. The plume drifted over larger parts of the western Soviet Union and Europe. From 1986 to 2000, 350’400 people were evacuated and resettled from the most severely contaminated areas of Belarus, Russia and Ukraine. According to official post-Soviet data, about 60% of the fallout landed in Belarus.



Nuclear reactor after the disaster- Reactor 4: Center

236

Chernobyl - Explosion of the Nuclear Reactor and Victims

Death cloud over Nuclear Reactor 4 in Chernobyl

Terrible victims of the Reactor disaster

The estimated total death toll of the Chernobyl disaster varies extremely: Between 1984 and 2004 it ranges between about 4'000 and 985'000 (!!) depending on the source!

Invalids: in Belarus, Russia and Ukraine: ≈ 148'000 (!)

Land affected: ≈ 63'000 square miles or ≈ 163'000 km^2 (!)

(see also Appendix p. 5-A-4-5 for more information)

237

5.5 Secondary Pollutants

Secondary pollutants such as Ozone (O_3) are those that are not directly emitted from a source but form when primary pollutants react chemically in the atmosphere (s. Ref. R.5.5.1).

Other Secondary Pollutants are:

- Peroxyacethyl nitrate: $C_2H_3NO_5$
- Hydrogen peroxide: H_2O_2
- Aldehydes: R – CHO

In the following we consider only Ozone, O_3. Ozone is ambivalent, i.e. it has both, positive and negative properties:

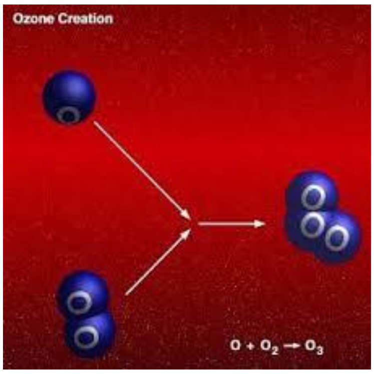
Positive: Screening of dangerous UV- radiation from the Sun

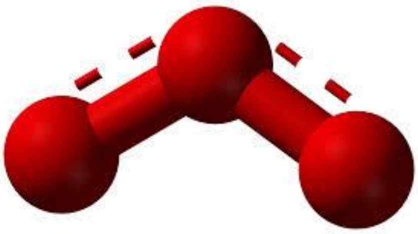
Negative: Ground-level Ozone irritates breathing and is an important Secondary Pollutant.

In Chapter 2, pp 22, 23, 37 - 42, we have already discussed some aspects of Ozone. Ozone is ambivalent: Without stratospheric Ozone, terrestrial life would not be possible; on the other hand, ground-level Ozone is a pollutant. For this reason, we include here some complementary information.

238

Ozon O_3

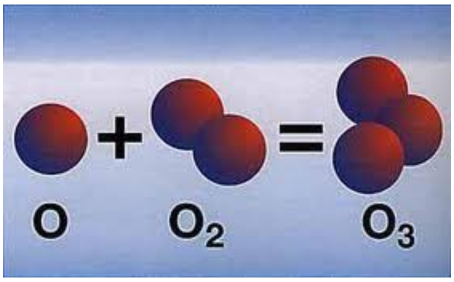




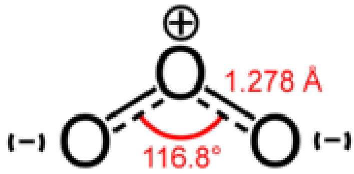
Ozone is ambivalent: In the Stratosphere it is an important protection from the dangerous UV- radiation (s. pp 241 – 243). On the other hand, ground-level Ozone is an important secondary pollutant for human beings (s. p. 244).

239

Ozon O_3 : Molecule and molecular properties



Formation of O_3-molecules from atomic (O) and molecular oxygen (O_2)



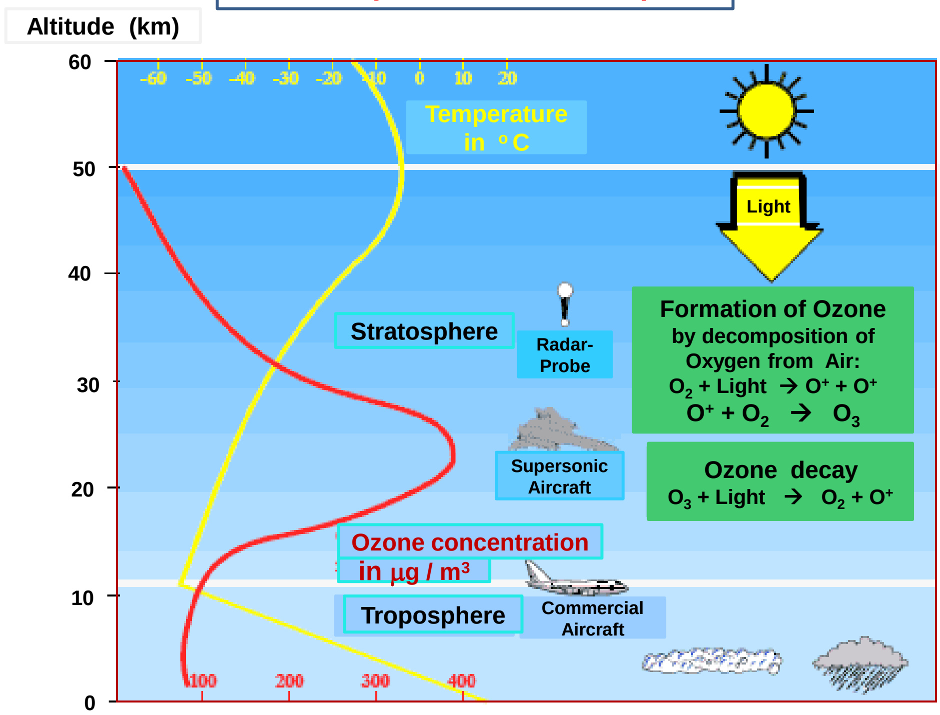
Sructure of the O_3- molecule with bond lengths and bond angles. O_3 is a polar molecule with a dipole moment of 0.534 D. (1 D = Debye ≈ 0.208 e Â; e = charge of electron, 1 Â = 1 Ângstöm = 10^{-8} cm)

Ozone (O_3) is a molecule containing three oxygen atoms. At normal conditions, traces of Ozone gas decay within a couple of days into the dimeric stable molecules O_2. On the one hand, O_3 is a strong oxidizing agent which can be harmful for living beings On the other hand, the Ozone layer present in the lower Stratosphere protects human beings from damage caused by the harmful UV radiation of the Sun (see p. 241).

O_3 is a very strong oxidizing agent (much stronger than O_2) and is used for many industrial goods and consumer products. But on the other hand, its large oxidation potential is harmful for the mucosae and the tissues of the respiratory tract of humans and animals. In addition, also plant tissues are damaged if exposed to concentrations larger than 100 ppb (p. 244). For this reasons, Ozone present near the ground is a severe danger and a pollutant for respiration

240

Ozone Layer in the Stratosphere



241

Without Ozone no Life

The Ozone contained in the Ozone layer filters out the UV- radiation emitted by the Sun in the wavelength region between 200 nm and 315 nm; the intensity maximum is located at about 250 nm (1 nm = 10^{-9} m). This absorption of the UV- radiation by Ozone is of prime importance for live on Earth.

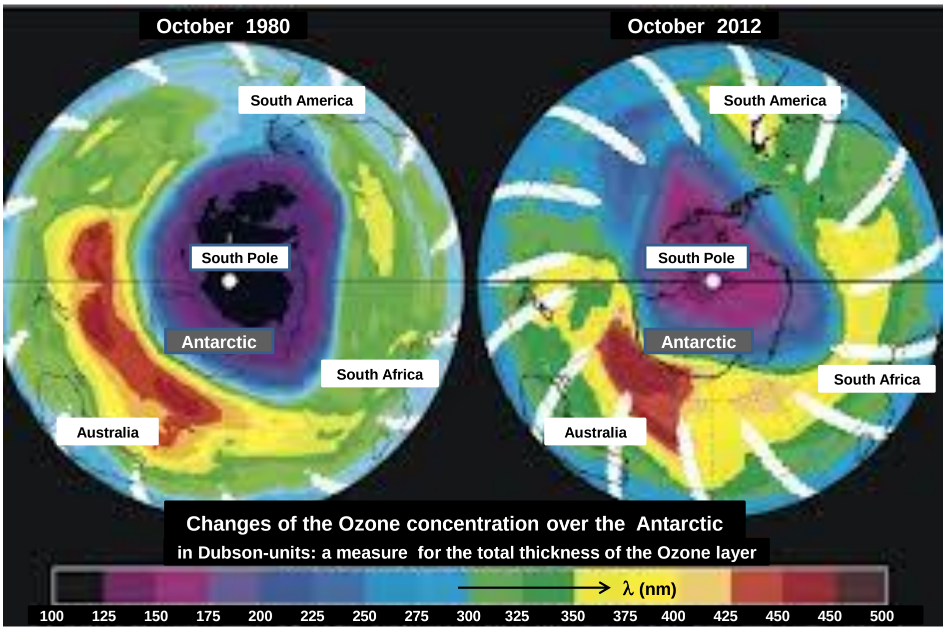
It should be mentioned that already the natural oxygen molecules O_2 and nitrogen molecules N_2 do absorb UV- radiation with wavelengths smaller than 200 nm. But the O_3 – molecules of the Ozone layer absorb in addition the UV-C radiation (200 nm – 280 nm) and the whole UV-B band (280 – 315 nm). The small remaining part of UV-B, which still reaches the surface of the Earth is responsible for sunburn as well as for the decomposition of the DNA in living tissues of humans, animals and plants.

The most important effect of Ozone in the medium UV-B range at 290 nm is drastically apparent if one realizes that the radiation intensity in the Stratosphere above the Ozone layer is about 350 million times larger than at the surface of the Earth. Despite of this enormous reduction of the UV-B radiation, a small intensity of UV-radiation still reaches the surface of the Earth. On the one hand, this UV- radiation is responsible for sunburn, but on the other hand it also enables the production of Vitamin B12 for humans.

The Ozone layer has a very small effect for the absorption of the long wavelength radiation of UV-A (315 – 400 nm), but this radiation neither produces sunburn nor does it destroy the DNA.

242

Temporal development of Ozone hole (see also Chapter 2, p. 41)



There is evidence for the fact that the size of the Ozone hole in the Antarctic reduces slowly and that it could be recovered by the year 2050.

243

Ground- level Ozone

Ozone is ambivalent, i.e. it has positive and negative effects (pp 240 – 243). While the stratospheric Ozone is protecting us against harmful UV-radiation, ground- level Ozone is usually harmful for humans, animals and plants.

At sunny and windless periods in summer, the Ozone pollution increases. This pollution is harmful for both, human health (Asthma, other respiratory problems, irritation of nucous, etc.) as well as for vegetation, buildings, materials and the climate.

Ground-level Ozone is formed by the two following precurser pollutants: nitrogen oxides (NO_x : pp 200, 201) and volatile organic compounds (VOC: pp 210, 211); under the influence of sunlight, Ozone and other secondary pollutants are formed.

Plants damaged by Ozone (left)
and healthy plants (right)

Main contributers for these precursor stages are:

- Motorised traffic (most important)
- Industry and commerse

EU-benchmarks for O_3- concentrations c:

- No danger for $c < 110\ \mu g/m^3$
- For one-hour mean values of $c \geq 180\ \mu g/m^3$: information of the population.
- For $c \geq 200\ \mu g/m^3$: Respiratory tract irritation.
- For one-hour mean values of $c \geq 360\ \mu g/m^3$: warning the population, since for larger con-centrations there is danger for human health.

244

Appendix - Chapter 5

5-A-0

Air pullution in Beijing

The air pollution in China takes on a dramatic scale !

People wear masks on a day with Air Quality Index (AQI) of 320 and larger !

For AQI- values and ranges see pp 192 and 5-A-1-2

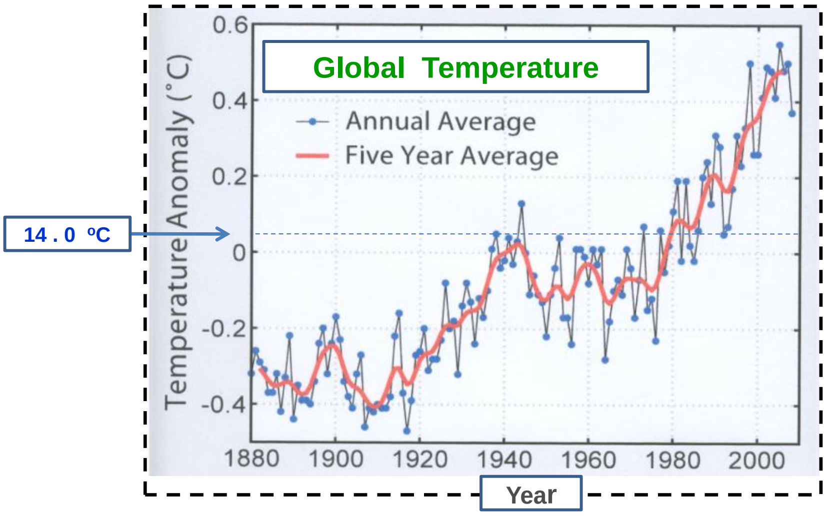
5-A-1-1

Air Quality Index (AQI)

The AQI converts concentrations of fine particles (Particulate Matter (PM)) to a number on a scale ranging from 0 to 500. Air quality conditions range from «Good» (0 < AQI < 50) over «Unhealthy» (151 < 200) to «Hazardous» (301 < 500). [At December 12, 2013, an AQI-value of 755 has been measured! (s. p. 192)].

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

5-A-1-2



Global warming is unambiguous today. This conclusion follows from observations of the global increase of the average temperature of air and oceans, the melting of ice and snow over large areas, as well as from the global increase of Sea levels.

The most important part of the increase of the mean temperature observed since the middle of the 20 the century is due (with a high degree of probability) to the observed increase of the concentration of anthropogenic greenhous gases, in particular CO_2 which accounts for about 60 %.

5-A-2-1

Gas warfare of World Ware I (1914 – 1918)

Victims of gas gas warfare

The Gas warfare of World War I was the beginning of the utilisa-tion of chemical weapons with **chlorine gas** (Cl_2) by German forces at Aprile 22, 1915. The famous chemist and later Nobel Price winner (!) Fritz Haber suggested already by the end of 1914 to employ this lethal gas. The equally famous Nobel-Price winner Walther Nernst was also substantially involved in the study of the scientific aspects of this weapon. In addition to chlorine gas, the much more toxic **phosgene gas**, (CCl_2O), was also used.

The German Chief of General Staff, Erich von Falkenhayn, and the chemist and industrialist Carl Duisberg were strongly involved and responsible for the application of toxic gases.

As a response of the toxic gas attacks of the Central Powers (Germany, …) the oposing military allians (the «Triple Entente»: (England, France, Russia, …) also used toxic gases.

It can be assumed, that out of the 10 millions deads of World Ware I, about 90'000 victims were killed by gas warfare !

Fritz Haber

Walter Nernst

Erich Falkenhayn

Carl Duisberg

5-A-3-1

Zyklon-B: Poison for Mass Destruction of Nazi-Germany

The deadly effect of hydrogen cyanide, HCN, has been used in the National Socialist death camps as for example Auschwitz-Birkenau for murdering millions of people (Holocaust). The HCN- concentrations (Zyklon B) in the Gas Chambers were different depending on the special conditions, but they were always larger than 300 ppm ≈ 0.332 g/m^3 = 332 mg/m^3 HCN at 25 ^{0}C. (s. Appendix 5-A-3-3).

Gas Chamber of Nazi in Auschwitz - Birkenau

Since the liquid evaporates already at room temperature, the vapours are easily enhaled or are difusing through the skin. Zyklon B blocks the cellular respiration. In case of an intoxination, the cells are unable to convert the vital oxygen.

Large concentrations are causing rapid breathing, paralysis, fainting, convulsions and respiratory arrest. A concentration of 300 ppm for several minutes is deadly.

Zyklon B in a suitable substrate, for example in diatomite

Label of a 500 g can used in Auschwitz

5-A-3-2

Concentrations of foreign gas in Air: Conversion from ppmv to mg/m^3

Definition: 1 ppmv = 1 parts per million by volume:

1 ppmv = 1 μL_{FG} / 1 L_A ; (FG = Foreign Gas; A = Air) 1)

Ideal gas law: $P_A*V_{FG} = n_{FG}*(R*T_A) = (m_{FG} / M_{FG})*(R*T_A)$ 2)

P_A = Air pressure; V_A = Air volume; V_{FG} = volume of foreign gas; R= universal gas constant

m_{FG} = mass of foreign gas; M_{FG} = Molar mass of foreign gas; $n_{FG} = m_{FG}/M_{FG}$;

From 1) and 2): ppmv = $V_{FG} / V_A = [(R*T_A) / (P_A*V_A)]*(m_{FG} / M_{FG})$ 3)

or: $(m_{FG} / V_A) = (M_{FG}*P_A) / (R*T_A)*$ ppmv 4)

<u>Example: Hydrogen cyanide (HCN)</u> (s. p. 5-A-3-2)

M(HCN) = 27.0253 g; T = 298 K (25 ^{0}C) ; P_A = 1 atm;

R = 8.314'463 J/(mol K) = 8.207*10^{-5} (atm*m^3) / (mol*K) ;

Let: c(ppmv) = 300*10^{-6} (s. p. 5-A-3-2) for HCN;

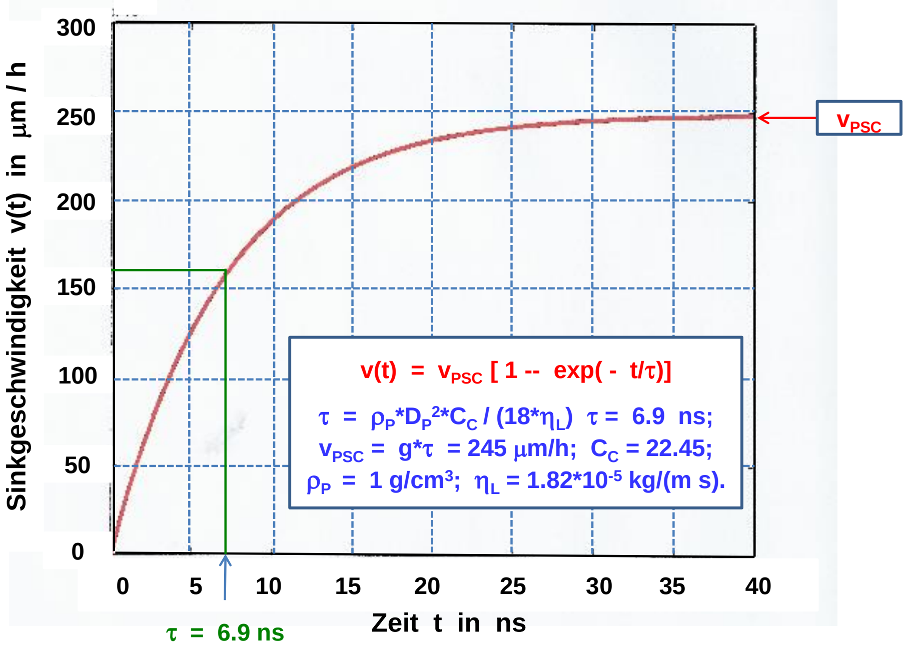
→ c(mg(m^3) = [27.0253 / (8.207*10^{-5}*298)]*300*10^{-6} ;

It follows: c(HCN) = 0.332 g / m^3 = 332 mg / m^3

In the mass destruction chambers of the Nazi (p. 5-A-3-2), such a concentration was already deadly !

5-A-3-3

Sinkgeschwindigkeit v(t) für Partikel mit Durchmesser D_P = 0.01 µm = 10^{-8} m



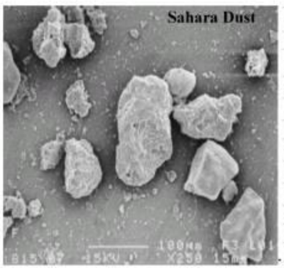
5-A-4-1

Sahara – Staub: Herkunft und Partikelgrössen

Ueber 50% des globalen troposphärischen Aerosols sind Mineralstaubpartikel, die hauptsächlich aus den Wüstenregionen wie der Sahara (Bild links), der Gobi oder anderen ariden Gebieten der Subtropen stammen. Der Eintrag von Staub in die Atmosphäre ist abhängig von der Korngrössenverteilung am Boden, der Rauigkeit des Geländes und der Bodenfeuchte, sodass erst oberhalb einer kritischen Windgeschwindigkeit Mineralstaub vom Boden aufgewirbelt wird. Mit hohen Windgeschwindigkeiten einhergehende bodennahen Turbulenzen werden Partikel vom Erdboden schnell in grosse Höhen und danach oft auch über weite Strecken transportiert. Die chemische Zusammensetzung ist aus dem Bild rechts ersichtlich.

Mit ca. 1.8 Milliarden Tonnen pro Jahr ist Winderosion von Mineralstaub die stärkste Aeorsolquelle der nördliche Hemisphäre; fast zwei Drittel davon ist Sand aus der Sahara. Wenn die feinsten Partikel mit der Grösse des Schluffs (Korngrösse von 0.002 bis 0.063 mm oder 2 µm bis 63 µm) in dichten Wolken hoch in die Luft gehoben werden, nennt man das Phänomen einen Staubsturm. Dieser ist nicht zu verwechseln mit einem Sandsturm, bei dem die grösseren Sandpartikel (Korngrössen 0.002 mm bis 2 mm) verfrachtet werden. Bei diesen wird eine niedrige Wolke aus bewegtem Sand gebildet, der lediglich wenige Zentimeter bis maximal 2 m vom Boden in die Höhe reicht.

Saharastaub in Nordafrika vom 4. 4. 2014



Dust Composition

Sahara Dust, Fiume 1901-03-10

Component	% Mass
SiO_2	49.5
Al_2O_3	12.1
CaO	11.5
Fe_2O_3	10
CO_2	9
Mn_3O_4	2
MgO	0.4
Organics	5.5
Traces	0.2

Sahara-Staub und Sahara-Sand

5-A-4-2

Sahara – Dust in Austria and Germany

Sahara–Dust in Tyrol

Seefeld in the Federal Province Tyrol (Austria) at the afternoon of February 21, 2004. The Sahara dust darkened the sky.

(Picture from Friedrich Föst)

Visit from North Africa

«A glaring red Sky, loaded with finest sand particles»: This was the appearance of the Sunrise on April 3, 2014 over Remscheid (Governorate Düsseldorf in North-Rhine Westphalia). The darkening was due to a low-pressure area which extended from England to Marocco where it lifted the desert sand.

5-A-4-3

Chernobyl: Radioactive contamination Areas from Fallout

Here, we confine ourselves to the nuclear Fallout caused by the catastrophe. It was the Graphite-fire in the Reactor that released most of the radioactive particles into large altitudes of the atmosphere (1500-10'000 m).

The clouds containing tje radioactive Fallout have initially been distributed over large parts of Europe and finally over the whole Northern Hemisphere. Changing air streams drove the clouds to Scandinavia, then over Poland, Chechia, Austria, Southern Germany and Northern Italy. A third cloud reached the Balkans, Greece and Turkey. Depending on the regional rainfalls, the ground was contaminated to different degrees. The quoted data indicate the start of the radioactive Fallouts.

The Sievert (unit symbol Sv), according to the Swedish physician and physicist Rolf Sievert, is a measure for the radiation dose. It is used for the determination of the radiation load of biological organisms and for the evaluation of radiation risks; 1 mSv = 0.001 Sv.

- 0.01 – 0.03 mSv: Dose obtained by an X-ray of the thorax.
- 10 – 20 mSv: Dose obtained from a Computer Tomography of an adult.
- 1'000 mSv: About 10% of the exposed people are developing cancer and Leukemia.
- 3'000–4'000 mSv: without medication: 50% of exposed persons are dying.
- > 8'000 mSv: Death within very short times after short-time radiation exposure.

some examples

5-A-4-4

References: Chapter 5

R-5-0

5.1 Air Contamination - General

R.5.1.1 p. 192: Air pollution – General

a) Air quality index: http://en.wikipedia.org/wiki/Air_qualizy_index
b) Beijing Air Pollution Exposes China's Health & Environmental Risks
http://www.globalsherpa.org/shona-air-pollution-health-environment
c) Luftverschmutzung: http://de.wikipedia.org/wiki/Luftverschmutzung
d) Bild: «Luftverschmutzung in Peking: Atmen kann tödlich sein» – Bernhard Zand (Spiegel Online)
http://www.spiegel.de/wissenschaft/natur/feinstaub-pekings-luftverschmutzung-erreicht-drastische-werte-...

R.5.1.2 p. 193: Form and Sources of Air Pollution

a) Outdoore Air Pollution - European Lung Foundation - ELF
http://www.europeanlung.org/en/lung-disease-and-information/risk-factors/outdoor-air-pollution
b) Indoor Air Pollution - European Lung Foundation - ELF
http://www.europeanlung.org/en/lung-disease-and-information/risk-factors/indoor-air-pollution
c) left: Arten und Quellen der Luftverschmutzung – European Lung Foundation (ELF)
Forms and Sources of Air Pollution (ELF)
www.de.european-lung-foundation.org/17473-arten-und-quellen-der-luftverschmutzung.htm
d) right: Arten der Luftverschmutzung - Changes of Natural Composition of Air :
(Arranged and adapted to English by P. Brüesch)

R.5.1.3 p. 194 : Origin and Sources of Pollutants
Table from Reference R.5.1.2 c) - (Translated from German to English by P. Brüesch)

R.5.1.4 Luftverschmutzung: Ein Leitprogramm für den Geographieunterricht
ETH – Institut für Verhaltenswissenschaften
Geographisches Institut - [PDF] www.edu.org/Umweltverschmutzung
[Herausgegeben von S. Reinfried und J. Roth]

R-5-1

5.2 Primary Air Pollution

R.5.2.0 p. 195: Definition of Primary Air Pollutants
Primary Pollutants: (pp 195 – 220) ; Secondary Pollutants: pp 221 - 233)

a) Air Pollution - http://en.wikipedia.org/wiki/Air_pollution
b) What is the difference between primary and secondary Pollutants ?
http://www.ask.com./science/difference-between-primary-secondary-pollutants-4219898c68d9019f
c) Primary Pollutants - http://apollo.lsc.vsc.edu/classes/met130/notes/notes/chapzer18/primary.html
d) Primary & Secondary Pollutants
http://www.greenfacts.org/glossary/pqrs/primary-pollutant-secondary-pollutant.htm
e) Unit 11: Atmospheric Pollution // Section 3:Primary Air Pollutants
http://www.learner.org.courses/emvsci/unit/text.php?unit=11&secNum=3 :
f) What are the Primary and Secondary Air Pollutants ?
http://www.publishyourarticles.net/knowledge-hub/environmental-studies/
whate-are-the-primary-amd-secondary-air-pollutands

R.5.2.1 pp. 196 - 197: Carbondioxide – CO_2

a) Carbon dioxide - http://en.wikipedia.org/wiki/Carbon_dioxide
b) Respiratory center - http://en.wikipedia.oth/wiki/Tespiratory_center
c) Kohlenstoffdioxid - http://de.-wikipedia-org/wiki/Kohlenstoffdixid
p. 196: Pictures of «Levis structure of CO_2» from: www. google ch/search
p. 196: Picture of «Space-filling model» of CO_2: from: www.google.ch/search
p. 197: Picture of «Carbone dioxide toxicity» from Reference R.5.2.1 a)

R.5.2.2 p. 198: Carbon monoxide – CO

a) Carbon monoxide http://en.wikipedia.org/wiki/Carbon_monoxide
http://en.wikipedia.org/wiki/Carbon_monoxide
b) Kohlenstoffmonoxid - http://de.wikipedia.org/wiki/Kohlenstoffmonoxis
Pictures of «Space-filling model» and «Lewis structure» from www.google.ch/search
c) CO: Farblos, geruchlos und tödlich : Gefährliches Kohlenmonoxid: http://www-daserste.de/information/ratgebe-service/gesundheit/sendung/rbb/2013kohlenmonoxid-19012013-100.htm/kohlenmonoxid-19012013-100.html

R-5-2

R.5.2.3 p. 199 : Carbon monoxide - Poisoning

a) Carbon monoxide Poisoning - http://en.wikipedia.oth/wiki/Carbon_monoxide_poisoning
b) Carbon Monoxide – Health Effects - http://www.engineeringtoolbox.com/carbon-monoxide-d_893.html
Right-hand Figure: CO-concentration versus Exposure Time
c) Kohlenmonoxid (CO) - Left-hand Figure: : CO-Emissionen in Deutschland 1998: 5800 [kt/Jahr]
http://www.kfztech.de/kfutecjnik/motor/abgas/co.htm
Figure texts translated from German to Englisch by P. Brüesch
d) Farblos, geruchlos und tödlich: Gefährliches Kohlenmonoxid
http://www.daserste-de/information/ratgeber/gesunfheit/sendung/rbb//2013/Kohlenmonoxid-19012013-100.html

R.5.2.4 p. 200: Nitrogen oxides NO_x and Nitrous oxide N_2O

a) NO_x - http://en.wikipedia.org/wiki/NOx
b) Nitrogen dioxide: NO_2 - http://en.wikipedia.org/wiki/Nitrogen_dioxide
c) Nitric oxide: NO - http://en.wikipedia.org/wiki/Nitric_oxide
d) Nitrous oxide: N_2O - http://en.wikipedia.org/wiki/Nitrous:oxide
e) Stickoxide - http://de.wikipedia.org.wiki/Stickoxide

R.5.2.5 p. 201: NO_x- Toxicity and Emissions

a) Nitrogen Dioxide Toxicity - http://emedicine.medscape.com/article/302133-overview
Author: Bader Kamanga - Updated April 28, 2014 . Medscape: Drugs, Diseases & Procedures
b) Health and Environmental Impacts of NOx
http://www.extraordinaryriadtrip.org/research-library/air-pollution/understanding-air-pollution/nitrogen-dopxide/---
c) Nitrogen dioxide - http://en.wikipedia.otg/wiki/Nitrogen_dioxide
d) Stickoxide (NO_x) - http://www.kfztech.de/kfztechnij/motor/abgas/nox.htm
Figure of NO_x – Emission in Germany 1998
(Figure description translated from German to English by P. Brüesch)
e) Luftverschmutzung: Ein Leitprogramm für den Geographieunterricht (1995)
Herausgegeben von S. Reinfried und J. Roth
ETH Institut für Verhaltenswissenschaft – Geographisches Institut
[PDF] www.educ.org/Umweltverschmutzung
f) Stickstoffoxid (NO_x) – Emission
http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/publc/thema. do?nodeldent=3573
g) Rauchgasentstickung . http://de.wikipedia.org/wiki/Rauchgasentwicklung

R-5-3

R.5.2.5 (cont.)

h) Untersuchungen zur Rolle der Vegetation beim Austausch von Stickstoffdioxid mit der Atmosphäre
Kesselmeier, Jürgen - Max-Planck-Institut für Chemie, Mainz
Ueber die eindeutige Rolle der Vegetation als Senke für Stickstoffdioxid (NO_2)
Studies of the role of vegetation exchanging nitrogen dioxide with the armosphere
http://www.mpg.de/4996506/Stickstoffdioxid?c=5732389

i) Tabakrauch - http://www.bag.admin.ch/themen/chemikalien/00238/01355/01358/10340/index.html?lamg=de

k) Stickstoffdioxid NO_2 - «Wirkung auf den menschlichen Körper», NO_2 ist im Zigarettenrauch enthalten und ist ein stark toxisches Gas ! - http://www.seilnacht.com/Chemie/ch_no2.htm

R.5.2.6 p. 202: Methane – CH_4

a) Methane - http://epa-gov/climatechange/ghfwmissions&gases/ch4.html
http://en.wikipedia.org/wiki/Methane - (with molecucar structure)
b) Methane Emissions - http://en.wikipedia.org/wiki/Methane - (with molecucar structure)
c) Volcanic Gases - http://www.geo.ntu.edu/bolcanoes/hazards/primer/gas.htmk
d) Natural gas (with molecucar structure) - http://en.wikipedia.org/wiki/Methane
e) Methan - http://de.wolopedia-org/wiki/Methan
f) Erdgas - http://de.wikipedia.org/wiki/Erdgas

R.5.2.7 p. 203: Methane - Dangers

a) Reference R.5.2.6 a) under Safety
b) Methane Safety - http://www l.agric.gov.ab.ca/$Departement/deptdocs.nsf/all/agdex903
c) Methane Sources – Rice Paddies d) - Nassreisfelder sind ein Entstehungsort für Methan
http://www.ghgonline.org/methanerice.htm
d) Flammability diagram (of Methane) - http://en.wikipedia.org/wiki/Flammability_diagram
e) Flash point - http://en.wikipedia.org/wiki/Flash_point
f) What are volcanic methane explosions?
http://khno2.com/2014/1/01/what-are-volcanic-methane-explosions/

R.5.2.8 p. 204: Sulfur oxides – General

a) Sulfur oxide - http://en.wikipedia.org/wiki/Sulfur_oxide
b) Sulfur oxides (SO_x) - Swedish Pollutant Release and Transfer Register
http://uosalappisiffror.naturvardsverket.se/en/Substances/Other-gases/Sulphur-oxides/
c) SULPHUR OXIDES (SO_x) - http://dwb.unl.edu/teacher/nsf/c09/c09links/www.casahome.org/sulphur.htm

R-5-4

R-5-2-8 (cont.)

d) Sulfur dioxide - http://en.wikipedia.org/wiki/Sulfur_dioxide
e) Schwefeloxide - http://de.wikipedia.org/wiki/Schwefeloxide - (contains Table of p. 204 listing SO_x – molecules)
f) Disulfur monoxide - http://en.wikipedia.org/wiki//Disulfur_monoxide
g) Disulfur dioxide - http://en.wikipedia.org//wiki/Disulfur_dioxide
h) Schwefeldioxid - http://de.wikipedia-org/wiki/Schwefeldioxid
i) Schwefeldioxid http://www.cumschmidt.de/sm_so2.htm // http://www.cumschmidt.de/sm_so2.htm

R.5.2.9 p. 205: Sulfur dioxide and Sulfuric acid

a) See References d), h), and i) of p. R.5.2.8
b) Air Pollution from Sulfur Dioxide - https://www.tceq.texas.gov/airquality/sip/criteria-pollutants/sip-so2
c) Sulfur Dioxide - http://www.cleanairtrust-org/sulfurdiaxide.html
d) About Sulfur Dioxide - http://naei.defra.gov.uk/overview/pollutants?pollutant_id=8
e) What is the damage caused by sulphur dioxide (SO_2) by human beings and the environment?
http://www.mma.gob.cl/retc_ingles(1316/w3-articke-51518.html
f) Sulfuric acid - http://en.wikipedia.org/wiki/Sulfuric_acid
g) Sulfuric acid - http://www.britannica.com/EBchecked/topic/572815(sulfuric-acid
i) Schwefelsäure – H_2SO_4 - https://de.wikipedia.rg/wiki/Schwefel%C3%A4ure
(Molekülstrukturen von SO_2 und H_2SO_4: s. unter www.google.ch/search - Bilder)

R.5.2.10 p. 206: Sulfur trioxide

a) Sulfur trioxide - http://en.wikipedia.org/wiki/Sulfir_trioxide
b) Sulfur Trioxide & Sulfuric Acid (H_2SO_4)
http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxic-47
c) Schwefeltrioxid - http://de.wikipedia.org/wiki/Schwefeltrioxid
(Molekülstrukturen von SO_3: s. unter www.google.ch/search - Bilder)
d) Schwefeltrioxid - http://www.cumschmidt.de/sm_so3.htm

R.5.2.11 pp 207 - 208: Ammonia .(NH_3)

a) Ammonia - http://en.wikipedia.org/wiki/Ammonia
b) Ammoniak - http://de/wikipedia.org/wiki/Ammoniak
(Molekülstrukturen von Ammoniak – NH_3 und Ammoniakvergiftung - www.google.ch/search - Bilder
c) Hyperammonemia - http://en.wikipedia.org/wiki/Hyperammonia

R-5-5

5.3 Volatile Organic Compounds

R.5.3.1 p. 209: Toxic Organic Gases - Title

R.5.3.2 p. 210: Volatile Organic Compounds - VOC's - General

a) http://en.wikipedia.org/wiki/Volatile:organic_compound
b) Flüchtige organische Verbindungen
http://de.wikipedia.org/wiki/F1%C3%BCchtige_organische_Verbindungen
Figure of the Isoprene-molecule: s. Isopren – Images
Figure: zeitlicher Verlauf von VOC in der Schweiz: s. «Flüchtige organische Verbindungen» : Bilder

R.5.3.3 p. 211: Volatile Organic Compounds - Toxicity

a) Sick-Building-Syndrom - http://de.wikipedia.org/wiki/Sick-Building.Syndrom
b) Flüchtige organische Verbindungen (VOC)
http://www.bafu.admin.ch/luft/00585/10765/index.html?lang-de
c) Formaldehyde - CH_2O - http://en.wikipedia.org./wiki/Formaldehyde
d) Formaldehyd - CH_2O - http://de.wikipedia.org/wiki/Formaldehy
e) Dichlormethane - CH_2C_{l2} - http://en.wikipedia.org/wiki/Dichlormethane
f) Dichlormethan (DCM) - CH_2C_{l2} - (CAS-Nummer: 75-09-2) - Begründung zu Dichlormetan in TRGS 900
www.baua.de/cae/serviet/.../900-dichlormethan.pd
g) Tetrachlorethylene - C_2Cl_4 - http://en.wikipedia.org/wiki/Tetrachlorethylene
h) Tetrachlorethen - C_2Cl_4 - http://de.wikipedia.org/wiki/Tetrachlorethen
. i) Benzene - C_6H_6 - http://en.wikipedia.org/wiki/Benzene
k) Benzol - C_6H_6 - http://de.wikipedia.org/wiki/Benzol

R.5.3.4 p. 212: Hydrogen Cyanide (HCN) in the Atmosphere

a) Atmospheric Hydrogen Cyanade (HCN): Biomass Burning Source, Ocean Sink ?
Quinbin Li, Daniel J. Jacob, Isabelle Bey, Robert M. Yantosca; Y. Zhao, Y Kondo, and J. Kondo
Geophysical Research Letters, Vol. 27, No.3, pp 357 – 360, February 1, 2000
b) What drives the observed variability of HCN in the Troposphere and lower Stratosphere ?
Q. Li, P.I. Palmer, H.C. Pumphtey, P. Bernath, and E. Mahleu
Atmospheric Chem. Phys. 9, pp 8531 – 8543, 2009

R-5-6

R.5.3.4 (cont.)

c) Hydrogen cyanide: Deadly HCN gas in fire smoke threatens responders / Fire Fighting in Canada
http://www.firefightningincanada.com/health-and-saftey/hydrogen-cyanide-june-2007-1254
d) Brandgase - www.toxcenter.org/stoff-infos/brandgase.pdf - HCN im Brandgas
e) Chemical Studies of Tobacco Smoke - Gas Chromatographic Determination
of Hydrogen Cyanide and Cyanogen in Tobacco Smoke - http://jat.oxfordjournals/1/1/38.abstract
f) Tabakrauch - http://de.wikipedia.org/wiki/Tabakrauch - Blausäure im Tabakrauch
g) Cyanwasserstoff - https://de.wikipedia.org/wiki/Cyanwasserstoff
(Vergiftung der Juden durch den Nationalsozialismus in Auschwitz-Birkenau – Holocaust)
h) Linear Molecular Geometry
[Containing BeH_2, CO2; and HCN] - Figure of HCN
http://chemiwiki.uedavis.edu/Inorganic_Chemistry/Molecular_Geometry/Linear_Molecular
i) Blausäure (Cyanwasserstoff) HCN - http://www.seilnacht.com/Chemie/ch_hcn.html
k) Noxes: http://de,wikipedia.org/wiki/Noxe

R.5.3.5 p. 213: Persistant Organic Compounds - POC's

a) Persistent organic pollutant
http://en.wikipedia.org/wlki/Persistent_orga/wiki/Persistent_organic_pollutant
b) Persistant Organic Pollutants: A Global Issue, A Global Response
http://www2.epa.gov/international-cooperation/persistent-organic-poööutants-global-issue-göobap-response
c) [PDP¨ Persistente Organische Verbindungen (POP's)
krimhild.uff.uni_bremen.de/.../POP_de.pd...
d) Langlebige organische Schadstoffe - http://de.wikipedia.org/wiki(Langlebige_organische_Schadstoffe
e) p. 213: Lerneinheit 2,3,7,8-Tetrachlordibenzo-p-Dioxin-ChemgalPedia
http://www.chemgapedia.de/vsengine/vlu/de/ch&6/ac/bibliothek/vlu/dioxin.vlu/Page/vsc/de/ch/6/ac/bibliothek/dioxin

R.5.3.6 ¨p. 214: «Agent Orange» - Dioxin - Vietnam War -1

a) Agent Orange - http://en.wikipedia.org/wiki/Agent_Orange
s. also left-hand picture at p. 215: Deformed Vietnam babies
b) US helping to clean Agent Orange contaminated parts of Vietnam-Mirror Online
«A little late but greatly appreciated»: American helps to clean toxjc Agent Orange it sprayed in Vietnam War
http://www.mirror.co.uk/news/world-news/us-helping-to-clean-agent-orange-contaminated-1244991
c) Persistente organische Schadstoffe (POP) als Problemstoffe
http://www.lfu.bayern.de/analytik_stoffe/analytik_org_stoffe_pop/index.htm

R-5-7

R.5.3.7 p. 215: «Agent Orange» – Dioxin - Vietnam War – 2

a) Agent Orange - http://en.wikipedia.org/wiki/Agent_Orange
b) Monsanto's Agent Orange Still Poisoning Children in Vietnam
http://www..cheeslave.com/monsantos-agent-orange-still-poisoning-children-in-vietnam
Left-hand picture: «Agent Orange» Children Vietnam
c) Agent Orange: Dioxin, Entlaubungsmittel und der Vietnamkrieg: :
http://pharmgesch-bs.de/Seminar/agent%20orange-Dateien/agent%20orange.htm
d) Agent Orange - http://www,agentorange.vietnam,org/background/
Right-hand picture: Agent Orange – Medical preparation of malformed children

R.5.3.8 p. 216 – 217: The Seveso Disaster with Dioxin

a) Seveso disaster - http://en.wikipedia.org/eiki/Seveso_disaster
b) Seveso disaster . http://www.digplanet.com/wiki/Seveso_disaster
c) The Seveso Accident; Its Nature, Extent and Consequences
http://anmhyg.oxfordjournals.org/content/22/4/327
d) Seveso - Unglück - http://de.wikipedia-org/wiki/Sevesounglück%C3%BCck
e) MSE - Management System Engineering - Pictures on p. 216
http://www.mse-consulting.com/de/branchen/chemieindustrie.php
f) Dioxin-Skandale - Seveso - p. 217: Picture: Chloracne – victim
http://einestages.spiegel.de/static/entry/das_ieberal_fift/78322/chorakne.html
g) Als die Giftwolke kam - http://www.wissen,de/als-die_giftwolke-kam -
h) Seveso - Opfer des Chemkalienwahnsinns
http://www.greenpeac.de/themen/chemie/nachrichten/artikel/seveso_opfer_des_chemikalienwahnsinns

R.5.3.9 pp 218 – 220: The Catastrophe of Bhopal

a) Bhopal disaster - http://en.wikipedia.org/wiki/Bhopal_disaster
b) Katastrophe von Bhopal - http://de.wikipedia.org/wiki/Katastrophe:von_Bhopal
c) Reinventing memories - Photo of victims: Apocalypse: Widespread deaths - p. 219
http://santanusc.blogspot.ch/2010/12/compensating.riff.raff.html
d) Union –Carbide – Manager nach 25 Jahren verurteilt
http://www.stern.de/panorama/bhopal-katastrophe-union-carbide-manager-nach-25-jahren-verurteilt-1572075.html
e) Methyl isocyanate - http://en.wikipedia.org/wiki/Methyl_isocyanate

R-5-8

R.5.3.9 (cont.)
f) Methylisocyanat - http://de.wikipedia.org/wiki/Methylisocyanat
g) «Stadt unterm Leichentuch»
http://einestages.spiegel.de/static/topicalbumbackground/5588/stadt_unterm_leichentuch.html
h) Warren Anderson (American businessman)
http://en.wikipedia.org/wiki/Warren_Anderson_(American_businessman)
i) Warren Anderson - http://de.wikipedia.org/wiki/Warren_Anderson
k) 90 – jähriger soll für die grösste Chemiekatastrophe aller Zeiten haften
Foto rechts oben: Warren Anderson . CEO zur Zeit des Unfalls; nachher in die USA geflohen
Foto rechts unten: Warren Anderson (heute über 90 Jahre alt) lebt in der USA - http://derhoningmannsagt.wordpress.com/2011/03/25/90-jähriger-soll-für-grösste-chemiekatastrophe-aller-zeiten-haften/
l) Images of pictures of victims of Bhopal catastrophe - see Google under Images and Bilder

5.4 Particulate Matter (PM's) in the Atmosphere - Formation and Dynamics

R.5.4.0 p. 221: Primary and Secondary Air Pollutants

a) What are Primary and Secondary Air Pollutants ?
http://www,publishyourarticles.net/knowledge-hub/environmental-studies/what-are-the-primary-amd-secondary-air-pollutands
b) Unit 11: Atmospheric Pollution / / Section 4: Primary Air Pollutants
http://www.learner.org/courses/envsci/unit/text,php?unit=11&sec/Num=3
c) Unit 11: Atmospheric Pollution / / Section 4: Secondary Air Pollutants
http://www.learner.org/courses/envsci/unit/text.php?unit=11&secNum=4
d) Primary Pollutants – Research Article from Environmental Encyclopedia
http://www.boolrags.com/research/primary-pollutant-enve-02#gsc.tab=0
e) Primär- und Sekundärschadstoffe - ec.europa.eu/health/.../de/.../primaerschadstoff-sekundaerschadstoff.htm

R.5.4.1 p. 222: Secondary Air Pollutants and Particulates

a) Air pollution - http://en,wikipedia.org.wiki/Air_pollution
b) Particulates - Particulates - Wikipedia - http://en.wikipedia.org/wiki/Particulates
c) Anthropogenic and natural air pollution emissions - http://www.eoearth.org/view/article/169978/
d) Particulate Matter (PM) - Basic Information - contains Figure of p. 222 - http://www,epa.gov/pm/basic.htm
e) Feinstaub - http://de.wikipedia.org/wiki/Feinstaub
f) Aerosol - http://de.wikipedia.org/wiki/Aerosol

R-5-9

R.5.4.2 pp 223: Fine Particulates: Categorization

Feinstaub – Kategorisierung von Schwebeteilchen
(Tabel from Reference R.5.4.1 e); translated from German to Englisch by P. Brüesch)

R.5.4.3 p. 224: Particle size D_p and Knudsrn- Number Kn - Partikelgrösse D_p und Knudsen-Zahl Kn

a) Part of the Information is contained in the Article from Otto Klemen:
[PPT] – Partikel - Unweltmeteorologie – 11.. Aerosolpartikel
www.uni-muenster.de/.../env_meteo_u11aerosolphysik...
(Representation and Text adapted and translated from German to English by P. Brüesch)
b) Knudsen number - http://en.wikipedia.org/wiki/Knudsen_number
c) Knudsen – Zahl - http://de.wikipedia/wiki/Knudsen-Zahl

R.5.4.4 p. 225: Knudsen number Kn and Cunningham Correction Factor C_c

a) Particulate Matter - www.ce.udel.edu/~dentel/434/Lecture%203a.pdf
Contains also information about the relation between the Knudsen-Number Kn and the Cunningham Correction factor C_c; in addition, it contains a Figure illustrating the functions $Kn(D_p)$ and $C_c(D_p)$ versus the particle diameter D_p.
b) Particulate Matter - www.ce.udel.edu/~dentel/434/Lecture%203a.pdf - (with Figure of Slip Correction)

R.5.4.5 p. 226: Viscosity of air

a) Viscosity - http://en.wikipedia(org/wiki/Viscosity
b) Viscosity and Reynolds numbers - physikpraktika.uni-oldenburg.de/download/GPR/pdf/E_Viskositaet.pdf
c) Viskosität - http://de.wikipedia.org.wiki/Viskosität%A4t

R.5.4.6 p. 227: Stokes Law: Friction force acting on a falling spherical particle

a) Stokes' Law http://en.wikipedia.org/wiki/Stokes
b) Drag equation - http://en.wikipedia.org/wiki/_physics
c) Drag (physics) - http://en.wikipedia.org/wiki/Drag_(physics)
d) Gesetz von Stokes (mit Cunningham Korrektur-Faktor) - http://de.wikipedia.org/wiki/Gesetz_von_Stokes
e) s. Reference R.5.4.4 a) for Cunningham Correction Factor

R-5-10

R.5.4.7 p. 225, p. 227: (cont.): Remarrks to Knudsen-number $Kn(D_p)$ and Conningham-correction factor $C_c(D_P)$

f) see Reference R.5.4.4 for Figure (complemented by P. Brüesch)
g) Slip Correction Factor
http://aerosol.ees.ufl.edu/aerosol_trans/section06.htmll

This Reference contains a physically appealing comment explaining the Cunningham «Slip Correction factor C_C: «For very small particles (with a diameter of less than 1 μm), it is found that the settling velocity (Sink-geschwindigkeit) is faster than that predicted by Stokes law, Why is that?
Answer: A critical assumption of Stokes law is that the relative velocity of the gas (air molecules) right at the particle surface is 0. This is true if the medium (air) is «continuous». As the particle gets smaller, the medium is no longer «continuous» to the particle and each (gas) molecule is no longer invisible to the particle. Gas molecules moving around the particle may miss the particles which we call «slip» (ein Teilchen schlüpft durch die umgebenden Luftmoleküle). So, the velocity of the gas right at the surface is no longer 0 due to the missing collision. Since the collision is the source of drag (Reibung), the particle's settling velocity becomes faster than previously theorized due to smaller-than expected resistance. (The article cited also contains an illuminating motion- picture of both, a «continuous» air-medium with larger particles as well as for small slipping particles in a non-continuous «medium).

R.5.4.8 p. 228: Particle's setting velocity – Figure

a) Stationary setting velocity with and without Cunningham correction factor. The Figure has been constructed by P. Brüesch from Literature data (viscosity and mean free path of air, etc.) and a MATLAB- Program. The calculation has been performed für normal conditions.
b) Physical quantities:::
1) Viscosity η : : http://de.wikipedia.org/wiki/Viskosität%C3%A41
Value for air: $\eta_L = 18.2\ 10^{-6}$ kg/(m s) at 20 ^{0}C and 1 atm from:
Tabelle 2; «Stoffgrössen für trockene Luft» bei 1.013 bar und 20 ^{0}C
- www. versorgung.entsorgung.w-hs.de/---/Tabelle_2-Stoffgr…
2) Mean free path λ_A: of air . Molecules - Mean free path - http://en.wikipedia.org/wiki/Mean_free_path
λ_A = 68 nm = 6.8 10^{-8} m at 1 bar and at room temperature

R-5-11

R.5.4.9 p. 229: The velocity of fall and the acceleration of particles falling in air.

The equation (5.6) for a particle falling in air is an inhomogeneous differential equation of first order of the form: dv/dt = a(t) v + b(t) with initial conditions v(t=0) = 0. In the present case, a and b are independent on time t which simplifies considerably the solution. One obtains immediately the solution for the time-dependent velocity v(t) as quoted in equation (5.7) at p. 229)

a) Differential equation of a particle falling in air:
Part of the information is contained in the Article of Otto Klemm: Partikel-Umweltmeterologie-11…Aerosolpartikel
www.uni-muenster.de/.../env_meteo_u11aerosolphysic... (Differential equation solved by P. Brüesch)
b) «The effects of linear and quadratic drag on falling spheres: an undergraduate laboratory»
Julia P. Owen and William S. Ryu: Eur. J. Physics 26 (2005 - 9 M pp 1085 .- 1091
www.physics.emery.edu/edu~weeks/journal/9wen-ejp05.pdf
c) «Drag physics» - http://en.wikipedia.org/wiki/Drag_(physics)

R.5.4.10 p. 230: Velocity of fall v(t) of a spherical particle P with diameter D_P = 100 μm
(Calculation and Figure from P. Brüesch)

R.5.4.11 p. 231: Velocity of fall v(t) of a spherical particle with diameter D_P = 1 μm
(Calculation and Figure from P. Brüesch)

R.5.4.12 p. 232: Asbestos Minerals– General

a) Asbestos - http://en.wikipedia.org/wiki/Asbestos
b) Asbest - http://de.wikipedia.org/wiki/Asbest

R.5.4.13 p. 233: Properties - Problems

a) Classification of hydrous layered silicates - http://www.gly.uga,edu/Schroeder/geol6550CM07.html
b) Chrysotile - http://en.wikipedia.org/wiki/Chrysotile
c) Chrysotil - http://wikipedia.org/wiki/Chrysotyl
http://wikipedia.org/wiki/Chrysotyl - (Bild unten links)
d) Asbest – Vom Rohstoff zum Problemstoff (von Gunter Ries; mit Fotos von Kristallstrukturen)
www.scilogs.de/mente-et-malleo/asbest-vom-rohstoff-zum-Problemstoff

R-5-12

R.5.4.14 p. 234: Asbestosis

a) Asbestosis - http://en.wikipedia.org/wiki/Asbestosis
b) http://de.wikipedia.org/wiki/Asbestose
(Bild unten links: Asbestose und Lungenkarzinome)
c) Asbestsanierung eines Schieferdachs ((Asbestos removal of a slated roof)
http://www._rathscheck,de/Forum.fuer-Bauherren/Asbestsanierung-auch-mit-Schiefer-steuerlich-absetzbar/
(Bild unten rechts :Asbestsanierung)

R.5.4.15 p. 235: Nanoparticles - Pollutants

a) Ultrafine particle (Nanoparticles) - http://en.wikipedia.org(wiki(/Ultrafine_particle
b) Landesanstalt für Umwelt, Messungen und Naturschutz - Baden - Würthenberg
Wirkungen (von Feinstaub) auf den Menschen
http://www.lubw.baden-wuertemmberg.de/servlet/is/18796/
(Bild (retouchiert): Ablagerung von Feinpartikeln im menschlichen Atemtrakt)
(Figure – Text translated to English by P. Brüesch)

R.5.4.16 pp. 236, 237: Effect of the Chernobyl disaster

a) Chernobyl disaster
http://en.wikipedia.org/wiki/Chernobyl_disaster
b) Effects of the Chernobyl disaster
http://en.wikipedoa.org/wiki/Effects_of_the_Chernobyl_disaster
c) Chernobyl Death Toll: 985'000, Mostly from Cancer
http://www.globalresearch.ca/new-book-concludes-chernobyp-death-toll-985-000-mostly-from-cancer/20908
d) Chernobyl Q&A
http://www.friendsofchernobylcenters.org/facts.html
e) Nuklearkatastrophe von Tschernobyl
http://de.wikipedia.org/wiki/Nuklearkatastrophe_von_Tschernobyl
f) Einige wichtige Dosis- und Grenzwerte;
in: Fragen und Antworten zu Strahlenschutz-Aspekten in Japan
http://www.bfs.de/de/kerntechnik/unfaelle/fukushima/strahlenschutz_japan.html

R-5-13

5.5 Secondary Pollutants

R.5.5.1 p. 238: Secondary Pollutants - General

a) Secondary pollutants - http://science.jrank.org/pages/6028/Secondary-Pollutants.html
b) Beispiele für Sekundärschadstoffe - FACHWISSEN WEBSEITE (/)
http://www.yibacon.com(beispiele-fürsekunärschadstoffe/

R.5.5.2 pp 239 - 243 : Ozone

a) Ozone - http://en.wikipedia/org/wiki/Ozone
b) Ozone layer - http://en.wikipedia.org/wiki/Ozone_layer
c) Ozone Science: The Facts Behind the Phaseout
http://www.epa.gov/ozone/science/sc_fact.html
d) Ozon - http://de.wikipedia.org/wiki/Ozon
e) p. 241: Picture of Ozone layer in the Stratosphere
s. Images: Ozon layers in the Stratosphere // s. Bilder: Ozonschicht in der Stratosphäre
Figure Text translated from German to English by P. Brüesch
f) Ozonschicht soll sich bis 2050 regeneriert haben
www.welt.de/wissenschaft/umwelt/article109695690/Ozonschicht-soll-sich-bis-2050-regeneriert-haben.html
(Pictures of p. 243 Ozone layers 1998 and 2012; Figure Text rewritten by P. Brüesch)

R.5.5.3 p. 244 : Health problems caused by ground-level Ozone

a) Ground-Level Ozone - https://www.ec.gc.ca/air/default.asp?lang=En&n=590611CA-1
b) Ground-Level Ozone - EPA: Environmental Protection Agency
http://www.epa.gov/groundlevelozone/
c) Ozone (O_3) Standards - http://www.epa.gov/ttn/naaqs//standards/ozone/s_o3_index.html
d) Ground-level Ozone - Health Effects
http://www.epa.gov/groundlevelozone/health.html
e) How Ozone Pollution Works – Avoiding and Reducing Ozone
http://science.howstuffworks.com/environmental/green-science/ozone-pollution1.htm
(Picture: Ozone-damaged plant and healthy plant)
f) BAFU - Luft – Ozon – Sommersmog - http:// www.bafu.admin.ch./luft/00575/00577/index.html/lang=de
g) Ozon . Grenzwerte - Richtwerte / Allum – Allergie, Umwelt und Gesundheit
http://www.allum.de/stoffe-und-ausloeser/ozon/grenzwerterichterte

R-5-14

Appendix – Chapter 5

R.A.1.1 p. 5.A-1-1: Air pollution in Beijing

a) Six years of Beijing air in one scarcy chart
http://qz.com/197786/six-years-of beijing-air-polution.summed-up-in-one-scarcy-chart/
b) Die Luftverschmutzung in China nimmt dramatische Formen an (Keystone)
www.blick.ch/.../ausland/chinas-behoerden-geben- - upper Picture – Air contamination
lower Picture found under «Air pollution in Beijing» - Pictures

R.A.1.2 p. 5-A-1-2: Air Quality Index (AQI) – A Guide to Air Quality and Your Health
http://airnow.gov/index.cfm?action=aqibasics.aq

R.A.2.1 p. 5-A.2.1: Global Warming

a) s. In «WATER»: (P. Brüesch) - Reference R-0-4 - Chapter 5: pp 246 - 249
b) Global warming - http://en,wikioedua,org/wiki/Global:warming
c) Globale Erwärmung - http://de.wikipedia.org/wiki/Globale_Erw%C3%A4rmung

R-A-3-1 Use of toxix gas in World War I (1914 – 1918)

a) World War I - http://en.wikipedua.org/wiki/World_War_1
b) Erster Weltkrieg - http://de.wikipedia.org/wiki_Erster_Weltkrieg
c) Chemical weapons in World War I - http://en.wikipedia.org/wiki/Chemical_weapons_in_World_War_I
d) Gaskrieg während des Ersten Weltkrieges
http://de.wikipedia.org/wif/Gaskrieg_w%C3%A4hrend:des:Ersten_Weötkrieges
e) Fritz Haber - http://de.wikipedia.org/wiki/Fritz_Haber
f) Walther Nernst - http://de.wikipedia.org/wiki/Walther_Nernst
g) Erich von Falkenhayn - http://de.wikipedia.org/wiki/Erich_von_Falkenhayn
h) Carl Duisberg - http://de.wikipedia.org/wiki/Carl_Duisberg
i) Chlorine - http://en/wikipedia.org/wiki/chlorine
j) Chlor - http://de.wikipedia.org/wiki/Chlor
k) Phosgene - http://en.wikipedia.org/wiki/Phosgene
l) Phosgen - http://de.wikipedia.org/Phosgen

R-5-15

R-A-3-2 p. 5-A-3-2: Hydrogen Cyanide: HCN - Zyklon B – Holocaust

a) Hydrogen cyanide: http://wikipedia.org/wiki/Hydrogen_cyanide
b) Cyanwasserstoff - https://de.wikipedia.org/wiki/Cyanwasserstoff
(Vergiftung der Juden durch den Nationalsozialismus in Auschwitz-Birkenau – Holocaust)
c) Zyklon B. http://de.wikipedia.org/wiki/Zyklon_B
d) Allgemein - Zyklon – B: http://www.zyklon-b.info/produkt/allgemein.htm
e) The Holocaust - http://en.wikipedia.org/wiki/The_Holocaust
f) Auschwitz – Birkenau: http://www.jewishvirtuallibrary.org/source/Holocaust/(aogas.html
g) Gaskammer (Massenmord): http://de.wikipedia.org/wiki/Gaskammer_(Massenmord)
h) Die sieben Gaskammern von Auschwitz
http://www.deathcamps.org/gas:chambers/gas:chambers:auschwitz:de.html
i) Gaskammer Auschwitz – Bild & Foto von Bernd 1959 aus Krieg und seine Folgen (14103841) / fotocommunity
http://www.fotocommunity.de/pc/pc/dispöay/14103841
k) Holocaust denial: http://en.wikipedia.org/wiki/Holocaust_denial
l) akdh.net - Auschwitz und Leugnung des Holocaust: Der Leuchterreport
http://www.akdh.ch/ps/ps_Leucht.html

R-A-3-3 p. 5-A-3-3: Conversion of ppm to mg/m³

a) EPA On-line Tools for Site Assessment Calculations - Indoor Air Unit Conversion
http://www.epa.gov/athens/learn2model/part-two/onsite/ia_unit_conversion_detail.html
b) Air Dispersion Modelling Conversions and Formulas
http://www.aor-dispersion.com/formula.html
c) Konzentrationsrechner (Umrechnung von Konzentrationsgrössen, Gehaltsgrössen)
http://www.ansyco.de/CMS/frontend/index.php?itcatside=153
d) For a general conversion relation based on the ideal gas law of ppmv to mg/m³ and vice verse
see p. 5-A-3-3; Application to HCN: ppmv → mg / m³

R.A-4-1 p. 5-A-4.1: Sinkgeschwindigkeit v(t) für Partikel mit Durchmesser $D_P = 0.01\ \mu m$
(Berechnung und Figur erstellt von P. Brüesch)

R-5-16

R-A-4-2 p. 5-A-4-2: Origin and Particle Size

a) Mineral dust . Sahara dust - http://en.wikipedia.org/wiki/Mineral_dust
b) Intercontinental Transport of Dust: Historical and Recent Observational Evidence
Rudolf B. Husar; Chapter 11 of the Book: Intercontinental Transport of Pollutants., A. Stohl, Ed.
Springer Verlag 2004 - (right-hand picture)
c) Saharastaub über Bayern - http://www.sat1bayern.de(news/20140403/saharastaub-ueber-bayern
d) Saharastaub
http://www.dwd.de(sid_QJOSSdfdIDLkJXWtfyZc4YLqvg5tpxz8cQybk5wYhyKG72Jvh0yH!_453642259!...
Wetter und Klima – Deutscher Wetterdienst – Ozon, GAW, Luftchemie - Umweltthemen: Saharastaub
e) Sandsturm - http://de.wikipedia.org(wiki/Sandsturm
f) Schluff - http://de.wikipedia.org/wiki/Schluff

R-A-4-3 p. 5-A-4-3 Sahara Dust in Europe

a) Sahara Dust In European Skies
http://www.science20.com/chatter_box/sahara_dust_european_skies-77932
b) Wetter – Sahara-Staub in den Alpen - upper picture
http://www.wetter24.de/wetter-news/news/ch/abeb1c7bea2b88efb0250eg3baac4efb/article/sahara_staub_in_den_alpen... - from: «Bilder zu Sahara-Staub in den Alpen»
c) «Besuch aus Nordafrika» - lower picture - http://www1.wdr.de/fernsehen/aks/saharasand100.html

R-A-4-4 p. 5-A-4-4 Chernobyl – Spread of radio-active contaminates

a) Global Radiaton Patterns
(Spread of radio-active contaminates into the atmosphere from the Chernobyl accident ….)
http://users.owt.com/smsrpm/Chernobyl/glbrad.html
b) Fragen und Antworten zu Strahlenschutz – Aspekten in Japan
http://www.bfs.de/de/kerntechnik/unfaelle/fukushima/strahlenschutz_japan.html
enthält:: «Einige wichtige Dosis-und Grenzwerte»
contains: «Some important Doses and limiting values»
c) Picture of contaminated area of radio-active Fallout found under:
«Ausbreitung des Fallout von Tschernobyl - Bilder»

R-5-17

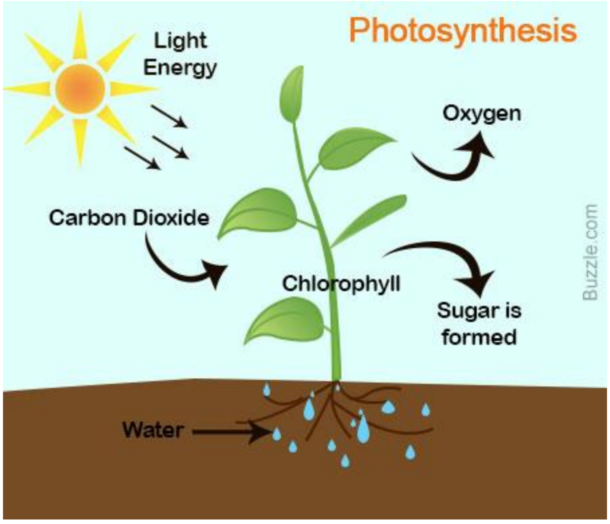
6. Photosynthesis and Respiration of Plants

245

6.1 Photosynthesis

246

Principle of Photosynthesis

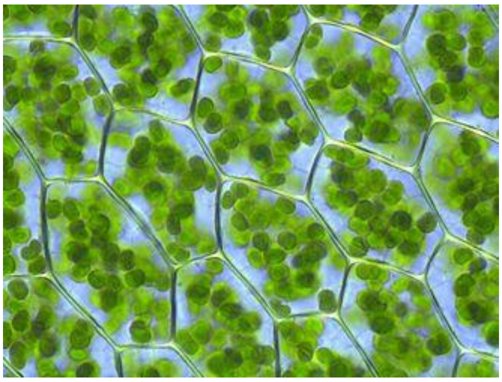


Photosynthesis is a process used by plants to convert light energy from the Sun into chemical energy that can be used to fuel the organisms' activities. Carbohydrates, such as sugar (glucose), are synthesized from carbon dioxide and water. Oxygen is also released, mostly as a waste product, Photosynthesis maintains atmospheric oxygen levels and supplies most of the energy necessary for almost all live on Earth.

247

Photosynthesis: Chloroplasts - Chlorophylls

In Photosynthesis, substances which are rich in energy are produced from low-energy substances with the help of light energy E = hν (ν = frequency of light, h = Planck's constant). This convertion is carried out by plants, algae and some groups of bacteria. In this biochemical process, light energy absorbed by pigments, usually Chlorophylls, is converted in chemical energy. This chemical energy is then used to convert low-energy, inorganic compounds such as CO_2 and H_2O to energy-rich compounds such as carbohydrates.



Plant cells with visible Chloroplasts
(here in the leaf blade of mosses)

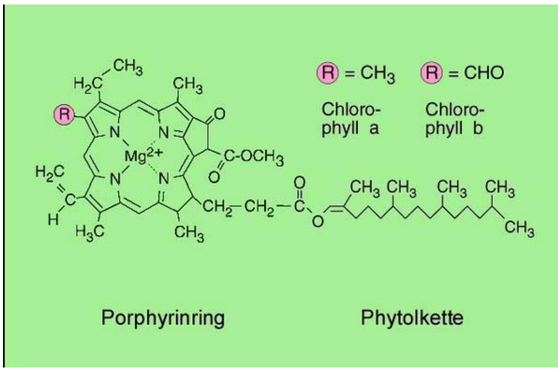
The Chloroplasts are organelles of celles of higher plants and green algues which are able to trigger photo-synthesis.

In Chloroplasts, different pigments are incorporated, mainly the green Chlorophyll. [The pigment Chlorophyll only absorbs the red and blue light, but reflects the green light; for this reason, the leaves appear to be green s. p. 250].

The pigments are able to absorb light, which is converted in chemical energy.

248

Struktur von Chlorophyll



Der «Kopf» des Chlorophyllmoleküls ist der entscheidende Teil für die Lichtabsorption. Er besteht aus einem Pophyrinring mit einem zentral angebauten Magnesiumatom.

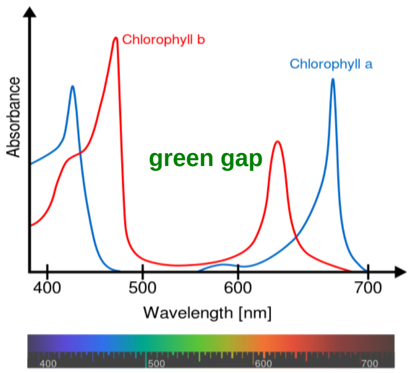
An den «Kopf» ist eine Phytolkette gebunden. Das ist ein langkettiger Alkohol. Damit wird das Molekül in der Thylakoidmembran (photosynthetisch aktive Struktur in den Chloroplasten) verankert.

Chlorophyll a und b unterscheiden sich nur in einer der funktionellen Gruppen am Porphyrinring. Diese funktionellen Gruppen sind an der Stelle, die mit R (für Rest) gekennzeichnet ist, mit dem Porpyrinring verknüpft.

249

Absorption of Light by Chlorophyll a and b

Chlorophyll absorbs the light emitted by the Sun in the wavelength region between about 400 nm to 490 nm (Soret - range) and in the red region between 620 nm and 700 nm (1 nm = 10^{-9} m). The Soret – range is the most intensive band in the visible absorption region of Chlorophyll. This region has been discovered by J.L. Soret. Chlorophyll a absorbs light within the violet, blue and red wavelengths while mainly reflecting green. The addition of Chlorophyll b next to chlorophyll a extends the absorption spectrum. In low light conditions, plants produce a greater ratio of Chlorophyll b to chlorophyll a molecules, increasing photosynthetic yield.



Absorption spectra of Chlorophyll a and b

The so-called «green gap» is the spectral range between 490 nm and 620 nm of Sun light which is outside the absorption spectrum of Chlorophyll a and b. In this spectral range, light is reflected by the leaves. This explains why most plants and trees appear green to the human eye.

250

Importance and Brutto Reaction of Oxygenic Photosynthesis

The oxygenic Photosynthesis produces molecular oxygen (O_2). The oxygenic Photosynthesis is not only the most significant biochemical process of the Earth, but it is also the oldest one. By formation of glucose, $C_6H_{12}O_6$ (p. 252), together with Sun energy it directly or indirectly triggers almost all existing ecosystems. This is accomplished by providing energy-rich building materials and energy sources for other living beings. The green plants, algae and cyanopacteria are using the energy of light for storing energy in the form of Adenosine triphosphate (ATP) (s. pp 254, 258, 259):

Part of the generated oxygen acts as an oxidant for cellular respiration (aerobic respiration) (p. 254). As a consequence, the oxygenic Photosynthesis allowed the formation of more highly developed life forms. The remaining oxygen generated by Photosynthesis is released into the air (p. 254) and is used for breathing of living beeings and for the formation of the protecting Ozon layer (pp 239 – 244).

The reaction equation for Photosynthesis includes a range of intermediate reactions which will not be discussed here. We rather restrict ourselves to the brutto reaction with 12 H_2O-molecules at the left- and 6 O_2- molecules at the right-hand side of the equation .

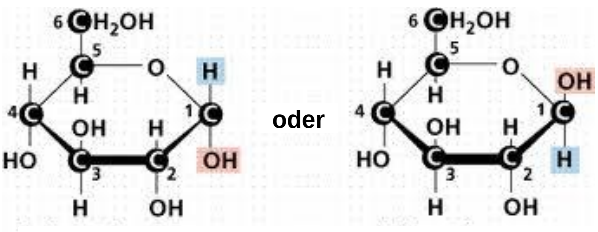
$$\underbrace{6\,CO_2}_{\text{Carbon dioxide}} + \underbrace{12\,H_2O}_{\text{Water}} \xrightarrow{\text{Light}} \underbrace{C_6H_{12}O_6}_{\text{Glucose}} + \underbrace{6\,H_2O}_{\text{Water}} + \underbrace{6\,O_2}_{\text{Oxygen}}$$

The colours of the atoms indicate, that the oxygen of the glucose originates from CO_2, but that the free oxygen is generated by the photodissociation (photolysis) of water. This fact could be established by radioactive tracer-experiments using isotopes ^{16}O and ^{18}O [s. Appendix 6-A-1-1]; (Net reaction: s. Ref. R.6.1.5).

251

The Glucose Molecule

The Glucose, $C_6H_{12}O_6$, (p. 251), produced in the brutto reaction of Photosynthesis, is a monosacharide (a single sugar) and belongs to the carbohydrates $[C_m(H_2O)_n]$. In nature only the so-called D-Glucose occurs (see right-hand Figure). This sugar is also known as Dextrose. Normally, Glucose does not appear in a free form but rather in the form of Polymers, such as lactose, starch or cellulose. In plants, the Glucose polymers are acting both, as reserve materials as well as components of cell structure. All living beeings are capable to produce Glucose from specific input products if the need arises.



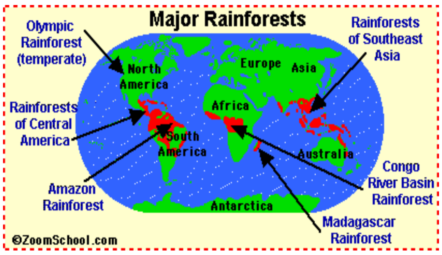
α-D-Glucose β-D-Glucose

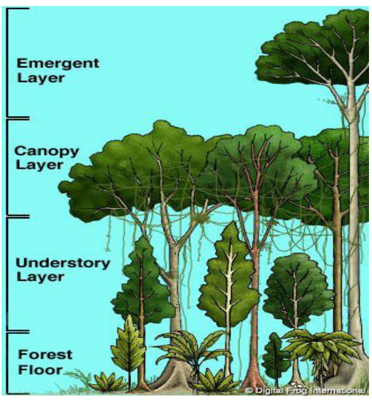
D-Glucose exists in two forms: α–D- Glucose and β –D–Glucose. The two forms differ only in the direction of the orientation of the -H and –OH groups of the carbon atom 1. If α-D-Glucose molecules are chemically bound, a Starch polymer is formed. If β-D-Glucose molecules are bound, a Cellulose-Polymer is formed.

252

Photosynthesis in Rainforests

In a bell around the equator, the climate is usually warm and humid (right-hand Figure). Here, the Rainforest can thrive because in this region it encounters optimal conditions: Temperatures are between 20 and 28 ^{0}C, and it is coupled with high precipitation over the whole year.

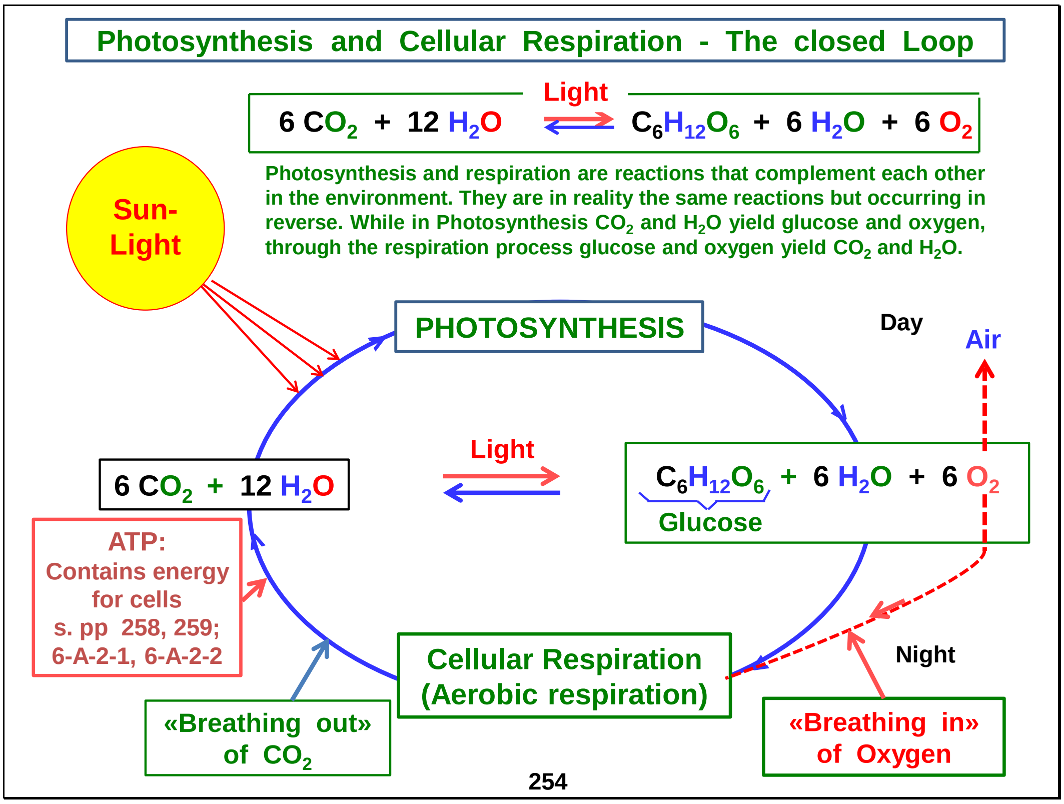




a) Emergent Layer: small number of very large trees, called emergents growing above the general canopy, reaching heights of 45–55 m, occasionaly even heights of 70-80 m.
b) Canopy Layer: contains the majority of the largest trees, typically 30-45 m tall. The densest areas of biodiversity are found in the forest canopy, a more or less continuous cover of foliage formed by adjacent treetops.
c) Understory Layer: lies between the canopy and the forest floor. It is the home to a nunber of birds, snakes, lizards and predators such as jaguars, leopards and boa constrictors.
d) Forest Floor: receives only 2 % of Sunlight. Only plants adapted to low light can grow in this region-

The foliage of the large trees makes a decisive contribution to the regeneration of the Earth's Atmosphere. Together with Sun light, the leaves absorb the Carbon dioxide, CO_2, of the air and by means of Photosynthesis they transform the harmful CO_2 into oxygen (O_2) and Glucose (s. pp 247 – 251; 254). One part of oxygen is used for cell respiration, the other part is released into the air for breathing of almost all living beings. As expected, photosyntetic capacity increases with canopy height.

253


Photosynthesis and Cellular Respiration - The closed Loop
Light
6 CO_2 + 12 H_2O ⇄ $C_6H_{12}O_6$ + 6 H_2O + 6 O_2
Photosynthesis and respiration are reactions that complement each other in the environment. They are in reality the same reactions but occurring in reverse. While in Photosynthesis CO_2 and H_2O yield glucose and oxygen, through the respiration process glucose and oxygen yield CO_2 and H_2O.
Sun-Light
PHOTOSYNTHESIS
Day
Air
6 CO_2 + 12 H_2O
Light
$\underbrace{C_6H_{12}O_6}_{\text{Glucose}}$ + 6 H_2O + 6 O_2
ATP: Contains energy for cells s. pp 258, 259; 6-A-2-1, 6-A-2-2
Night
Cellular Respiration (Aerobic respiration)
«Breathing out» of CO_2
«Breathing in» of Oxygen
254

6.2 Cellular Respiration

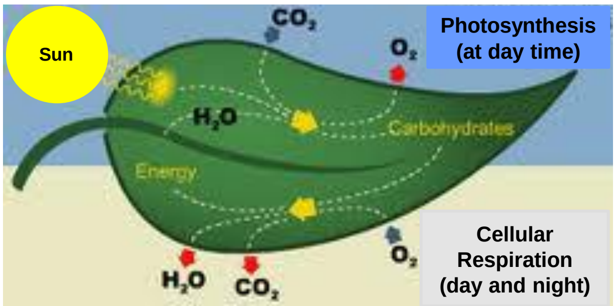
255

Cellular Respiration and Photosynthesis - Facts

The Photosynthesis of pants not only produces free oxygen for the atmosphere but it also uses part of the oxygen in chemically bounded form for its cellular respiration for energy supply (p. 254). In contrast to animals and human beings, plants do not have a blood circulation which transports oxygen at the locations of need, but the oxygen is rather distributed by diffusion.

The undersite of the leaf of a plant growing at land contains a large density of stomata (s. P. Brüesch in «Water», Chapter 4, pp 217, 218). With these very small «mouths» they are «breathing in» oxygen during night (cellular respiration).

Plants are breathing during day and night. During day, Photosynthesis is dominating, i.e. more CO_2 is absorbed than emitted. Because of the missing sun light during night, Photosynthesis is stopped and the plant reduces its activity to cellular respiration. At the morning and at the evening there are specific times, at which Photosynthesis and respiration are balanced (compensation points).



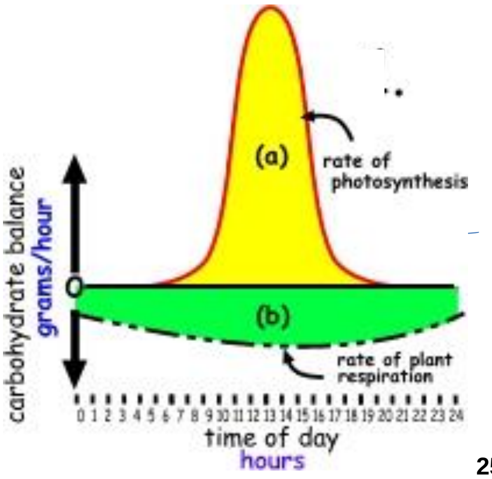
256

Rates of Photosynthesis and Respiration of Plants in 24 hours

Since Photosynthesis produces carbohydrates, the rate at which the amount of carbohydrates change is positive (yellow area (a)). During the time of solar radiation it reaches a maximum (in the Figure at about 13:30 am). (The same is also true for the production of oxygen).

On the other hand, respiration consumes carbohydrates (green area (b)). Hence, the rate at which carbohydrates change is negative for respiration.

The area in yellow represents the total amount of carbohydrate produced in a 24 h period (due to Photosynthesis). The area in green (b) represents the total amount of carbohydrate consumed due to respiration.



For a green plant to survive, grow, and produce mature fruit, area (a) (yellow), must exceed area (b) (green).

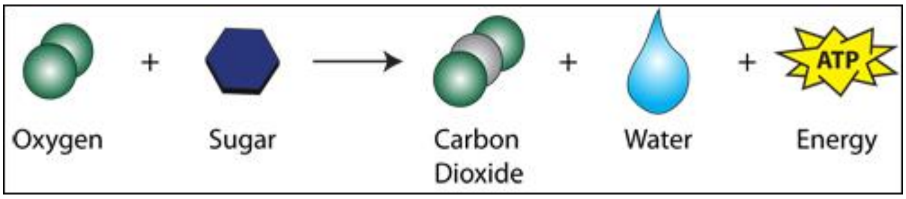
Cellular Respiration of Plants – 1 : Glucose → ATP

The respiration of plants as well as of animals consists of the inhalation of oxagen O_2 and in the release of carbon dioxide, CO_2. By the continuously occurring slow process of combustion in each plant cell, the operating power for the maintenance of vital activity is gained.

In case of particularly vivid cellular respiration occurring in freshly germinating seeds as well as in fresh blooming buts, an excess force is generated, which is noticable as a temperature increase.

If oxygen used for the maintenance of respiration is absent, all life activities such as growth, irritability, cellular respiration and photoplasmic movements are temporarily ceasing. After a prolonged time of oxygen deficiency, death by suffication occurs.

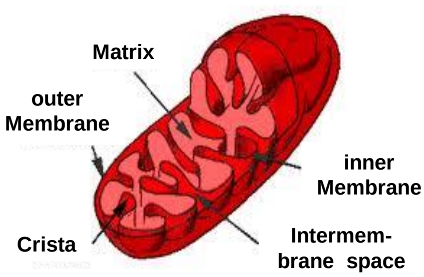
During respiration, the energy-rich glucose (sugar) is decomposed. The energy gained in this process is stored in cells as ATP (pp 6-A-2-1, 6-A-2-2), p. 254 and picture below) . The cellular respiration can be represented by the following reaction:



Reaction illustrating the cellular respiration of plants

Cellular Respiration of Plants – 2 : Mitochondria

A mitochondrion is a cell organelle (a cell organ) which is enclosed by a double layer cell membrane (i.e. a cell which contains a cell nucleus) and is used for power generation.
Mitochondria are large grain-shaped cell organelles. They frequently occur in cells, which have a high energy demand.
Mitochondria contain a double membrane. The outer membrane isolates the mitochondrium from the exteriour and contains channels for the permeability of molecules.
The inner membrane contains numerous invaginations which are so-called cristae (from lat. crista «Kamm»). These cristae considerably increase the surface of the inner membrane, where chemical reactions can take place, thereby increasing the ability to produce ATP (pp 6-A-2-1, 6-A.2-2).



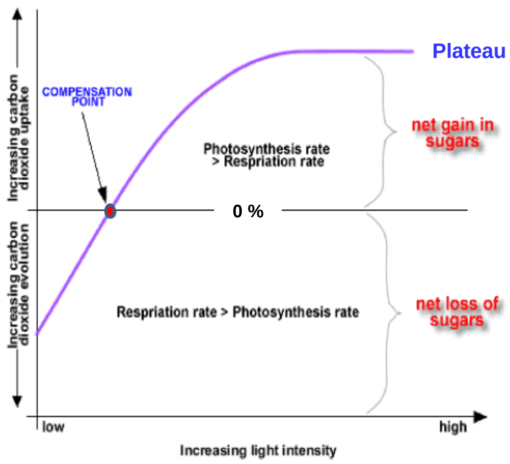
Mitochondrium

In the mitochondria the chemical processes of the respiratory chain take place. This makes it possible to use absorbed glucose (p. 252) for the synthesis of ATP with a high degree of efficiency. ATP is synthesized in the intemembrane space (between the two membranes of the double cell membrane) and can than be delivered to the cytosol (liquid component of the the cell).
Mitochondria represent an intracellular storage for calcium and play an important role for the homeostasis (maintenance of a state of equilibrium) in the cell.

259

Compensation point for Light in Plants

We have discussed Photosynthesis and Respiration of plants at pp 251, 254, 256 – 258.
Photosynthesis: $6\ CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$.



Plateau: either light saturation has been reached or another factor has become limiting, e.g. CO_2

The (light) compensation point is the amount of light intensity on the light curve where the rate of photosynthesis exactly matches the rate of respiration.

At this point, the uptake of CO_2 through photosynthetic pathways is exactly matched to the respiratory release of CO_2, and the uptake of O_2 by respiration is exactly matched to the photosynthetic release of oxygen.

This point is reached during early mornings and late evenings. Respiration is relatively constant whereas photosynthesis depends on the amount of sunlight.

Let $[O_2]$ be the concentration of O_2; then

$[O_2] < 0$: Cellular respiration.
$[O_2] > 0$: Photosynthesis.
$[O_2] = 0$: At the compensation point, the net concentration of oxygen, $[O_2]$, is exactly zero.

260

Coloured Leaves of Deciduous Trees (Laubbäume) in Autumn

Trees which shed leaves in autumn are preventing their drying out in winter where the water from the soil is freezing and can no longer be absorbed by trees. Transpiration of the plants takes place over the stomata of the leaves (see P. Brüesch in «WATER», Chapter 4, Section 4.6, pp 202 – 223) which are not present anymore. After defoliation, no frost protection is necessary.

Before defoliation, many vital elements as for example Sodium (Na), Sulfur (S), Iron (Fe), Phosphorus (P), Potassium (K), and Manganese (Mn) as well as the mobilisable Carbohydrates are displaced into the storage tissue of the trunk and branches. Mobilisable Carbohydrates are present in a form, in which they can be transformed; this is the case for sucrose. In the following spring, these nutrients are delivered to the young developing leaves.

Ahorn leaves at different seasons: geen, yellow and red

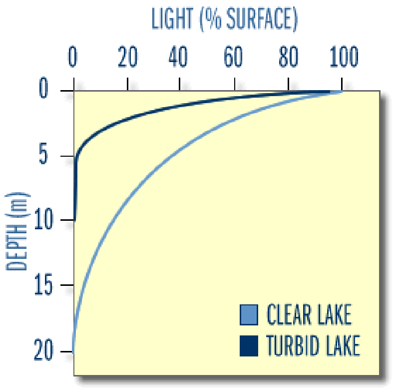
During winter, the trees fall into a «winter sleep» and are living from the nutrients which they have stored during summer. In this way, they are able to survive the winter time where no new leafs are growing. In this dormant state, the deciduous trees are living on the abundant Glucose which they have stored in the central vacuols of the trea..

261

Aquatic Plants: Photosynthesis and Respiration

262

Light Attenuation in a «clear» and in a turbic Lake



LIGHT VERSUS DEPTH PROFILES FOR A CLEAR LAKE ($k=0.2\ M^{-1}$) AND A TURBID LAKE ($k=0.9\ M^{-1}$).

With increasing depth of water in a lake, the intensity of the incident sunlight decreases. The absorption and attenuation are major factors controlling temperature and Photosynthesis. Photosynthesis provides the food that supports much of the food web. It also provides much of the dissolved oxygen in the water.

The light intensity I(0) at the lake surface varies seasonally and with cloud cover and strongly decreases with depth d below the surface (see Figure). The deeper into the water column that light can penetrate, the deeper Photosynthesis can occur. For clear water, the intensity I of the light decreases exponentially with d. If k is the vertical extinction coefficient of clear water, the decay of light intensity for «clear» water (k = 0.2) is approximatively exponential, i.e.

For «clear» water (k = 0.2), the Extinction Law predicts $I(20\ m) / I(0) \approx 1.8\ \%$.

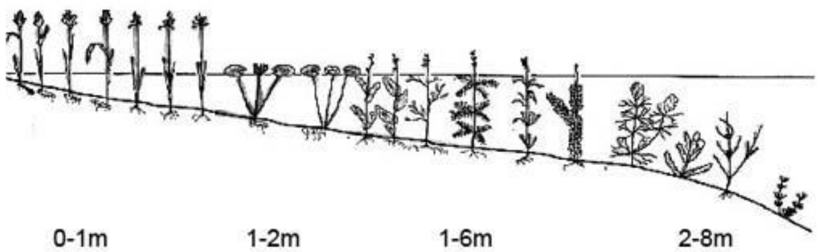
$$I(d) \approx I(0) \cdot \exp(-k\,d) \qquad \text{(Extinction - Law)}$$

The rate at which light decreases with depth depends upon the amount of light-absorbing dissolved substances and the amount of absorption and scattering caused by suspended materials. The Figure shows the light attenuation profiles for two lakes with attenuation coefficients $k = 0.2\ m^{-1}$ («clear» water) and $k = 0.9\ m^{-1}$ (turbid water).

263

Aquatic Plants: Photosynthesis and Respiration

Plant zones at a shallow lake shore



With increasing depth of water in the lake , the intensity of light for Photosynthesis decreases rapidly. This gives rise to a zoning of the plant population at the shore, such that the most light-hungry plants are growing at the shallowest waters, whereas deeper below the surface, more modest species are found. Therefore, at a natural flat sea or at a pondside, the above illustrated plant zoning is usually found .

264

General Properties and Species of Aquatic Plants

In our lakes most of the higher plants belong to the pondweed and have nothing to do with „seawood“ or algae .

In contrast to terrestrial plants, water plants do not possess a rigid supporting tissue. If they are removed from water they are flabby. In water, however, they are standing upright and are following the water movement flexibly without braking. Their stems are very tenacious and elastic. In contrast to land plants , water plants do not need an evaporation protection; theire leaves are therefore very soft and tenuous. This allows for a direct uptake of nutrients from water through the leaves .

The roots function in the first place as ground anchors to the bottom of the pond .

According to the Figure at p . 223, the following species of water plants exist:

a) Reed bed plants

b) Floating leaf plants

c) Pondweed plants

d) Plants which are completely sub-merged under the surface of the water

265

a) Reed bed Plants

Reed beds constitute a subgroup of march plants. They are located at river banks and penetrate the water up to a depth of about 1.5 m. With the help of their strong Rhizomes they are able to form dense reed beds. [A Rhizome is a hypogean (underground) shoot system]. An im-portant example is the reed (Schilf-rohr).

Respiration and Gas Exchange: An influx and an outflux of air is established through the broken straws and is driven by the transpiration and the Venturi-effect (in the latter, wind generates a suction within the broken straws).

The numerous aerenchyma cells (*) of the Rhizones are connected with the leaves through a continuous air chamber system. In this way, the photosynthetically produced atmospheric oxygen can quickly penetrate into the Rhizomes. Similar to nitrogen and CO_2, this produced oxygen can be stored in the aerenchyma cells.

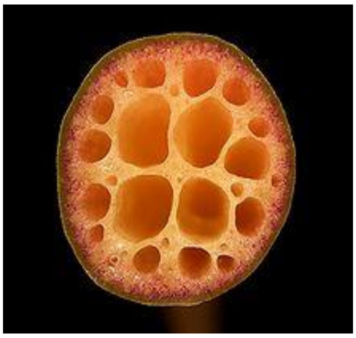
At the beginning of the growth of new shoots (still within the water columns), respiration exceeds photosynthesis.

(*) Aerenchyma are large air-filled cavities that provide a low-resistance internal pathway for the exchange of gases (such as oxygen) between the plant organs above the water and the submurged tissues).

266

b) Plants with floating leaves: Water lilies

Nymphaea alba: a water lily species



Air chambers in the stem

Plants with floating leaves (e.g. water lilies and Lotus plants) represent a particularity: their roots are sticking to the underground while their leaves are floating at the water surface. By the presence of air chambers, the leaves are able to float on the surface, and on the other hand, these air chambers also transport the air through the hollow stem into the roots. Due to this air transport, the roots do not suffocate in the oxygen-deficient sludge. The water transport through the Xylem conduits is driven by the root pressure and not by transpiration pull as in tall terrestrial trees (s. Chapter 0, p. E; Ref. R.0.4).

The stomata of the leaves used for respiration are located at the upper surface of the leaves; this is in contrast to terrestrial plants where the stomata are at the lower surface of the leaves. These plants are thus breathing the oxygen of the air (not the oxygen dissolved in water). The leaves have wide-mashed air-filled cavities and the air is transported to the Rhizomes (see p. 266).

As mention above, Photosynthesis and Respiration takes place at the upper surface of the leaves. .

267

Plant with floating leaves - Respiration of a Lotus leaf

Indian Lotus flower

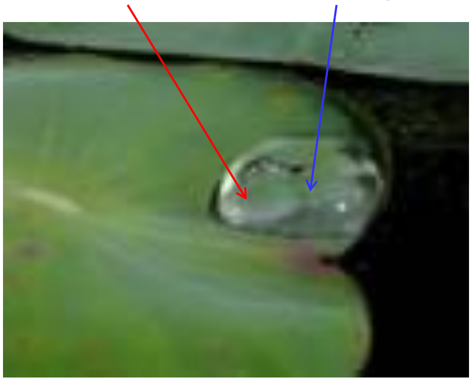
Lotus leaves are hydrophobic

normal water lilies are hydrophilic

Lotus leaves in the rain. On the surface of the Lotus leaves, rain drops are formed, i.e. they are hydrophobic.
Normal water lilies in the rain are completely wetted, i,e. they are hydrophilic.

Air bubble

Water drop



Lotus leaves are hydrophobic: The picture shows a water drop at the surface of the leaf. On the left side of the water drop an air bubble appears which is generated by the respiration of the leaf. (This picture has been obtained by a snapshot of a Video recording).

268

Pondweeds

On the leaves of pondweeds one finds many snails, insects, grubs, hydra and water-mites. Some fish species are depositing their spawns on the surface of the pondweeds.

Pondweeds are plants which are used by fishes as spawning sites and for food.

The pondweed zone has a depth of 2 - 5 m. The leaves of these plants are growing under water, only the blossoms extend over the water surface. Within the dense population of pondweeds, swarms of juvenile fishes, all possible invertebrates and lurking pikes can be observed during summer time.

Underwater plants (fully submersed plants) depend on the small CO_2- concentration in water for Photosynthesis. For this reason, submersed plants living in standing waters have narrow or cut-leaves. Diffusion of CO_2 contained in water into the plants is slow but the diffusion path is short. Due to the absence of transpiration, the plants can not gain mineral salts from the bottom of the lake. Their Xylem conduits are reduced.

269

Completely submerged water plants

These plants are blooming also under water. Normally, no part of the plant ever reaches the water surface.

Fragile stoneworts
(Chara globularis)

Stoneworts are often covered with calcium carbonate, ($CaCO_3$), They are found at the bottom of the water body, where they are growing and thriving along the surface of the ground.

Most organisms denoted as algae are water plants. This implies that they have the same biological needs as pond plants. They have a cellular metabolism in which they respire sugar to water and carbon dioxide. For covering their energy need they are able to synthesize sugar from light, CO_2 and H_2O. The process of Photosynthesis is the same as that of higher plants.

Many stonewort plants are present at chalky habitats and are then covered with a rigid crust of salt. The reason for this crust formation lies in the fact that during intensive Photosynthesis they extract anorganic substances such as calcium carbonate ($CaCO_3$) from the water, resulting in a decalcificiation of water.

Biologically, algae are indispensable: they produce a large part of oxygen which is present today in our atmosphere.

270

Appendix: Chapter 6

6-A-0

Photosynthesis: Tracer-Experiments with ^{18}O

Tracer- method for the determination of the free oxygen of Photosynthesis: The experiments are based on compounds which are marked with heavy oxygen ^{18}O.

«Crossing» of two separate experiments:

- Isotope tracing of H_2O
- Isoptope tracing of CO_2

with heavy (non-radioactive) oxygen)

Experiment 1: $6\ CO_2 + 12\ H_2{}^{18}O \rightarrow C_6H_{12}O_6 + 6\ {}^{18}O_2 + 6\ H_2O$

→ By using isotope tracing of water, the isotope appears in the generated oxygen !

Experiment 2: $6\ C^{18}O_2 + 12\ H_2O \rightarrow C_6H_{12}{}^{18}O_6 + 6\ O_2 + 6\ H_2{}^{18}O$

→ By using isotope tracing of carbon dioxide, the isotope appears in the carbohydrate, ($C_6H_{12}O_6$), and in the water at the product side.

These experiments proov that the free oxygen originates from the photolysis of water:

$$H_2O \rightarrow 2\ H^+ + 2\ e^- + (1/2)\ O_2$$

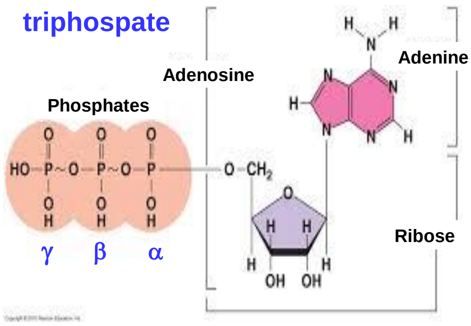
The 6 water molecules at the right-hand side of the brutto reaction are evaporated through the stomata of the leaves into the Atmosphere (s. P. Brüesch, Ref. R.0.4: Chapter 4 about «Watter», pp 217, 218).

6-A-1-1

ATP and ADP - Molecules

ATP

Adenosine triphospate



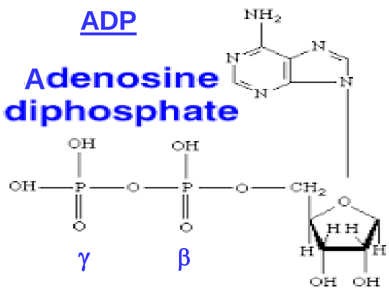
ATP is the universal and immediately available energy carrier in each cell of plants and animals and at the same time it is an important regulator for energy supplying processes.

The ATP- molecule supplies energy for chemical, osmotic or mechanical work. For this supply, the 3 phosphates α, β, and γ are of central importance: If the bond between α and β is broken, the less energetic ADP is produced.

The energy released by the reaction of ATP to ADP is used by the cell for the regeneration of ATP (s. p. 6-A-2-2).

ADP

Adenosine diphosphate



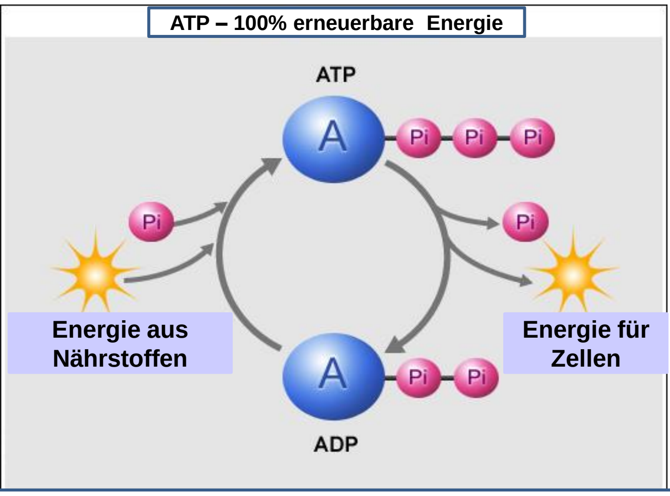
Phosphorylation of substrates by means of ATP produces a product and ADP which can be written in the following form:

ATP + substrate → product + ADP

In this reaction the bond between the α- and β-phosphates is broken. The product is more energetic than the substrate. The less energetic ADP is again phosphorylated by energy producing reactions in the body to give the energy richer ATP (s. p. 6-A-2-2).

6-A-2-1

Der ATP – ADP - Zyklus



Alle lebenden Zellen brauchen eine Energiequelle um z.B. Moleküle aufzubauen oder Muskeln zu spannen: Diese energiereiche Substanz ist ATP (Adenosintriphosphat). Beim Aufbrechen des ATP-Moleküls wird Energie frei; dabei entsteht das energieärmere ADP (Adenosindiphosphat) . Durch Andockung eines Phosphats entsteht aus ADP wieder ein ATP- Molekül (s. p. 6-A-2-1). Die dazu benötigte Energie stammt bei Tieren aus der aufgenommenen Nahrung und bei Pflanzen durch Zersetzung der Glucose (s. p. 254). [In der Figur steht Pi für Phosphat].

6-A-2-2

Carnivorous Plants

Carnivorous plants have special leaves, called leaf pitchers, with which they are able to catch protozoons or arthropods, but larger species are also able to demolish frogs and mouses. They often are living at extreme habitats such as fenlands or blanc rocks and therefore they need and are able to improve their supply with mineral substances as well as nitrogen compounds.

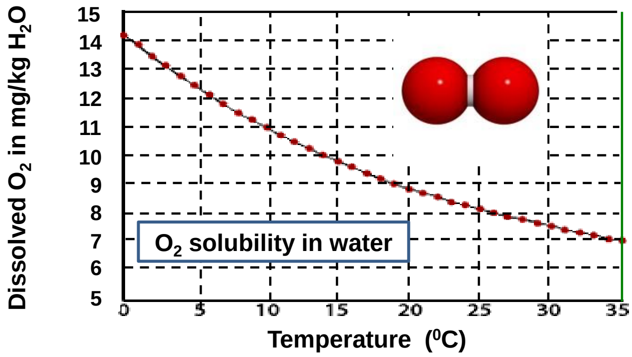
In addition, an adequate supply of light and water must be ensured such that the pitched leaves are able to carry out sufficient Photosynthesis for energy conversion. The shape of a leaf is rolled up in order to be a better trap for prays, but at the same time, this shape decreases the efficiency for Photosynthesis.

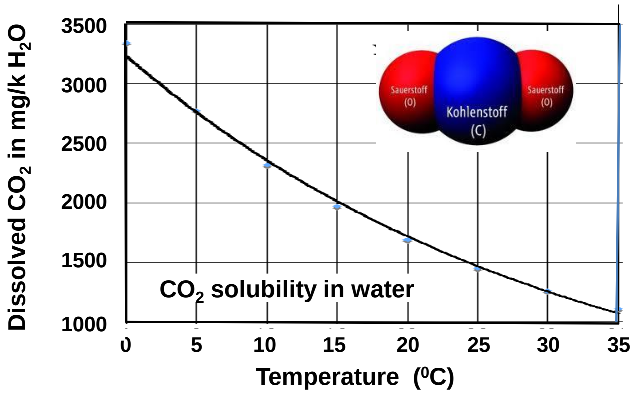
Carnivors must also supply additional energy for glands, hair, adhesives and digestive enzymes of non-photosynthetic structures. To provide such structures, the plant needs ATP, (pp 254, 6-A-2-1, 6-A-2-2) and in addition, it is cell-breathing biomasses (decomposition of energy-rich glucose, see pp 251, 254, 256, 258). The energy gained is partly stored in cells such as ATP. For all these reasons, carnivorous plants have a reduced Photosynthesis, and an increased Respiration.

The bean weed, a carnivorous plant is demolishing flying insects .

Certain Carnivorous («pitcher plants») can demolish frogs or mouses !

6-A-2-3



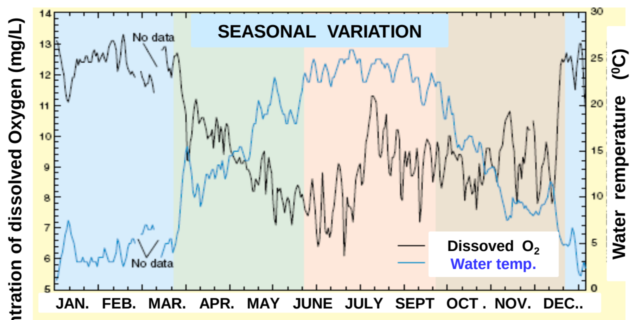


Saturation concentrations of O_2 and CO_2 in fresh water as a function of temperature (approximate values)

Over the ordinary temperature range (0 – 30 ^{0}C), the solubility of CO_2 is about 200 times larger than that of O_2.

6-A-3-1

Mean dissolved O_2- concentration and H_2O- temperature in Passaic River in N.J



MEAN DAILY DISSOLVED-OXYGEN CONCENTRATION AND WATER TEMPERATURE, PASSAIC RIVER BELOW POMPTON RIVER AT TWO BRIDGES, N. J., JANUARY-DECEMBER 1998

The Figure shows that the concentration of dissolved oxygen in surface water is controlled by temperature and has both, a seasonal and a daily cycle.

Cold water can hold more dissoved oxygen than warm water (see Figure in p. 6-A-3-1).

In winter and at the beginning of spring the O_2 – concntration is large; in summer and autumn it is small. (The concentration of dissolved oxygen is inversely related to water temperature (p. 6-A-3-1)).

Rules for practically important CO_2- concentrations

- **A CO_2-concentration of 0.5–1 mg/L is not sufficient for a good plant growrh**
- **Values between 5 - 15 mg/L provide an abundant plant growth**
- **A CO_2-concentration larger than 20 mg/L can be harmful for fishes**
- **In drinking water, CO_2 concentrations of 6 – 8 mg/L are favourable**
- **Limiting value: für a good plant growth but also for fishes, the CO_2- concentration should not be smaller than about 10 mg/L.**

6-A-3-2

References: Chapter 6

R-6-0

6.1 Photosynthesis

R.6.1.0 Advances in Photosynthesis – Fundamental Aspects
Edited by Mohammed Mahdi Najafpour – ISBN 978-953.307-938-8
Chapters published February 15, 2012 under CC BY 3.0 lcense

R.6.2.0 Allgemeine Botanik - Kurzes Lehrbuch für Mediziner und Naturwissenschafter
von Wilhelm Nultsch - 6. überarbeitete Auflage - Georg Thieme Verlag Stuttgart (1977)

R.6.1.1 p. 247: Photosynthesis - Principle

a) Photosynthesis - https://en.wikipedia.org/wili/Photosynthesis
b) Difference and Similarities Between Chemosynthesis and Photosynthesis
http://www.buzzle.com/articles/differences-and-similatities-between-chemosynthesis-and-photosynthesis.html/
c) Getting startet - What is Photosynthesis? Where does Photosynthesis happen? Plant Cells, Respiration, Starch, Why do plants need energy?
http://science.jrank.org/kid/spages/67/GETTING-STARTED.html
d) Was ist die Photosynthese ?? - Growlight Solutions
http://www.growlightsolutions.com/2011/11/was-ist-die-photosynthese

R.6.1.2 p. 248: Photosynthesis: Chloroplasts and Chlorophyll

a) For picture of Chloroplasts see Ref. R.6.1.1 a(of p. 247
b) Difference between Chlorophyll and Chloroplasts
http://www.differencebetween.net/science/nature//difference-between-chlorophyll-and-chloroplasts/
c) Photosynthese - http://de.wikipedia.org/wiki/Photosynthese - (contains also picture of Chloroplasts)
d) Chlorophylle - http://de.wikipedia.org/wiki/Chlorophylle
e) Chloroplast - http://de.wikipedia.org/wiki/Chloroplast

R.6.1.3 p. 249: Structures of Chlorophylls

a) Structure and Reactions of Chlorophyll - http://www.ch.ic.ac.uk/localprojects/steer/chloro-htm
b) Porphyrin of Chlorophyll - http://encyclopedia2.thefreedicationary.com/Porphrin+ring
c) Information about the Phytol «tail» of Chlorophyll is found in:
- Chlorophyll Analysis - http://www.secchidipin.org/chlorophyll.htm
- John Baez: Diary - Nay 2014 - http://math.ucr.edu/home/baez/diarynay_2014.html

R-6-1

R.6.1.3 p. 249: Structures of Chlorophylls - (cont.)

d) Information about Chlorophyll a and Chlorophyll b in: - «Light is part of the electromatnetic spectrum» http://plantphys.info_plantphysiology/light,shtml
e) Strukturformel des Chlorophylls - (Structure with Porphyrin ring and Phyrol tail) http://www.uni-duessldorf.de/MathNat/Biologie/Didaktik/Fotosynthese/datei/chloroph.html

R.6.1.4 p. 250: Absorption of light by Chlorophyll a and b

a) Chlorophyll a - http://wikipedia.org/wiki/Chlorophyll_a - (contains absorption spectra of Chlorophyl a and b)
b) Chlorophyll b - http://en.wikipedia.org/Chliriphyll_b
c) Referenz R.6.1.2 c): Photosynthese
d) Grünlücke - http://de.wikipedia.org/wiki/Gr%C3%BCnl%C3%BCcke
e) Soret – Bande - http://de.wikipedia.org/wiki/Soret-Bande

R.6.1.5 p. 251: Importance and brutto reaction of oxygenic Photosynthesis; from References R.6.1.1, R.6.1.2
Brutto reaction of Photosynthesis: : $6\ CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$
Net reaction of Photosynthesis: : $6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$

a) A Primer on Photosynthesis and the Functioning of Cells
http://www.globalchange.unich.edu/globalchange1/current /lectures/kling/energyflow/psn_primer.hrml
b) Stoff- und Energiewechsel - http://fehertamas.com/2009/stoff-und-energiewechsel
c) Tracer-Methode zur Aufklärung der Herkunft des freien O_2 bei der Photosynthese;
Ursprünglich bewiesen durch Experimente von Samuel Rubens und Martin Kamen
Die Darstellung im Anhang 6-A-1-1 stammt aus :
Historische Experimente zur Ernährung der Pflan… - www.tired-joe-com/.../Slript%20Bio%20Teil%20VI.p---

R.6.1.6 p. 252: a-D-Glucose and b-D-Glucose

a) Glucose : http://en,wikipedia.org/wiki/Glucose
b) The Interactive Library: What is the difference between alpha and beta Glucose ?
http://www.edinformatics.com/interactive_molecules/a_b_glucose_differences.htm
Picture from Google under a-D-Glucose and b-D-Glucose
c) Glucose: http://de,wikipedia.org/wiki/Glucose
d) Carbohydrate - https://en.Wikipedia.org/wiki/Carbohydrate

R-6-2

R.6.1.7 p. 253: Photosynthesis in Rainforests

a) Rainforest - http://en.wikipedia.org/wiki/Rainforest
http://en.wikipedia.org/wiki/Rainforest
b) Pictures of Rainforests: found under «Bilder of Tropical Rainforests»
c) Layers of Rainforests - http://en.wikipedoa.org/wiki/Rainforests
d) Photosynthetic capacity in central Amazonian rain forests
F.E. Carwell et al . Tree Physiology 20, 179 – 185 (2000)
http://www.treephys.oxfordjournals.org/content/20(179.full.p...
e) Tropischer Regenwald - http://wikipedia.org/wiki/Tropischer_Regenwald
f) AMAZONAS.de - Regenwald - http://www.amazonas.de/amazonas/wissen_regenwald1.html
g) Der tropische Regenwald . Die «grüne Lunge» der Erde
Die massive Zerstörung hat verheerende Folgen für Mensch und Natur
von Britta Pawlak - http://www.helles-koepfchen.de/tropischer-regenwald.html

R.6.1.8 p. 254: Photosynthesis and cellular respiration - The closed Loop

a) Photosynthesis vs. Respiration - http://www.diffen.com>Science>Biology
b) How are Photosynthesis and Cellular Respiration coupled Reactions ?
https://answers.yahoo.com/question/index?qid=20100707235728AAb03qh
c) Cellular respiration - http://en.wikipedia.org//wiki/Cellular_respiration
d) Closed loop Diagram from P. Brüesch constructed from different Literature sources
e) Sauerstoff in Pflanzen – wie ein Lebenselixier gleichzeitig Stressfaktor und
Signalstoff sein kann (Max – Planck – Gesellschaft)
Oxygen in plants – how an elixir could cause stress and act as a signal in parallel
http://www.mpg.de/4982054/Pflanzen_Sauerstoff
f) Element: Luft - Photosynthese - Auch Pflanzen brauchen Luft
http://www.kindernetz.de/infonetz/thema/luft/fotosynthese/~/id=128294/nid=128294/did=128266/lnw2rxt/
g) Wovon ernähren sich Pflanzen? Die Entdeckung der Photosynthese
[p. 3: Zellatmung] - www.caucau.ch/science_files/2.2_Fotosynthese.üdf
h) Atmung - http://de.wikipedia.org/wiki/Atmung
s. p. 1 unter: « … und Abgabe (Ausatmung) des Kohlenstoffdioxids….»
s. p. 2 : Kommentare über «Aerobe Atmung»

R-6-3

6.2 Cellular Respiration

R.6.2.1 p. 256: Cellular Respiration in Plants

a) s. Ref. R.6.1.8: References a), b), c), d)
b) Biology - Biology Rocks - Photosynthesis, Cellular Respiration, & Fermentation
https://sites.google.com/site/mochebiologysite/online-textbool/photosynthesis
c) Cellular Respiration - http://biolgyiupoi.edu/biocourdes/N100/2k4ch7respirationnotes.html
d) Photosynthesis abd Cellular Respiration - Study Guide
http://quizlet.com/20356514/photosynthesis-and-cellular-respiration-study-guide-flash-cards/
e) Atmung der Pflanzen - http://de.academic.ru/dic.nsf/meyers/8795/Atmung
Figure from: www.goggle – Images - (Figure – Text translated from German to English by P. Brüesch)

R.6.2.2 p. 257: Photosynthesis vs Respiration
«Plants and Light – Energy Input into Ecosystems»
http://resources.yesican-science.ca/tomatosphere/final/activity9a.html

R.6.2.3 p. 258: Respiration of Plants – 1

a) Cellular Respiration Tutorial - http://www.hartnell.edu/tutorials/biology/cellularrespiration.html
(with Figure summerizing the the cellular respiration)
b) Atmung der Pflanzen - Meyers grosser Konversationslexikon - Referenz von R.6.2.1
c) Protoplasmic movement: produced by the inherent power of contraction and relaxation
of protoplasm; such movements are of three kinds: muscular, streaming and cillary.
http://medical-dictionary.thefreedictionary.com/protoplasmic+movement

R.6.2.4 p. 259: Respiration of Plants – 2: Mitochondria

a) Cellular respiration - http://en.wikipedia.org/wiki/Cellular_respiration
b) Cellular Respiration - Mitochondria
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/C/CellularRespiration.html
c) Mitochondrion - http://en.wikipedia.org/wik/Mitochondrion
d) Mitochondrium - http://de.wikipedia.org/wiki/Mitochonrium
(Aussenmembran – Innere Membran – Matrix - Cristae)

R-6-4

R.6.2.4 (cont.)

e) Mitochondrium - Mach Med - http://flexikon.docchrck.cpm/de/Mikrochondrium
f) Die Pflanzen - Struktur und Funktion - http://www.u.helmich.de/bio/cytologie/01/Pflanzenzelle.html
g) Organell - http://de.wikipedia.org/wiki/Organell
(Ein Organell oder eine Organelle (Verkleinerungsform zu Organ) ist ein strukturell abgrenzbarer Bereich einer Zelle mit einer besonderen Funktion).

R.6.2.5 p. 260: Compensation point for Light in Plants

a) Compensation point - http://en.wikipedia.org/wiki/Compen
b) What is the compensation point in Photosynthesis ?
http://in.answers.yahoo.com/question/index?qid=20090326025745AAwNeP2
c) Compensation point - http://en.wikipedia/.org/wili/Co,pensation_point
d) Encyclopedia-com - Compensation point - http://www..encyclopedia.com/topic/compensation_point.aspx
e) Plants and light - http://tomatosphere.org/teachers/guide/grades-8-10/plants-and-light
f) Lichtkompensationspunkt - http://wikipedia.org/wiki/Lichtkompemsationspunkt
[Der Lichtsättigungspunkt wird von **Schattenpflanzen** wesentlich schneller erreicht als von Lichtpflanzen]
g) Figure from google.ch/search - Figure text rewritten by P, Brüesch for better readability.

R.6.2.6 p. 261: Coloured leaves of deciduous trees in autumn

a) How Deciduous Trees Adapt to Winter
http://www,blogster.com/lhale3/how-deciduous-trees-adapt-to-winter
b) Deciduous -. http://en.wikipedia.org/wiki/Deciduous
(Deciduous means «falling out of maturity»)
c) What are Deciduous Trees and Shrubs: Types of Deciduous Trees and Shrubs
http://www.garfenungkniwhow.com/ornamental/trees/tgen/what-aredeciduousplants-htm
d) How Deciduous Trees Adapt to Winter
http://www,blogster.com/lhale3/how-deciduous-trees-adapt-to-winter
e) Blattabwurf und Laubfärbung
http://www.uni-duesseldorf.de/MathNat/Biologie/Didaktik/Winterprojekt/se2/botanik2/blattabw.htm
f) Laub (Botanik) - http://de.wikipedia.org/wiki/Laub_(Botanik)
g) Ahornbäume: Die Ahorn-Arten - Der Ahornbaum - http://www.garten-treffpunkt.de/lexikon/ahornaeume.aspx

R-6-5

3. Aquatic Plants

R.6.3.1 p. 262: Aquatic Plants: Photosynthesis and Respiration (Title)

a) Aquatic Plants
http://www.botgarf.ucla.edu/html(boranytextbools/lifeforms/aquaticpkants//fulltextonly.html
b) Aquatic Plant –Wikipedia, the free encyclopedia - http://en.wikipedia.org/wiki/Aquatic_plants
c) Wasserpflanzen - http://de.wikipedia.org/wiki/Wasserpflanze

R:6.3.2 p. 263: Lake Ecology - Light (see - Oekologie – Licht)
Light Attenuation in «clear» and in a turbid Lake
(Lichtabschwächung in «klaren» und turbiden Seen)
http://www.lakeaccess.orgecology/lakeecologyprim3.html

R.6.3.3 pp 264 : Gewässerbiologie: Wasserpflanzen
Dr . Patrick Steinmann, Stein am Rhein
(Eine ausgezeichnete Einführung in das Gebiet der Wasserpflanzen)
Pflanzen mit zunehmender Wassertiefe : p. 1 in der Arbeit von Steinmann
http://www.psteinmann.net/bio_wasserpfl.html

R.6.3.4 p. 265: General Properties and Species of Aquatic Plants

a) References listed under R.6.3.1
b) Reference R.6.3.3

R.6.3.5 p. 266: Reed bed Plants

a) Reed bed - http://en.wikipedia.org/wikiReed_bed
b) Aerenchyma - http://en.wikipedia.org/wili/Aerenchyma
c) Kommentierte Literatur Recherche zum Thema «Röhricht»
bearbeitet von Dipl.-Biol. Kathleen Goersch - Projektleiter: Dr. Michael Schirmer
Universität Bremen - Januar 2002 - www.kuestendaten.de/.../Literaturecherche_Röhricht-Materialien.pdf

R-6-6

R.6.3.6 p. 267: Plants with floating leaves - Water lilies

a) Sone information is contained in Reference R.6.3.1
- Picture of «White Water lily» : see Reference R.6.3.1 b)
- Picture of «Air chambers in the stem»: see Reference R.6.3.1 c)
- unteres Bild des Querschnitts des Stiels einer Seerose: Ref. R.6.3.1
b) Text from: «Weisse Seerose» - http://de.wikipedia.org/wiki(Wei%C3%9Fe_Seerose
(translated to English by P. Brüesch)

R.6.3.7 p. 268: Plants with floating leaves Lotus flowers with leaves
Lotus leaves and water lily leaves

a) Lotus effect - http://en.wikipedia.org/wiki/Lotus_effect
[The Lotus effect refers to self-cleaning properties that are a result of very high water repellence (superhydropholicity), as exhibited by the leaves of the Lotus flower].
b) Lotusblumen - Plant with floating leaves - Respiration of a Lotus leaf
http://de.wikipedia.org/wiki/Lotusblumen
left-hand upper pictures: Lotus flower / left-hand lower picture: Lotus leaves and water lily leaves
c) right-hand picture:: Lotus leaf breathing / tanspiring through a drop of rainwater
www.youtube.com/watch?v=1-S1R1VLGE - By Vinod Eshwer - 24.04.2007

R.6.3.8 p. 269: Pondweeds

a) COLUMN – Pondweeds play an imortant part in underwater ecosystem
www.peacecountrysun.com/.../cokumn-pondweeds
b) Pondweed - http://www.encyclopedia.com/topic/pondweed.aspx
c) Pondweed - http://dictionary.reference.com/browse/pondweeds
d) References R.6.3.1 to R.6.3.3
e) Bild und Text zu Bild: Patrick Steinmann: Ref. R.6.3.3

R.6.3.9 p. 270: Fully submerged plants

a) Chara (alga) - http://en.wikipedia/Chara_(alga)
b) Armleuchteralgen - http://de.wikipedua.rg/wiki/Armleuchteralgen
c) Algen – Informationen zu Algen in Aquarien, Teichen und Natur - http://www.heimbiotop.de/algen.htm

R-6-7

References to Appendix - Chapter 6

R.A.1.1 p. 6-A-1-1: Tracer Photosynthesis - Tracer experiments: with ^{18}O

a) How Plants Work - http://www.howplantswork.com/2009/02(16/plants-dont-convert-co2-imto-o2/
b) Water is the Source of the Oxygen Produced by Photosynthesis
Life: The Science of Biology, Ninth Edition - @ 2011 Sinauer Associates
c) Photosynthese: Tracer- Experimente mit ^{18}O (s.. Ref. R.6.1.5, p. 251)
[PDF] Historische Experimente zur Ernährung der Pflan…
www.tired-joe-com/.../Slript%20Bio%20Teil%20VI.p---
d) Photolyse - http://de.wikipedia.org/wiki/Photolyse
e) Photolysis of Water - http://www.totrvista.com/conzent/biology/-iv/photosynthesis/-water.php

R.A.2.1 p. 6-A-2-1: Adenosine triphosphate (ATP) and Adenosine diphosphate (ADP)

a) Adenosine triphosphate - https://en.wikipedia/urg/wiki/Adenosine_triphosphate
b) Adenosine diphosphate - http://en,wikipedia.org/wiki/Adenosine_diphosphate
c) Structural Biochemistry / ATP - http://en.wilipedia.org/wiki/Structural_Biochemistry/ATP
d) Adenosintriphosphat - http://de.de,wikipedia.org/wiki/Adenosintriphosphat
e) Adenosindiphosphat - http://de,wikipepedia.org/wiki/Adenosindiphosphat
f) Phosphorsäureester - Monoester - Diester - Triester
http://de.wikipedia.org/wiki/Pgosphires%C3%A4ureester

R.A.2.2 p. 6.A-2-2: ATP - ADP cycle

a) Bernie's Basics - Renewable energy: you're soaking in it
Renewable energy: you're soaking in it - The ATP - ADP cycle
http://www.abc.net.au/science/articles/2011/05/25/3226741.htm
(Figure text rewritten for clarity)
b) Mystrry behind ATP - ADP - http://akidsheart.blogspot,ch/2013/06/mystery-behind-atp-adp.html
c) Spaltung energiereicher Phosphate - http://www.sportunterricht.de/ksportatpkp3.html

R.A.2.3 p. 6-A-2-3: Carnivorous Plants

a) Cornivorous plant - http://en.wikipedia.org/wiki/Carnivorous_plant
b) Carnivorous plants can photosynthesise, so why eat flies ?
http://www.thenakedscientists.com/HTML/questions/question/2797/

R-6-8

6.A.2.3 (cont.)

c) How do carnivourous plant respire ?
https://answers.yahoo.com/question/index?qid=20110214052023AAwFCWa
d) Fleischfressende Pflanzen - http://de.wikipedia.org/wiki/Fleischfressende_Pflanzen
e) Fleischfressende Pflanzen
http://www.tk.te/tk/a-z-navigation/fleischfressende-pflanzen10000403/535830
f) Fettkräuter - http://de,wikipedia,94t&wiki/Fettkr%C3%A44uter
g) Karnivore Gewächse - http://www.bg.uzh.ch/fundgrubeschafhaaeuser2010/eingang/karnivor.html

R-A-3-1 p. 6-A-3-1: Saturation concentrations of O_2 and CO_2 of watter as a function of temperature

Data collected from different sources by P. Brüesch
The absolut values of oxygen and carbon dioxide concentrations depend on the quality of water

a) O_2 concentrations - Oxygen Solubility in Fresh and Sea Water
http://www,engineeringtoolbox.com/oxygen-solubility-water-d_841.html
b) Dissolved Oxygen and Carbon Dioxide - butane.chem.uiuc.edu/pshapley/.../web-L23.pdf
c) Water Quality - Water Quality Assessment: Chemical: Dissolved Oygen and Biochemical Demand
http://www.cotf.edu/modules/waterq3/wqassess3f.htmk
d) CO_2 Solubility in Water
Diagrams found under Images of CO_2 Saturation solubility of CO_2 in water versus temperature
For direct comparison with the oxygen diagram, the concentrations given in g CO_2 / 100 g H2O
have been converted to mg CO_2 / kg H2O

R.A.3.2 p. 6-A-3-2: Water properties: Dissolved oxygen

Mean daily dissolved oxygen concentration and water temperature

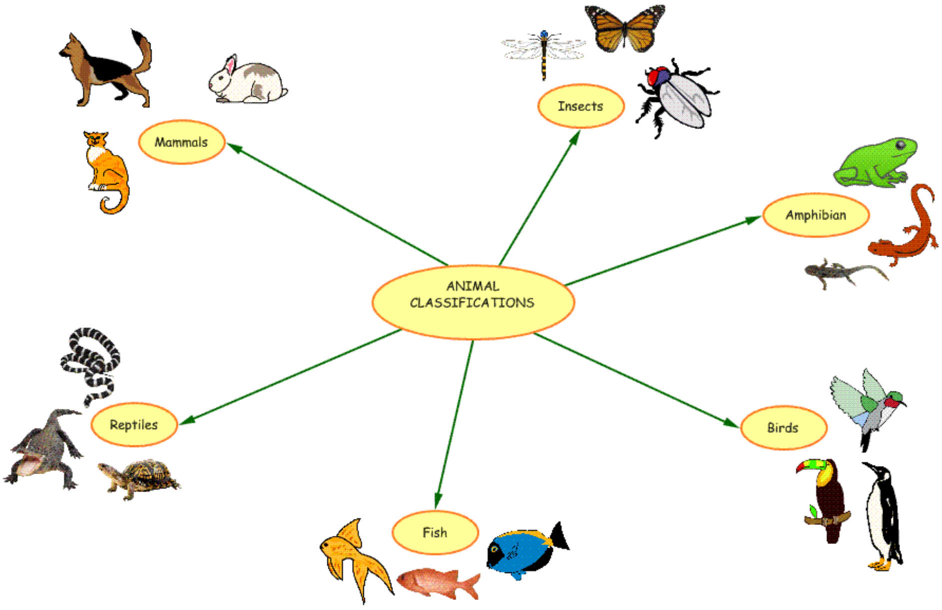
a) Water properties: Dissolved oxygen - Figure and Text from «Dissolved Oxygen, from USGS Water Science
Figure and Text from «Dissolved Oxygen, from USGS Water Science
for Scools: All about water - http://ga.water.usgs.gov/edu/dissolvedoxygen.htm
b) Rules for practically important CO_2 – concentrations in Waters and Lakes
- Carbon Dioxide in Water – About ScienceFairWater.com –
sciencefairwater.com/…/water…/dissolved…/carbon-d
- Werner H. Baur . Jörg Rapp: Gesunde Fische
2., neubearbeitete Auflage - Parce Buchverlag - https://books.google.ch/books?isbn=3826334027

R-6-9

7. Breathing of Men and Animals

271

7.0 Classification of Animals



Mammels, Reptilians, Fishes, Birds and Amphibians belong to the Vertebrates (about 3% of all animals). The remaining 97% are Invertebrates; an example of invertebrates are Insects (Arthropods).

272

7.0.1 Aerobic and Anaerobic Respiration

Aerobic respiration (cellular respiration, internal respiration) are processes in cells of living organisms in which hydrogen atoms (H) are oxidized; these H-atoms arise through different oxidative metabolic processes and are bound to special carriers. Elemental molecular oxygen (O_2) serves as an oxidizing agent and is thereby reduced to water. The purpose of aerobic respiration is the supply of energy in the form of ATP (s. pp 259 and p. 6-A-2-2). The term aerobic respiration is particularely used for biological processes of the respiratory chain in the inner membrane of the mitochondria (p. 259), at the end of which ATP is synthesized.

The cellular respiration is therefore a process in which energy-rich substances are decomposed. In cellular respiration, the glucose molecule $C_6H_{12}O_6$ is most often oxidized in a series of steps to so-called C1-units (one-carbon units such as CH_3-, CH_2OH-, CHO-…), CO_2 and H_2O. The over-all balance of cellular respiration is discussed at p. 258.

In contrast to aerobic breathers, anaerobic breathers are creatures, which do not need oxygen for their metabolism but are rather exhibited by oxygen. For the oxidation in their metabolism, not oxygen but rather alternative electron acceptors such as nitrates, trivalent iron ions (Fe^{3+}), quadrivalent manganese ions (Mn^{4+}), sulfates and CO_2.

Under oxygen-free conditions, as for example in sediments of lakes, etc., one often finds prokaryotes (organisms without cell nuclei (bacteria, blue-green algae)); their metabolic energy is delivered from anaerobic respiration. These respiration processes are known as nitrate respiration, sulfate respiration etc. Anaerobic respiration is a very old form of energy source, which goes back to the ancient time when oxygen was present in the atmosphere only as a tracer element.

273

7.0.2 Vertebrates: Overview - 1

Vertebrates are animals having a backbone. These notably include fishes, reptiles, birds, mammals, amphibians, as well as agnathans (ancient vertebrates). The Table below shows the classes of vertebrates and the percent values of each class. With 55 %, the fishes are by far the largest class.

The animal body is subdivided into head, barrel and tail. The sceleton consists of a backbone, the rips, the cranium (located at the frontside of the backbone), the shoulder- and the pelvic gurdle (Beckengürtel) as well as the extremities).

The respiration system of fishes consists of gills while the respiratory system of the other four vertebrate classes is the lung.

Vertebrate classes

55 %	Fishes	8 %	Mammels
12 %	Reptiles	5 %	Amphibians
16 %	Birds	4 %	Agnathans (ancient vertebrates)

Biological diversity in %

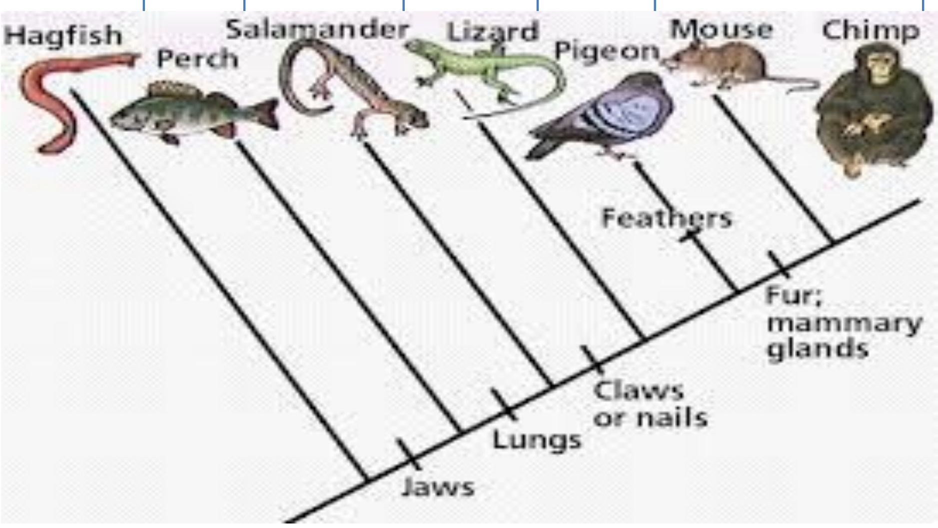
Vertebrates are spread worldwide. They are living on all continents. in-cluding the Antarctica, in the oceans down to the deep-sea, in freshwaters and in the inland in all biotopes including the high-mountain region. Birds and bats have the ability of active flying.

In biological systematics, vertebra-tes have the taxonomic rank of a subphylum (Unterstamm).

274

Vertebrates – Overview - 2

Cyclostomata	Fishes	Amphibians	Reptiles	Birds	Mammals



Only about 3% of all animals are Vertebrates; the remaining 97% are Invertebrates (s. p. 276 and p. 321)

275

7.0.3 Invertebrates: Overview

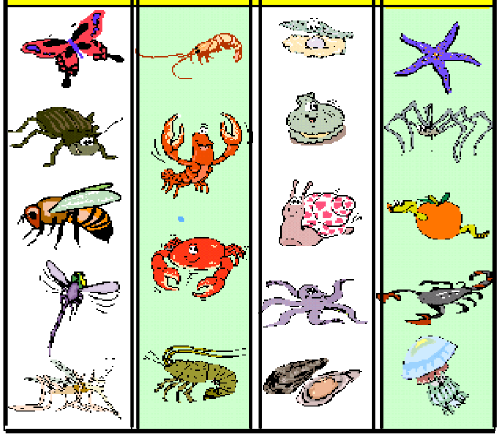
All animals without backbone are refered to as invertebrates. The majority of all living beings (about 97% !) belong to this animal species.

Invetebrates are oposed to and form an affinity group to vertebrates.

Well known examples of invertebrates are insects, worms, mussels, crustaceans (crabs), octopus, snails and starfishes.

List of Invertebrates

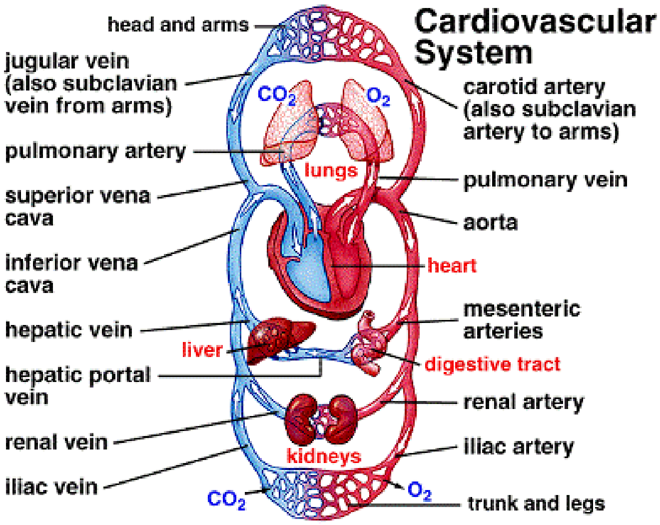
Insects	Crusta-ceans	Mollus-ces	and others



7.1 Respiration of Mammals

277

Mammals: Lung – Heart – Blood circulation – Blood vessels



Supplementary information are contained in the Appendix: p. 7-A-1-1

Veins: Blood vessels which transport blood to the heart. Venous blood is deoxynated blood (CO_2) which travels from the peripheral vessels, through the venous systen into the right atrium of the heart. Venous blood is dark red (here in blue). (However, the pulmonary vein carries oxygen rich blood (s. Figure and Ref. R.7.1.1).

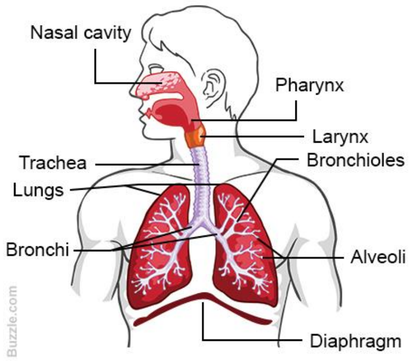
Artery: Blood vessels which transport blood away from the heart. Arterial blood is the oxygenated (O_2) blood in the circulatory system found in the lungs, the left chamber of the heart, and the arteries. Arterial blood is red in colour. (However, pulmonary artery carries deoxygenated blood (s. Figure and Ref. R.7.1.1)).

278

Pulmonary Respiration of Humans - 1

Respiration is defined as the gas exchange in the body: Oxygen (O_2) is inhaled and carbon dioxide (CO_2) is exhaled. Respiration belongs to the vital functions of the body [there are three vital functions for life, namely the brain activity, the respiration and the blood circulation]. By far the gratest part of the external respiration occurs over the lungs. The contribution of cutaneous respiration to pulmonary respiration is only about 1 %.

During inspiration, the air flows through the mouth and the nose and then passes through the pharynx to the larynx; it then passes the vocal cords across the trachea into the bronchia. This air way is also referred to as the respiratory passage. At the end of the bronchia the air enters the pulmonary alveoli from which oxygen enters the capillary vessels of the blood circulation and CO_2 is deposited. Oxygen is distributed over the body by means of the red blood cells.



In the case of normal shallow breathing, the chest is expanded by contraction of the pectoral muscles resulting in a reduced pressure in the lung.

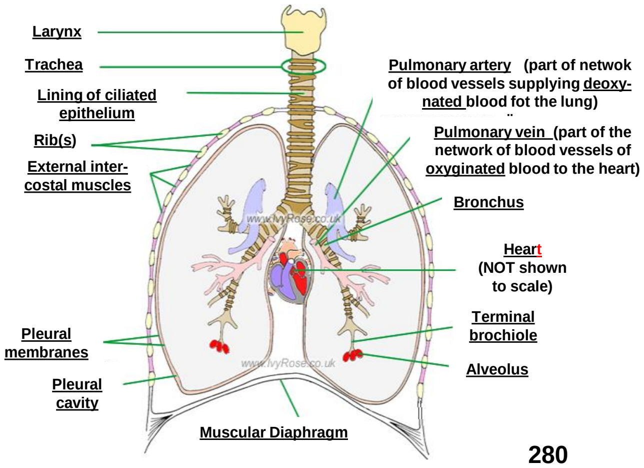
In the case of deep breathing, also called abdominal breathing, the diaphragm contracts, the belly expands forward and the volume in the chest extends downwards.

[Remark: Breathing through the skin of humans is less than 1%]

279

Pulmonary Respiration of Humans- 2

The lung is connected to the ribs, the breathbone and the diaphragm by the plura (a gliding displacement layer) which avoids collapsing.
The respiration is regulated by the respiration center in the extended spiral coral. Here. the CO_2- content in the blood is monitored. If it exceeds a certain limiting value, a respiratory stimulation triggers inhalation. After a brief pause for breath, the pectorial muscles and the diaphragm relax again. The lung extracts by its own elasticity and the air is expelled. The normal breathing frequency at rest is about 12 breaths per minute for adults, about 20 for adolescents, about 30 for young childs and about 40 for babies. An adult male at rest inhales about 500 mL air per breath volume. For a frequency of 12 breaths per minute, this corresponds to a volume of 6 L.



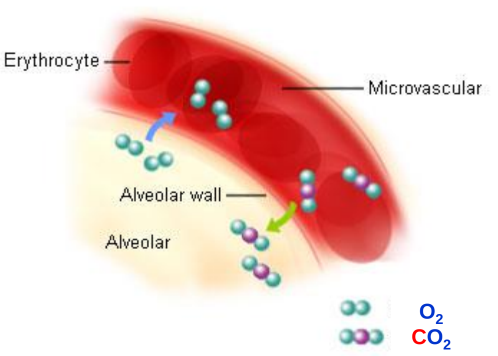
From the alveoli, oxygen diffuses into the blood; this is referred to as external respiration. At the same time, CO_2 leaves the blood and diffuses into the alveoli (s. pp 281, 282).

Besides the exrernal respiration, there is also an internal respiration: Each human cell needs O_2 for live. During metabolism, O_2 is consumed, whereby CO_2 is created (s. pp 281, 282).

280

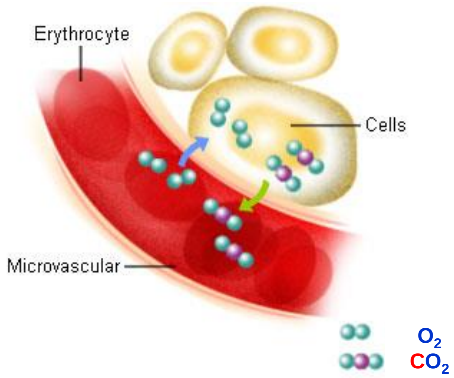
External and internal Respiration

External Respiration



- **Alveoli:** connects with the bronchioles, is where oxygen O_2 diffuses into the blood and carbon dioxide CO_2 diffuses out of the blood.
- **Alveolar wall:** a thin layer of cell, usually about 0.7 µm, which is so thin that O_2 and CO_2 can easily go through.
- **Microvascular:** the smallest blood vascular in the lungs, like capillaries.
- **Erythrocyte:** the red blood cells, contan <u>hemo-globin</u>, slowly go through the Microvascular, release CO_2 and absorb O_2.

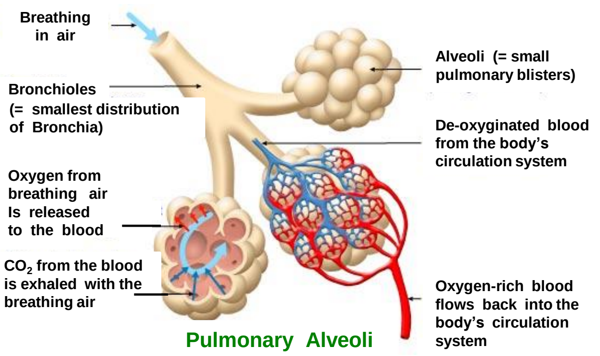
Internal Respiration



- **Cells:** about 10 – 20 µm; cell nucleus of mammels: 5 - 10 µm.
- **Blood pressure:** (blue arrow): pressure that pushes from the blood against the wall of micro-vascular and the tissue.
- **Osmotic pressure:** (the green arrow): pressure hat pushes from the tissue against the wall of micro-vascular and the tissue.

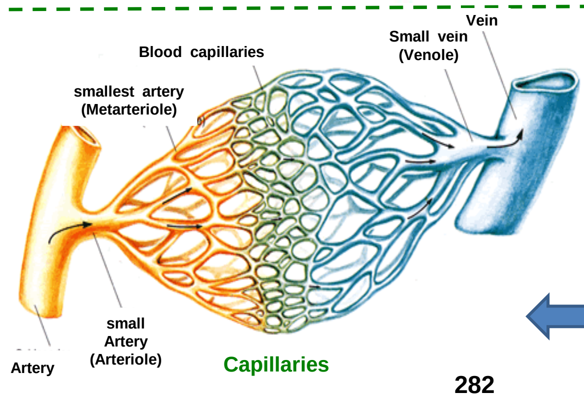
281

Pulmonary Alveoli and Capillaries



The <u>alveoli</u> are the structural elements of the lungs. During respiration, the gas exchange between the blood and the alveolar air takes place.

Alveoli have the shape of tiny bubbles. They are wound around the alveolar ducts like grapes and form alveolar sacks which are attached to the end of the bronchia. A single alveole has a rounded to polygonal basic form. Its diameter ranges between 50 and 250 µm.



<u>Hairpins</u> are microscopally small blood vessels (capillaries). They are connecting the arteria and veins in the blood circulation system. In these capillaries (alveoli), the energy exchange with the body cells takes place.

In the lung, the Alveoli, are enveloped by a network of capillaries (Haargefässe).

After leaving the heart, the blood vessels are getting narrow and narrower. Arteries are narrowing to metarterides (precapillaries) and to arterides before they are linking up to capillaries. The latter recombine to increasingly larger venules and veins.

282

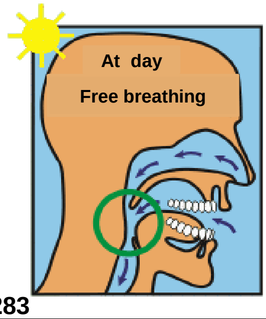
Yawning

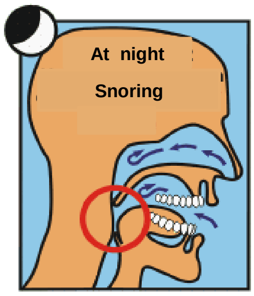
A yawn is a reflex of simultaneous inhalation of air and stretching of the airdrums, followed by exhalation of breath.
Yawing is commonly associated with tiredness, stress. overwork, lack of stimulation and boredom, though recent studies show it may be linked to the cooling of the brain. In humans, yawing is often triggered by others yawning. This «infectious» yawning has also been observed by chimpances and dogs.
The process of yawning starts with a deep breath where the mouth is widely openend and ends by closing the mouth with a simultaneous exhalation of air. It is highly probable that most mammels and even vertebrates are yawning.

Snoring

Snoring: During the day, the muscles are tense and the upper air passages are straightened: The breathing air can flow freely through the nose and the mouth to the lungs (left-hand picture).

At night, however, the body relaxes and the lower jaw sags down and backwards resulting in an obstruction of the respiratory tract. The breathing air must be sucked in with a considerable additional strain. Due to the impeded respiratory passage, large «wind velocities» are generated, putting the uvula (located in the middle of the soft palate) into vibrations. In this way, the snoring noise arises (right-hand picture).

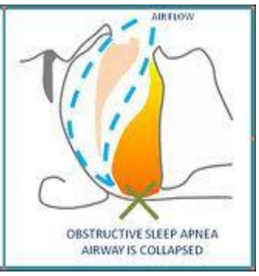




283

Sleep Apnoea and Breath – hold Diving

Sleep Apnoea Syndrom (SAS) is caused by a respiratory arrest (Apnoe) during sleep. The Apnoea leads to a reduced oxygen supply and to repeated wake up reactions. The so-called Obstructive SAS (OSAS) is by far the most frequent form. The direct origin of OSAS is a strong relaxation of the ring-like musculature around the upper air passages during sleep: The upper part of the airways collapses, resulting in a disability (obstruction) of this airway (s. also right-hand picture on p. 283).
The most common treatment is the use of a mask which generates a continuous air-overpressure of about 5 to 20 mbar.



Apnoe–diving: Before free-diving, the diver inhales air and in contrast to the scuba diver he uses only a single breath of air. The time period of holding the breath is referred to as Apnoe. The increase of pressure is one bar per 10 m → pains in the ears → the eardrum would ruptere after a few meters → Diver must frequently adapt air pressure in its pody parts against the external pressure → he presses air out of his lungs into the sensitive cavities. Because of his lungs this works only down to 25 - 35 m → The diver must adapt his body by using complicated equalization techniques e.g. by increasing the elasticity of its chest, midriff, etc.

By using all these adaptations, diving depths of more than 200 meters have been achieved ! The pressure of the water column above the diver is than more than 20 bar ! The dive time is about 20 minutes !

284

The most important pulmonary diseases

Asthma: Bronchia contraction. Trigger: allergies, extreme enduarance sport, stress.
Symptons: sudden shortness of respiration and chronic bronchitis.

Obstructive lung diseases: or Chronic Obstructive Pulmonary Diseases (COPD): It is due to a narrowing of the airways which impedes the air flow. The most important risk factor is smoking, but in addition, air pollution and other factors are contributing. Examples of COPD's are chronic bronchitis and pulmonary emphysema (irreversible hyperinflation of the pulmonary alveoli).

Restrictive lung disorder: Here, the flexibility of the lung is restricted. As a consequence, the volume of the lung and the flexibility to pressure changes are limited. Examples are sarcoidosis (disease of the connecting tissue and granuloma formation), pneumoconisis (black lung) and other diseases which are associated with a fibrosis of the lung tissue.

Pulmonary oedemata: Collection of fluid in the lung tissue. It should be distinguished between two types of oedemata: 1) «Permeability oedemata» in which the permeability of the capillaries is increased, and 2) «hydrostatic oedemata» (cardiogenic pulmonary oedemata, oedemata of altitude); in the latter, the pressure in the capillary strongly exceeds the pressure in the alveoli and the liquid from the capillaries is squeezed out.

Atelektase: Here, part of the lung is collapsed, and the alveoli contain no alveolar air or only very little air (see p. 282).

Inflammations of the lung: Such inflammations are pneumonia, in which the lung tissue is affected, as well as bronchitis, an inflammation of the bronchial tubes. In the case of acute bronchitis, the small bronchia are affected.

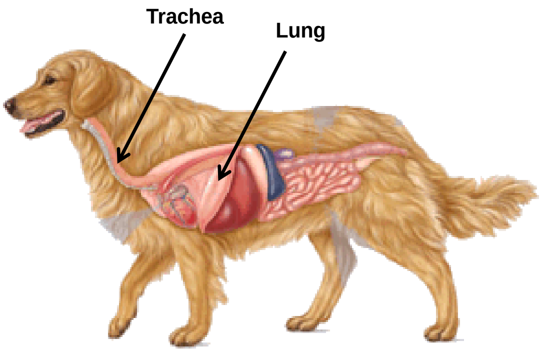
Neoplasms: Cancer diseases of the lung; they are known as bronchial carcinoma because they are due to the malignant growth of degenerate cells of the bronchial tubes or the small bronchia. Lung cancer is one of the most common malignant diseases of humans. Subtypes are: Squamous Cell Carcinoas (SAS), Adenocarcinoma, small and large cell carcinomas. Due to the filter function of the lung, the lung contains often metastases from other tumors.

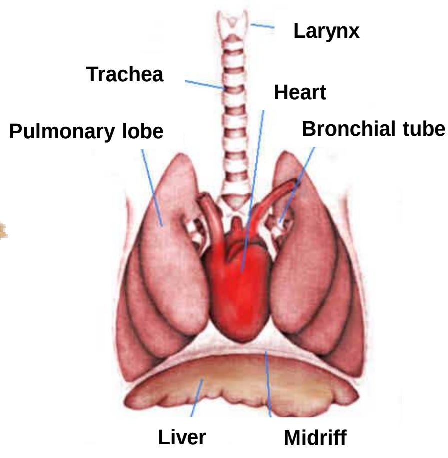
285

The Lungs of a Dog

The lungs of a dog occupy the largest part of the thorax. They are protected by the ribs and consist of 7 pulmonary lobs, three on the left-hand side and 4 on the right-hand side. The fourth lobe on the right-hand side is small and not visible in the picture below. [Note that humans have 3 lobes on the right lung and 2 lobes on the left lung]. The lungs and the bronchia belong to the lower airways.

For many animals, the respiration acts also as a temperature regulator, this is the case for the rapid shallow breathing of dogs. For quiet inhalation and exhalation, the inhaled air volume for one breath is known as the tidal air; for dogs it varies between 0.1 and 0.4 liter.





286

7.2 Respiration of Amphibians

287

Amphibians - Overview

The Amphibians (Toads, Frogs, Salamanders) are the phylogenetically oldest class of terrestrial vertebrates. Many species first spend a larval stage with gill breathing in water and only after a metamorphosis they start to spend a terrestrial live. Amphibians are <u>cold-blooded animals</u>, i.e. their body temperature adapts itself to the ambient temperature. Due to these properties, their scientific name is «Amphibia» (from the Old Greek adjective «amphibios» (dual live): In the course of a year, they often live in both, aquatic as well as in terestrial habitats. Many Amphibians are nocturnal in order to keep water losses over the skin as small as possible. In the following we show some amphibian species:

Common toad

Common tree frog

Fire salamander

Crested newt

288

Respiration types of Amphibian

Depending on the environment and season, adult amphibians have three different respiration systems: skin or cutaneous, oral or buccopharyngeal and lung or pulmonary respiration.

The following, slightly adapted Table from BLAUSCHECK (1985, p. 24 (our Reference. R.7.2.3), contains the percentage contributions of the respiration systems of the adult amphibians shown at p. 288.

Examples / Resp. organ	Skin	Oral respiration	Lungs
Common toad	27.6 %	0.9 %	71.5 %
Common free frog	24.2 %	1.1 %	74.7 %
Fire salamander	41.4 %	1.3 %	57.3 %
Great crested newt	73.7 %	3.0 %	23.3 %

1. In Skin or cutaneous respiration, gases are exchanged through the skin, which many types of the anphibians use including toads, frogs, salamanders and newts. In cuteneous respiration, gases pass through the skin and directly into blood vessels. This type of respiration is controlled by capillarity density, amount of blood flow and blood vessel radius. Cuteneous respiration also allows amphibians to breath underwater, as oxygen dissolved in the water is captured by the amphibian's skin.

2. In Oral or buccopharyngeal respiration, gas is exchanged between the buccal and the pharynx through rapid pulses in the trhroat. Air is first sucked in through the nostrils to fill the buccopharyngel cavity, then the throat is contracted. This forces the air from the buccopharyngeal cavity into the lungs, which expel the air through the throught. This type of respiration is less common than cutaneous but is present in most species of frogs .

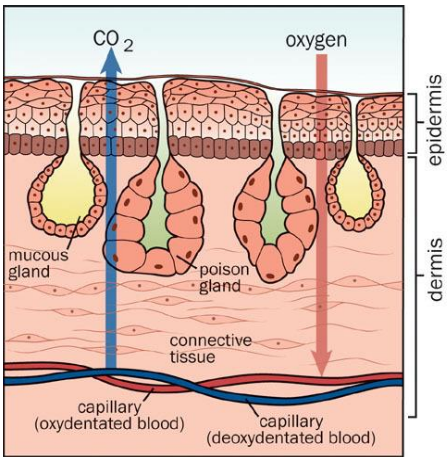
3. Pulmonary respiration is the use of simple paired lungs like most land-dwelling animals. In amphibians, pulmonary systems are most often found in some species of salamanders and caecilians, the worm-like amphibians. In caecilians, especially those with thin bodies, the left lung is usually larger than the right. [common caecilians = Erdwühlen].

289

Cutaneous respitation of Amphibians: Cross-section through skin

The thin moist skin of Amphibians is excellentely suited for the process of respiration. Subdermal, a dense capillary network is present which enables an exchange of substances by diffusion. This means that O_2 can be absorbed through the skin while CO_2 is desorbed. The absorption of O_2 through the skin is a passive process.
Many amphibians, in particular frogs, are moistening their skin with a slicky mucous layer, which is produced by the mucous gland. This is an effective means to escaping predators and sustains the skin respiration. The poison glands are emitting a skin poison which is a protection against animal grub.

For very small amphibians, cutaneous respiration is particularly important because in this case, the ratio of surface F to volume V, F/V, is large (for a sphere with radius R we have $F/V = 3/R$ while for a cylinder with radius R and length $L >> R$, $F/V \approx 2/R$); the smaller R, the larger is F/V.



The skin of amphibians may exhibit a wide variety of colors and patterns. In many species, these characteristics help them blend into their natural environments in order to avoid predation. However, certain amphibians display bright warning colora-tions and patterns that may include hues of red, yellow, orange, and black, which serve as bright signal to predators that they may be poisonous. Indeed, several species, such as the cane toads and poison arrow frogs, are equipped with skin glands that secrete powerful toxins.

290

7.3 Respiration of Reptiles

291

7.3.1 Reptiles – Some Examples

Reptiles or crawlers form a class of vertebrates between the lower (anamnia) and higher (amnions) vertebrates. Examples are Lizards, e.g. true Lizards, Varanides and the Chameleon. Other examples are Crocodiles, Turtles and Snakes.

True lizard

Veranus giganteous (with a length of up to 3 m and a mass of 70 kg)

Chameleon

Crocodile
(largest and most dangerous lizard!)

Turtle

Snake: Cabe cobra

292

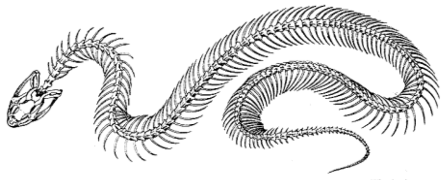
Reptiles – General Properties

As amphibians, reptiles are cold-blooded animals which regulate their body temperature as far as possible according to their behaviour and environment. Among others, animals such as lizards, chameleons, crocodiles, turtles and snakes belong to the class of reptiles (s. p. 292).

What reptiles all have in common is the scaling of their skin. Concerning their external shape, they have, however, little in common: Their external forms are, indeed, very different, starting from the wormlike blindworms and snakes to the foor-fooded lizards (to which also the crocodiles belong) and to the turtles. With the exception of the latter, the bodies of all reptiles are elongated; in addition, they are completely footless (snakes) or they have two or four extremities which often serve only as a support of the body gliding over the floor. In addition, however, there are also numerous walking or running species, as well as climbing and digging reptiles; many reptiles are also able to swim and to dive skillfully. In the primeval world also flying reptiles existed.

Their skeleton is almost completely bony, implying that reptiles belong to a higher stage than amphibians; they contain many cartilagenous parts. Ribs are present over nearly the whole length of the torso.

Scaling of the Inland Taipan snake



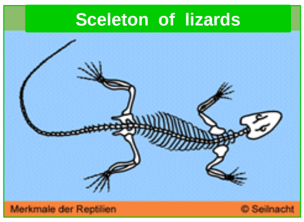
Skeleton of a snake consisting of flexible and connected vertebrae

Even at the young age, the lungs are providing the respiration; as a rule the lungs have the form of long, capacious sacks which extend well to the back of the animals (s. pp 302, 303).

293

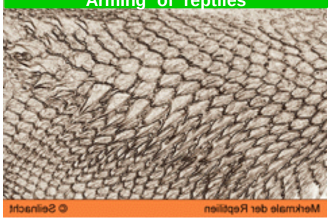
Characteristics of Reptiles

Sceleton of lizards



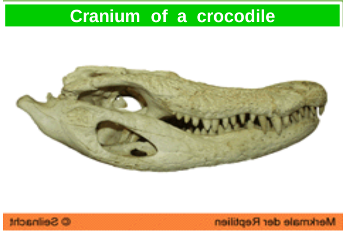
1) The extremities are armed with claws; these claws are a characteristic of lizards and other reptiles.

Surface structure of the Arming of reptiles



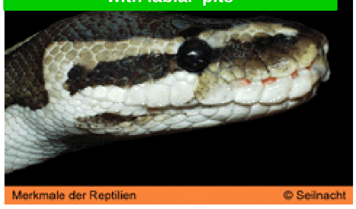
2) The skin is covered with scales of horn → effective protection against evaporation.

Cranium of a crocodile



3) The formation of a set of teeth is a further characteristic of reptiles → for hunting the prey.

Head of a phyton snake with labial pits



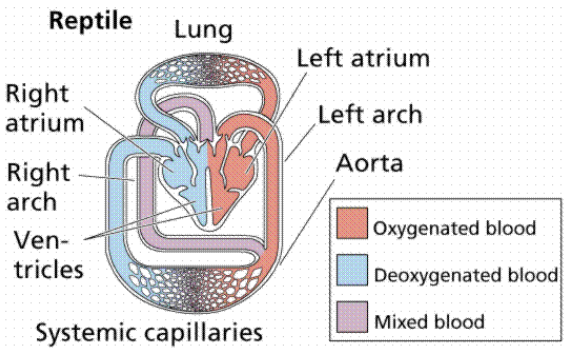
4) Venomous snakes have a sophisticated system of smell organs for the detection of their prey.

5) Reptiles have lungs with large indentations; each of which is folded ones more. This folding considerably increases the surface of the lungs.

6) Mammals have a substantially greater demand of oxygen and the lungs are strongly branched out. → Immense large number of pulmonary alveoli.

294

Respiration of Reptiles: General



The lungs of reptiles are large, and they are often divided internally into several chambers. The lining of the lungs may be folded into numerous small sacs called alveoli. Alveoli greatly increase the internal surface area of the lungs, thus increasing the amount of oxygen that can be absorbed. In most snakes, only the right lung actively functions (s. p. 303). It is elongated and may be half as long as the body. The left lung is either reduced to a small nonfunctional sac or absent entirely.

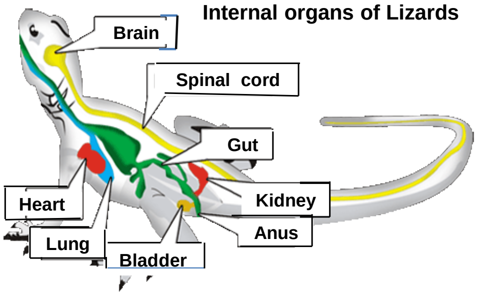
A reptile fills its lungs by expanding its rib cage. This expansion reduces the pressure within the thorax and draws air into the lungs. When the ribs return to their resting position, pressure within the thorax increases, and air is forced out of the lungs. Similar movements help humans to breath.

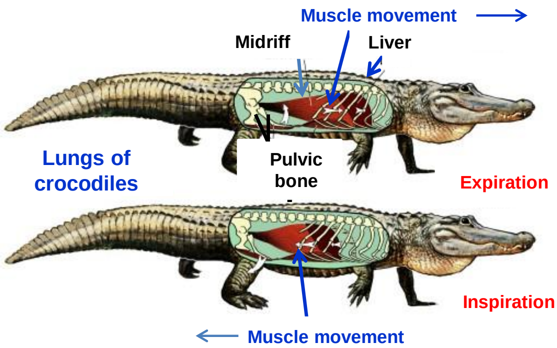
[right (left) arch: rechter (linker) Bronchialbogen); right (left) atrium): rechter (linker) Vorhof]

295

7.3.2 Respiration of Lizards

All crawlers. including lizards, have simple and structured lungs. However, their lung is already more developed than the lung of amphibians. The lung of crawlers is divided into a few chambers and their internal surface is increased by folds.





Crocodile: the sun worshipper

If crocodiles are breathing, they are supported by a refractor muscle which is comparable to our midriff. During inhalation, the muscle retrieves the organ and the air is sucked into the lungs. During exhalation, the liver is moving forward similar to a pump plunger. If crocodiles are walking, the swinging hips support the pumping function. In this way, running animals can even support their breath. Their breathing frequency increases and the air is inhaled more deeply.

296

7.3.3 Tortoises and Turtles - General

Turtoises and turtles are both reptiles from the order of Testudines, but in different classification families. They are one of the oldest animals of the world and exist about 150 Million years on Earth.

The major difference between the two is that tortoises dwell on land, while turtles live in the water some or nearly all the time.

The most obvious featur of any turtoise or turtle is it's shell; the dome-shaped shell is the animals primary defense mechanism against «would-be predators» (potential enemies). These reptiles are generally reclusive and shy in nature.

With a few exceptions, tortoises and turtles are lung breathers. They are cold-blooded and diurnal animals

Turtoises

Turtles

297

Tortoises: Properties and Examples

True tortoises are the testudes which are best adapted to a terrestric way of life. Already the ancient tortoises were terrestrial animals; this has been demonstrated by findings from the late Triassic. Today, 16 genera containg 48 species are known which are mainly living in the Tropics and Subtropics. The Egyptian tortoise (left-hand picture) belongs to the smallest tortoises. On the other hand, the largest tortoise is the giant Galápagos tortoise (right-hand picture); the latter animals can have a mass of up to 250 kg. [The largest tortoise of all times is said to be the now extinct Testudo atlas with a carapace length of 2.5 meters].

Egypten tortoises:
(mail: 9-10 cm, female up to 13 cm)

Galápagos giant tortoise with some specimens exeeding 1.5 meters in length

Tortoises have most often a high domed shell and are both, plant eaters as well as scavengers. For this reason they can walk at slow pace from one plant to the next one. As vegetarians there is no need to rush. Their legs are wide and their hind legs are columnar.

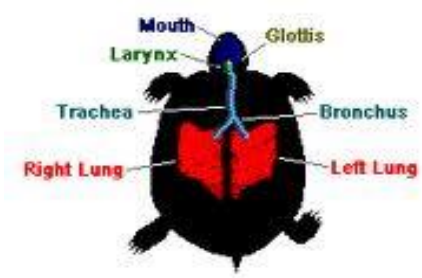
298

Respiration of Tortoises (and Tortles)

Mouth and Pharynx: Cavities inside the skull where food, water and air enters.

Glottis: Slit-like opening behind the tungue. It connects the pharynx (Rachen) and larynx (Kehlkopf). It closes when the turtle is underwater or eating.

Larynx: The upper end of the respiratory duct. It is connected to the glottis and leads into the trachea.



Trachea and Bronchii: The trachea is a long hollow tube between the lungs and the larynx. Halfway down, it divides into two tubes, called bronchii. One bronchus enters the left lung, the other the right lung.

Right and Left Lungs: Air passes from the bronchii into smaller tubes in the lungs called bronchioles. The bronchioles get progressively smaller and they end into a small cluster of air sacs. These air sacs, known as alveoli (see p. 282 for humans), located at the end of the bronchioles are where gases are exchanged. Oxygen (O_2) from air disolves into the blood, while carbon dioxide (CO_2) dîffuses out of the blood into the air.

299

Freshwater Turtles and Seawater Turtles

Among the Turtles there are freshwater turtles and seawater turtles. Turtles are hunters because in the aquatic element, they can reach considerable speeds. Their shells are shallower and more streamlined as those of the tortoises and their feet are fin-shaped, i.e. they have webs between the claws.

Their eyes are adapted to the life element of water: the lens of their eyes adjusts the angle of refraction of water and therefore, turtles are able to see clearly also underwater.

Marine turtles are laying their eggs ashore, most often at the place of their birth. For this purpose, they are often swimming several thousends of kilometers. The most well-known marine turtles are the «Hawksbill turtles», and the «Green sea turtles» (s. p. 301). The «Leatherback sea turtle» is also a remarkable species. It is the largest still living turtle reaching a mass of up to 750 kg!

Freshwater Turtle:
(Geoclemys hamiltonii)

Seawater Turtle: Torteiseshell Turtle
or Hawksbill Turtle

300

Respiration of Turtles

«Common musk turtles» are freshwater turtles and are able to stay underwater up to half a year without breathing. Their size is only about 7.5 - 10 cm and they are one of the smallest species of turtles. They are characterised by a lobed surface (papillae) of the oral cavity and pharynx space which is infused by small blood vessels. These papillae are thouroughly rinsed since the turtles supply their pharynx regularly with fresh water. Due to the large surface of these papillae, an exchange between O_2 and CO_2 is possible, i.e. the animals have developed something similar to gill breathing.

Many marine turtles are able to dive several hundred meters and do not require oxygen for several hours; the green sea turtle can stay under water up to 5 hours. This is possible by the slowdown of their heartbeat. During such extreme dives, the heartbeat is drastically reduced (9 heartbeats per minute). By taking breath, the lung deflates in a single breath and refills immediately.

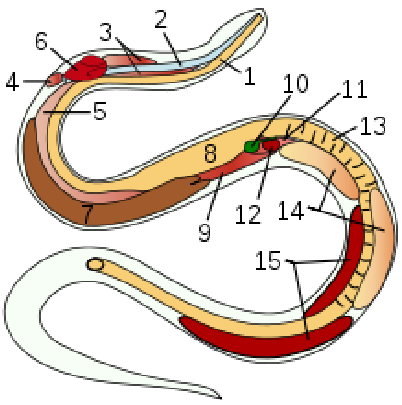
Common musk turtle, a freshwater turtle (Moschusschildkröte)

Green sea turtle: a marine turtle

7.3.4 Snakes

Snakes are a suborder of scaled reptiles. They are descnding from lizard-like ancestors. In contrast to lizards, their body is greatly enlarged and their extremities are nearly rudimentary. Today, about 3'000 species are known. Depending on the species, the size of snakes ranges between 10 cm for the slender blind snake and nearly 7 m for the reticulated phyton.

Due to their body shape, most of the internal organs are elongated. The left lung is underdeveloped. For respiration, only the right lung is essentially used. It extends up to two third of the body length.



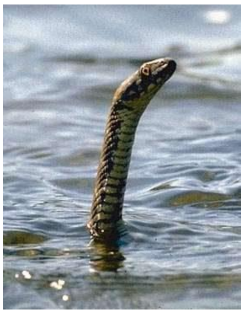
Anatomy of a Snake

1 Esophagus
2 Trachea
3 tracheal lung
4 rudimentary left lung
5 right lung
6 Heart
7 Liver
8 Stomach
9 Air sack
10 Gallbladder
11 Pancreas
12 Spleen
13 Intestine
14 Testicles
15 Kidneys

In the back, the trachea ends in an Air sack from which the snake can cover its oxygen demand in specific cases. (This may be the case during swallowing a large pray where the trachea is sometimes compressed; it also is a source of air for sea snakes in the case of long immersion times in the water). For sea snakes, the Air sack serves in addition as a hydrostatic organ.
As most of the reptiles, snakes are also cold-blooded animals.

Snake Respiratory System Anatomy

Glottis of a snake



Air breathing water snake

Snakes have a small opening just behind the tongue called glottis, which opens into the trachea (p. 302), or windpipe. Unlike what mammals have, the reptile glottis is always closed, forming a vertical slit, unles the snake takes a breath. A small piece of cartilage just inside the glottis vibrates when the snake forcefully expells air from its lungs. This produces a snake's characteristic hiss. Snakes are able to extend their glottis out of the side of their mouth while they eat, which allows for respiration while they consume large prey items.

The trachea is a long, strawlike structure supported by cartilaginous rings. This configuration is also seen in lizards. The trachea usually terminates just in front of the heart, and at this point it splits into the two prîmary bronchi, airways that direct air into either the left or reight lung.

In most snakes, the short left bronchus terminates in a vestigial, or rudimentary, left lung. The size and functional capacity of this lung varies depending on the species. It can be complete in some of the water snakes where it is used for hydrostatic purposes. The right bronchus terminates in the functional right lung. Water snakes can dive up to 180 meters and for breathing, they must return to the water surface only after 30 minutes to two hours (see picture).

Snakes breathe principally by contracting muscles between their ribs. Unlike mammals, they lack a diaphragm, the large smooth muscle responsible for inspiration and expiration between the chest and abdomen. Inspiration is an active process (muscles contract), whereas expiration is passiv (muscles relax).

The portion of a snake's lung nearest its head has a respiratory function; this is where oxygen exchange occors. The long portion nearest the tail, regardless of the lung's size, is more of an air sac (p. 302). The inside of these sac portions look more like the inside of a balloon than a lung. There is no exchange of respiratory gases.

303

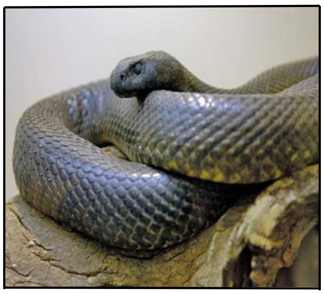
Venomous Snakes

Worldwide, about 3'000 species of snakes are known. About 1'300 of them are vemomous snakes. The latter occur in the following families:

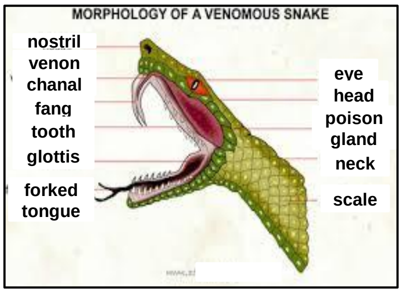
Venomous viper snakes with 2 subgroups:
a) Poisonous vipers (e.g. Mamba, Cobra, Coral snake)
b) Sea snakes (e.g. Late Taale snake, Flate-tailed Sea Snake, Taipan, Brown Hous Snake, Tiger snake)

Vipers with 3 subgrouβs:
a) Fea vipers (e.g. crossed viper, aspis viper, field viper, puff otter, saw-scaled viper)
b) Pit vipers (e.g. Rattle snake, Moccasins, ance-head viper, bamboo viper)
c) Original vipers: (mole viper; only one species)

One of the most venomous snake is the Inland Taipan of Australia and certain Sea snakes. The poison of the Inland Taipan emitted by one bite of a completely charged gland is theoretically sufficient to kill about 250 humans, 250'000 mice or 150'000 rats ! The Faint-Banded Sea Snake is even said to be about 100 times more toxic than the Inland Taipan and makes it the most poisonous snake of the world. But this snake seldom bites unless severely provoked and even then seldomly releases its entire store of venom.



Inland Taipan



Head of a poisonous snake

Faint-Banded Sea Snake

304

Snakes in Mythology and Snake poison in Medicine

Adam und Eve (Michelangelo)

Adam und Eve first live in the «Garden of Eden». Contrary to God's ban, the snake convinced them to eat from the «Tree of Knowledge». As a punishment, God expels Adam and Eve from the paradise.

Medusa's head (Rubens)

In the late classical Greek mythology, Medusa was first an incredible beauty. But when Pallas Athene surprised Poseidon during forcible rate of Medusa, she was extremely furious and turned Medusa into a monster: each wavy lock of her hair was changed into a venomous snake.

Left: Aesclepius with its staff of Aesclepius. In the Greek mythology, Aesclepius was the God of medicine. He was represented as a bearded man supporting himself on a staff around which a nonvenous snake was curled.
Right: Aesculapian snake with a drinking bowl as a symbol for a pharmacist The distinguished physician Paracelsus (1493-1541) coined the words: «Poison is in everything and no thing is without poison. The dosage makes it either a poison or a remedy».
Ambivalence: The poison of snakes is a further example of ambivalency: In small doses, snake poison can be be used as a medicine.

305

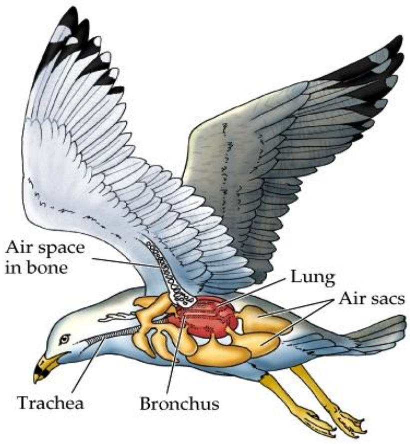
7.4 Respiration of Birds

306

Respiration of Birds: General

In contrast to mammals, the lungs of birds are incorporated rigidly in the thorax. Although the pleura is present in the embrionic stage, it then regresses. The avian lung is not lobed and during respiration, its volume does not change.

At the furcation of the trachea, the air-conducting system branches into the two main bronchi. This is also the location of the vocal organ. From the main bronchi, four groups of secondary bronchi are branching out. The secondary bronchi are followed by parabronchi; the thickness of the latter ranges between 0.5 to 2 mm.

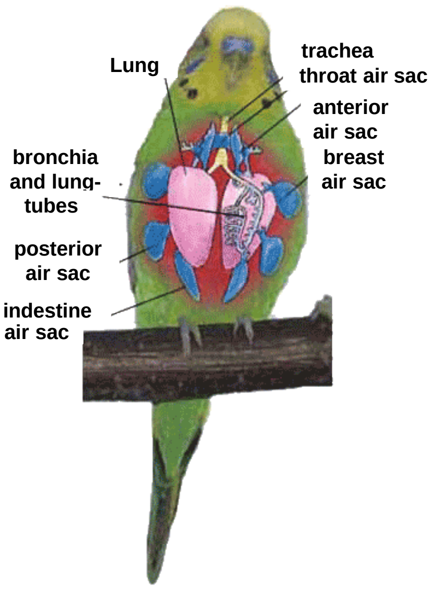


In the wall of the parabronchi there are small funnel-shaped bellmouths which are leading into the air capillaries. Normally, the air capillaries form a network of communicating pipes and function as the essential exchange tissue. Around this tissue, a dense network of blood capilla-ries is present.

In contrast to mammals, the respiration system of birds is not blind ending but it is rather an open tubular system. After perfusion of the lung, the air enters air sacs which function as air blowers for ventilation.

307

Respiration of Birds: Lungs and Air sacs



Respiratory system of Parrots

The air sacs of birds are thin-walled attachements of the lungs which conduct the air through the lungs similar to bellows. But in the air sacs no gas exchange takes place. These sacks are very thin with transparent walls. Beside their function as a «motor for respiration», they are also involved in the formation of the voice: high frequency expi-rations are modulated in the syrinc to produce the bird song. The third important function of the air sacs lies in their involement as thermoregulators by rejection of heat via evaporation (evaporation based cooling).

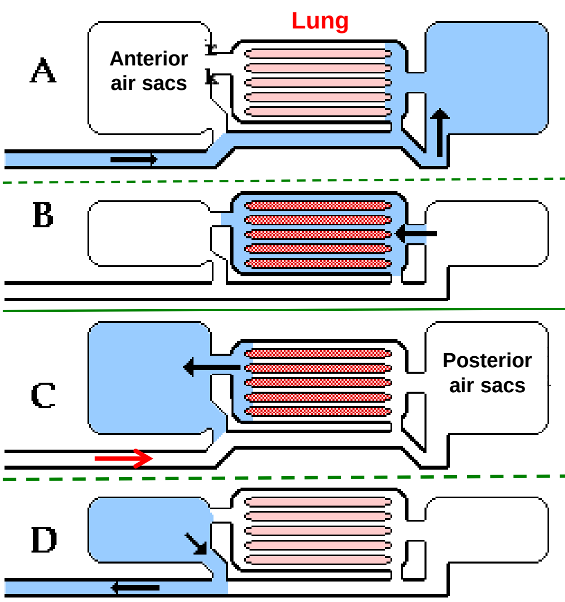
The anterior air sacs are located between two membranes of connecting tissue inside the thorax and embrase the heart and the true stomack. In the case of singing birds they are merging with the air sac of the collar bone.

The positions of the posterior breast air sacs are directly near the body wall and they are located behind the anterior air sacs.

The abdominal air sacs are thin balloons which are located between the intestinal loops and are pneumatizing the pelvic-girdle.

308

Respiratory cycles of Birds



A – First inhalation: Oxygen-rich air flows into the posterior air sacs. This is associated by an expansion of the air sacs.

B – First exhalation: Air is pressed into the lung capillaries. → Blood is supplied with O_2 and the air sacs are contracting.

C – Second inhalation: CO_2- enriched air is flowing into the anterior air sacs which expand again. At the same time, new oxygen-rich air (red arrow) is flowing into the posterior air sacs.

D – Second exhalation: From the anterior air sacs, O_2- depleted and CO_2- en-riched air is pressed out and the air sacs are contracting again.

For more detailed explanations s. p. 310.

309

Synchronization and Air Current in the Respiratory System

The air which a bird inhales with the first breath of air (process A in the diagram of p. 309, shown in blue), is flowing unidirectionally through the air sac - lung system: The individual steps [(A,B) and (C,D)] are the following: From the trachea, the air is first flowing into the posterior air sacs, which then extend together with the anterior air sacs. This corresponds to the first inhalation. In process B, the air flows into the lung (first exhalation) and thereby the air sacs are contracting. In process C, the air flows into the anterior air sacs whereby the air sacs are expanding again. In a second inhalation, fresh air is simultaneously entering again through the trachea (red arrow). Therefore, the first and the second inhalations are synchronized. Finally, the air is leaving the anterior air sacs and escapes into the atmosphere as illustrated in process D.

In processes A and [(A,B) and (C,D)], oxygen-rich air is enhaled while in the final process D, oxygen depleted and carbon dioxide enriched air is leaving

These processes have been experimentally confirmed: Oxygen sensors have been placed at different positions in the bird's respiratory system. In this experiment, the bird is inhaling pure oxygen in one breath which is followed by one breath of normal air. The oxygen sensors located at different sites are recording the times at which the pure oxygen reaches the sensors.

To sum up, it can be concluded that the air is flowing unidirectionally from the posterior air sacs through the rigid lung to the anterior air sacs. The total air flow contains two cycles (A,B) and (C,D); in each cycle there is an inhalation and an exhalation.

The combination of the small weight of the air sacs, the small weight of the hollow bones and their wings (Chapter 4, pp 148, 149) makes birds to be masters of flight.

310

7.5 Respiration of Fish

311

Systematics of Fish

Fish are aquatic living vertebrates which are breathing with gills (pp 316, 317). Lungfishes are also primary gill breathers in water but in addition they are also air breathing if the tip of their snout barily touches the water surface (s. p. 319). Two species of fish are distinguished, namely cartilaginous fish and bony fish (Osteichthyes); s. p. 315.

Fish

Cartilogenous Fish

Living almost exclusively in the Sea:

- Sharks
- Rays
- Chimaeras

Osteichthyes or bony Fish

Lobe-finned Fish

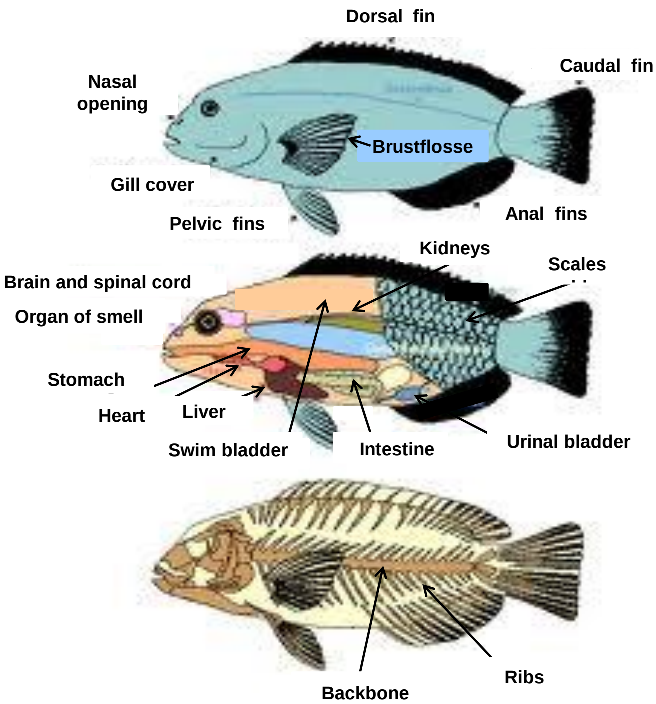
- Marine coelacanths
- Lungfish

Ray-finned Fish

- All other fish groups, including all European freshwater fish

312

Physiology of Fish



External appearance

Internal organs

Skeleton

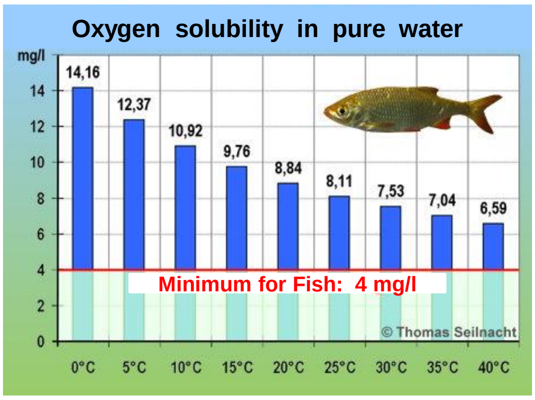
313

Oxygen concentration in Freshwater and Seawater

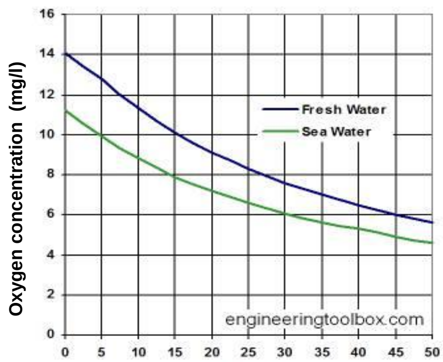
The oxygen content in air is about 21%. If air is in contact with pure water, oxygen (O_2) diffuses from air into water: The solubility of O_2 depends on temperature θ (in °C), on the atmospheric pressure P in Torr (760 Torr = 1 atm = 1013 hPa), and from the vapour pressure p of water (in Torr). There exist empirical approximate formulas for the «Dissolved Oxygen» DO in mg/l:

For $0°C < \theta < 30°C$ we have: $DO = [0.678 * (P – p) / (35 + \theta)]$
For $30°C < \theta < 50°C$ we have: $DO = [0.827 * (P – p) / (49 + \theta)]$ (s. Graphs)

In the Word's oceans, the oxygen concentration is smaller than in freshwater (s. right-hand Graph). With increasing depth below sea level, the O_2- concentration decreases and at about 1000 m below sea level it reaches a minimum; With increasing depth, however, the O_2-concentration increases again (s. Appendix 7.A.5.1).



Temperatur θ (^{0}C)



Temperature θ (^{0}C)

314

Differences between bony fish and cartilaginous fish

With a few exceptions, bony fish have air bledders, gill covers, scales and movable pectoral fins. The morphology of cartilaginous fish is different.

Because of the gas-filled air bledder, most bony fish are able to swim in different water depths without problems. For most bony fishe the function of the air bladder is the regulation of their density in such a way that they can easily float in water or sink slowly to the floor. However, not all bony fish dispose of an air bladder: fish species living on the ground or fish which are able to swim particularly well can renounce on an air bladder.

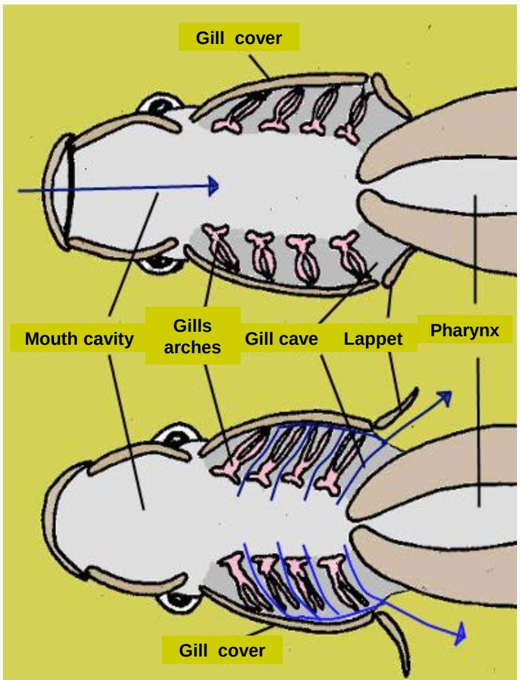
For the cartilagenous fish, the situation is even simpler: They do not require at all an air bladder because they have a low-weight sceleton of cartilage. In addition, their large and fatty liver generates a stronger buoyancy. As external characteristics, the immovable and often deck-like profile of the pectorial fins as well as the asymmetric caudal fins are an additional advantage. Sharks belong to the species of cartilogenous fish.

Their is also a disadvantage associated with the immovable pectorial fins: many cartilagenous fish are unable to swim backwards. But on the other hand, they are most often very flexible and fast swimmers.

Cartilagenous fish have a gill cover which covers the gill arches; between the gill arches there are slits, the so-called gill slits. Their skin is also different: while bony fish have scales, cartlagenous fish have a very leathery skin which consists on tooth-like scales. As an example, sharks are covered with such tooth-like scales.

315

Gill breathing of Fish



Waterway for gill breathing of fish

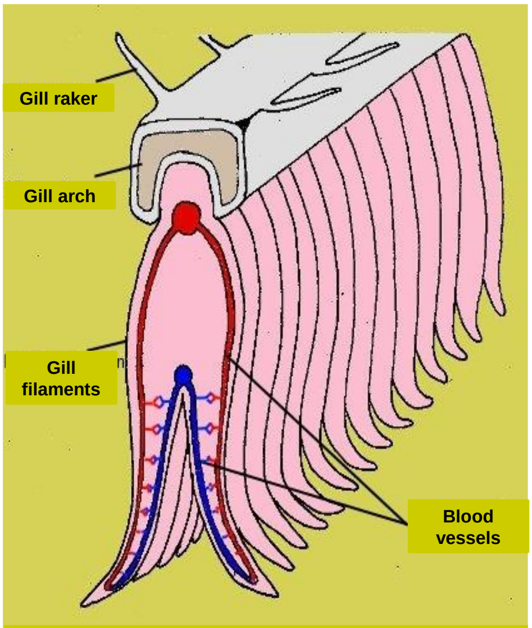
For many aquatic animals, gill breathing refers to the exchange of the gases O_2 and CO_2 between the blood and the ambient water. If water flows into the gills, O_2- rich water gets into contact with de-oxynated blood. This difference in partial pressure gives rise to a diffusion of O_2 dissolved in water into the blood. As a result of the counterflow, the blood leaving the gills contains more O_2 than the water streaming out.

As shown in the pictures, fish have 4 bony gill arches at each side which are located behind the gill covers. At the gill arches, the gill filaments are located (s. Figure at p. 317). The latter are filtering the water passing by, similar to the prongs of a comb. By this filtration, the sensible gill filaments are protected from dirt particles contained in the water (Figur p. 317).

Upon opening of the mouth, water is streaming into the mouth cavity. Upon closing the mouth, water passing the gills is pressed through the gill caves into the exterior air. Thereby, the gill covers are slightly lifted and a (skin) lapped is fold back. During the respiration process the pharynx remains closed.

316

Gill arch and gill filaments



Gill arch and gill filaments

The O_2– uptake and the CO_2- release takes place during the time in which the water is flowing around the gill filaments. In the gill filements, there is a large number of blood vessels. In the illustration on the left, they are shown in red and blue. If during the respiration process, water is flowing around the gill filements, oxygen diffuses from water into the blood vessels (shown in red). At the same time, CO_2, which has been produced as a waste product during the metabolism is released from the blood vessels back into the water..

The gill filaments are the lungs of the fish. They can work only in water. On land they would quickly stick together and the fish would inevitably suffocate. If the O_2– concentration in water is too small (< 4 mg/L, s. Graph, p. 314), the fishes will also suffocate in this water, particularly in view of the fact that the expen-diture of energy for breathing in water is signi-ficantly larger than in air.

Due to particular accomodations, some fish species are able to leave the water for longer periods of time. One possibility to achieve this is to supply their breathing water in the gill caves a second time with oxygen.

317

Sharks and Whales

White Shark – Sharkes are Fish

Breathing of sharks: Roughly, it can be distinguished between Whitetip sharks and Deep-see sharks.

Whitetip sharks have to be always in motion in order not to suffocate; for this reason, the are sleaping also during swimming. They are swimming with open mouth. Therefore, water can penetrate through the pharynx into the gills. Thereby, water is de-oxygenated and oxygen is transferred into the blood.

Deep-sea sharks are closing and opening the mouth alternatingly. Thereby, a suction is produced. Thus, they take care themeselves for the water influx. During this procedure, they use the oxygen dissolved in water. Sharks are cartilaginous fishes (s. p. 312).

Killer Whale - Whales are mammals

Whales are not fish but rather mammals which are living exclusively in water. As all mammals, whales are breathing air and have lungs. Whales are warm-blooded animals. Some species of whales belong to the largest animals of the Earth (Blue whales have body lengths up to 33 m and weihts up to 200 tons!

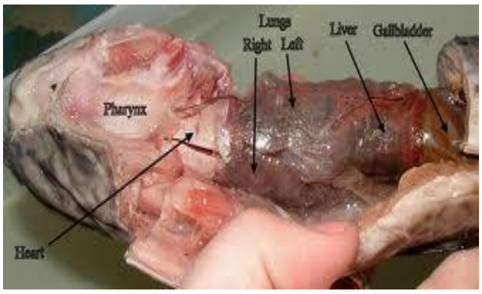
For breathing, whales have to expose their head above the water surface. They are first breathing out, whereby they are blowing a large water cloud into the air. If whales are taking air, they exchange 80 to 90 % of the air contained in the lung (for humans: only 10 bis 15 %). Sperm whales are able to dive up to 90 minutes and reach depths up to 3'000 m ! Bottlenose whales are able to dive with a single breath up to 2 hours!

318

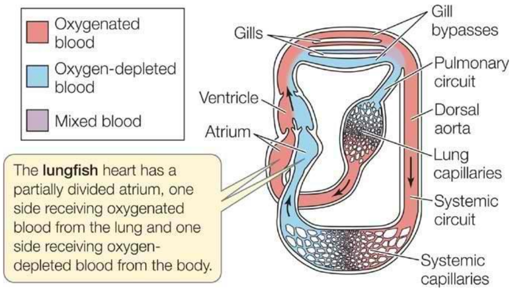
Lungfish

Lungfish are a subgenus of osteichtyes. They are «animals dipnoe» (double breathers) because they have both, gills for breathing in water, as well as lungs for breathing air at the surface of water. The lung of these animals is an organ located in the indestine which is homologous to the air bladder (s. p. 315). The Australian lung fish has a single lung. All other species (for example African lung fish) have lung pairs which are located ventrally. For breathing air, lung fish ascend every 30 zo 60 minutes to the water surface. Some species depend on pulmonary respiration. If they are kept too long under water, they are drowning – a very particular property for fish.

The two lungs of African lung fish are placed verically at the forearm. They have internal gills, which are, however, strongly receded and are therefore only partially available for gas exchange. Breathing through the skin is also of importance: by cotaneous respiration, they extract dissolved oxygen from water. The lungs are primarily used during rapid hunting, if they are scared up and during the dry season (aestivation.



Right and left lung of an African lungfish



Respiration system of «double breathers», consisting of gills and lungs

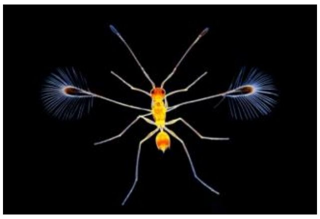
7.6 Respiration of Invertebrates

320

7.6.1 Invertebrates - General and Examples

The prevailing part of all animal species are the invertebrates. Today, about 95% of all known animal species belong to the invertebrates. Beside the absence of a backbone, these animals have in general not much in common. The largest invertebrate is the «Giant Squid» which can have a length of more than 16 meters, but it should be noted that this is a great exception. Most of the invertebrates are, however, very small. One of the smallest insects is the fairy wasp or fairyfly with a length of only 0.14 mm.

Giant Squid



Fairywasp or Fairyfly

321

Invertebrates: Examples

- Mollusces (for example: scallops, snailes)
- Arthropods
  - Insects (for example: ants, butterflies)
- Ringed worms (for example: leech)
- Cnidarians (for example: jellifish)
- Protezoa (for example: amoebae)

Snail (Mollusces)

Ants (Insects)

322

Respiration of two Mellusces: Giant Squids and Snails

Section 4.2 was devoted to flying and gliding of invertebrates. In this Section we discuss the breathing mechanism of some selected invertebrates; firstly we consider two mollusces, and then some Insects.

About Respiration of a Giant Squid

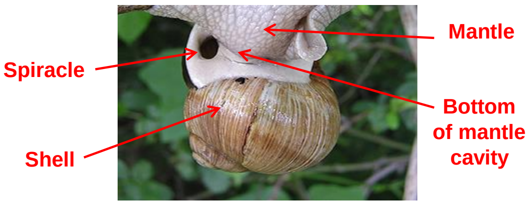
The Giant Squid is a cephalopod («Kopf-füssler»). Their gills are the primary respiratory organs. A large gill surface and a thin tissue of the gills allows an effective gas exchange both for O_2 as well as for CO_2. Since the gills are located in the mantle cavity, breathing is coupled to the movement: Thus, ventilation is not possible without moving. Therefore, they are obliged to swim continuously.

Giant squid: Clutches and suckers

About Respiration of a vineard Snail

For breathing in, the snail is lowering its mantle cavity at open spiracle, thereby creating a low pressure whereby oxygen-rich air flows in (s. Figure).

The gas exchange takes place at the top of the mantle cavity where oxygen diffuses from the respiratory air into the blood. In the opposite direction, CO_2 diffuses from the blood into the air. The respiratory organ is known as the internal lung although it is more similar to a single pulmonary alveoli.



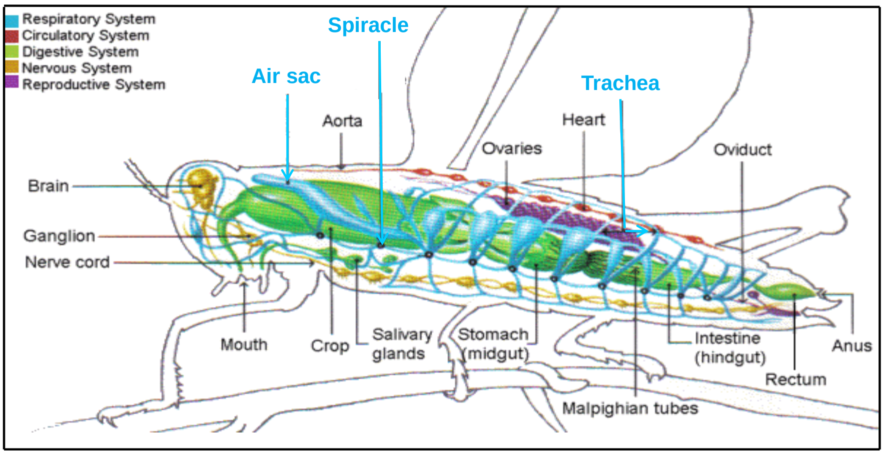
Shell orrifice of a vineard snail with mantle and spiracle

323

7.6.2 Respiration of Insects

In Chapter 4, Sections 4.2, we have discussed the flight of insectes. Here, we are interested in the process of respiration. Of course, we have to distinguish between land-living insects and aquatic insects. We first consider the breathing of land-living insects. (Breathing of aquatic insects is discussed at pp 332, 333 and in the Appendix 7-A-6-2, 7-A-6-3).

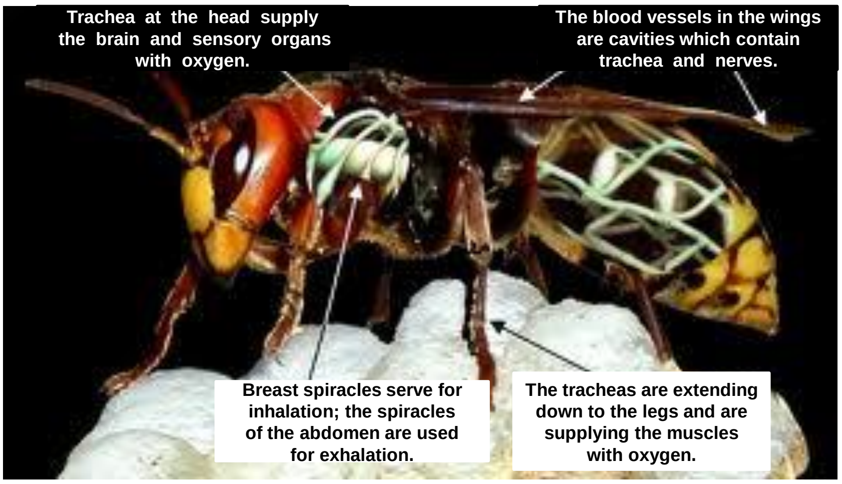
The following picture shows the internal organs of an air-breathing insect. It consists of three parts: the head, the breast (thorax) and the abdomen. For breathing, the Trachea (Atmungsorgan), the Spiracles (Atemlöcher = tiny holes), and the Air sac (Luftsack) are of special importance. Insects do not have lungs for breathing.



324

7.6.2.1 Insects: Trachea - Tracheole - Spiracles

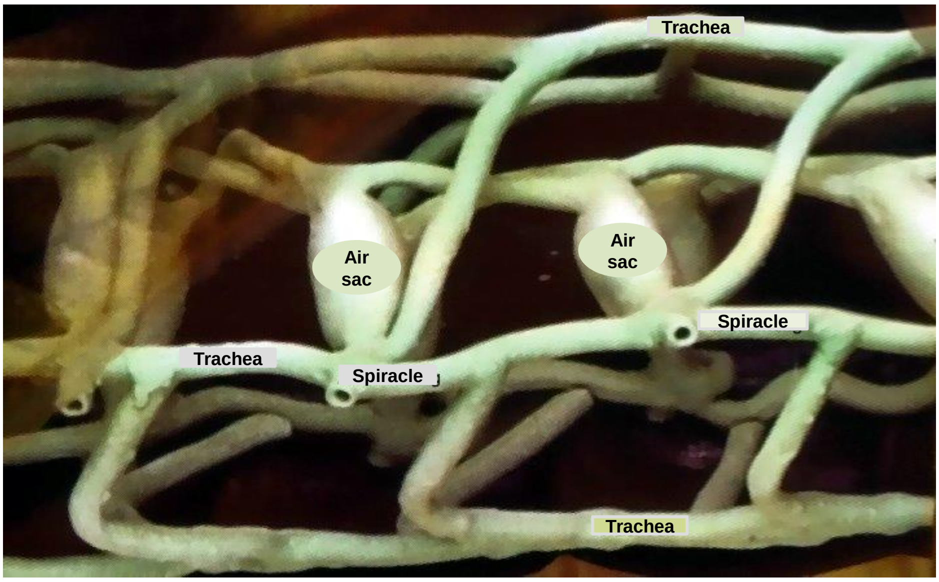
Insects do not breath through their mouths as we do and they do not have lungs, nor do they transport oxygen through their circulatory system. Instead, insects breath by inhaling the vital oxygen through an array of tiny holes (spiracles or stigmas) at their chitinous exosceleton. The spiracles are located at both sites of the body and for controling the gas exchange, they can be closed or obened. The spiracles are followed by a system of air ducts, the trachea, from which more and more branches reach out in ever more tiny capillaries. In this way, oxygen is directly transported to the individual tissues. Most of CO_2 is also exhaled through the tracheas and spiracles but part of it leaves the insect's body. [For complementary information about «Breathing of Insects»: s. also Appendix at p. 7-A-6-1].



325

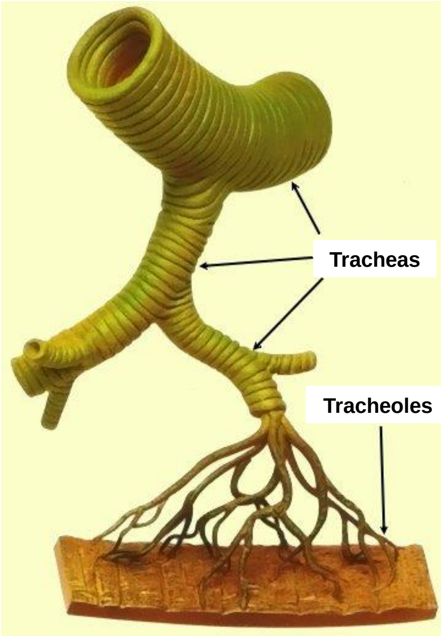
Insects: Trachea and Air sacs

The trachea of many insects are interconnected with air sacs which support air exchange and serve as oxygen storage. In addition, the air sacs reduce the weight thereby increasing the excellent flight capability. The picture also shows two spiracles for the inhalation of oxygen-rich air.



326

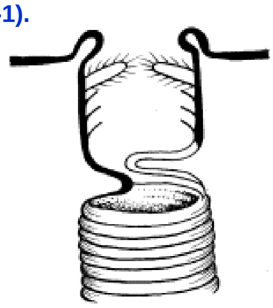
Insects: Trachea, Tracheole and Spiracles



a) Fine branching of the trachea in tracheole

a): The tracheal system is ever finer branched. The most tender branches (Tracheole) are extending deeply into the tissue, for example in a muscle, where oxygen is needed. The walls of the trachea are strengthened by spirals. For this reason, they can not be pressed together during respiration; they are, however, still elastic similar to the tube of a vacuum cleaner. The trachea consist of the same substance as the exoske-leton of insects: they actually consist on Chitin.

b): The spiracles (or stigmas) are closable. In this way, the gas transport can be regulated (see also pp 326, 7-A-6-1).



b) Spiracles or stigmas

327

7.6.2.2 Respiration of Butterflies

Butterflies constitute an insect family of more than 180’000 described species with 127 families and 46 subfamilies. After the bugs, butterflies are the second rich insect family of the World.

In a simple circular flow, the tubular heart pumps the blood (hemolymph) flowing around the organs through the body. <u>The blood transforms nutrients through the body, but neither oxygen nor CO_2</u>. The gas exchange takes place in the trachea (pp 325 – 327). The branched tube system of the trachea supplies all organs with oxygen. The oxygen is pumped by means of side-openings (spiracles or stigmas, pp 326, 327) into the body. The maximum transport path of this respiratory system is limited. The reason for this limitation lies in the fact that the grow potential and the size of butterflies and insects are generally small.

Orange-tip Butterfly

Peacock Butterfly

328

Butterflies in Art

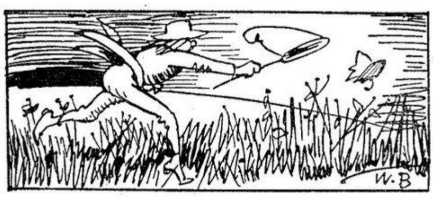
A Butterfly in Love

She was a flower, cute and fine,
Blooming in the bright sunshine.
He was a proud, young butterfly,
Devoted hanging on the flower, high.

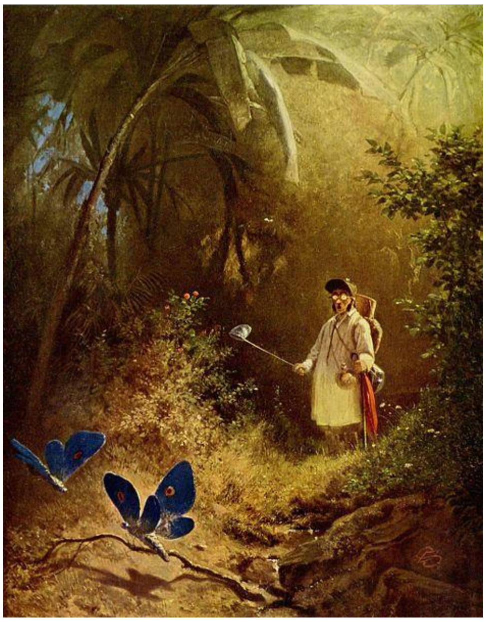
Oft a bee came round to visit
And zoomed around the flower a bit.
Oft a beetle crawled up and down
On the flower’s blooming crown.

Oh God, how this pained the butterfly
His hurt then almost made him cry.

But what really horrified him most,
And was the worst, and then came last.
An old ass ate the whole plant
He loved the most in all the land.



Wilhelm Busch (1832 – 1908)
(Poem and Drawing from 1895)



The Butterfly Hunter
Carl Spitzweg (1808 – 1885)
(Drawing from 1840)

329

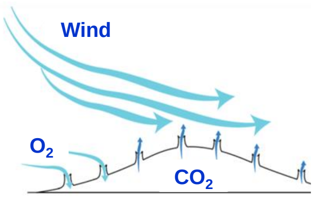
7.6.2.3 Ants: Breathing – Anthill and its Ventilation – Wedding flight

a) Carpenter ant

Ants are a family within the order of hymenopterous insects. The number of ant species is about 12'000 ,where about 200 species are living in Europe. The Figure shows the three parts of the insect: the head, the breast (thorax) and the abdomen (s. p. 324).

b) Anthill

All known ants are organized into colonies. Ant colonies contain up to several millions individuals. In an anthill, always three castes are living: Workers (females), femail ants (including the queen) and male ants. The worker ants are wingless. Only the mature females and the males have wings and are able to fly.



c) Ventilation of an Anthill

If air is flowing over the hill, the (CO_2-rich) stale (used) air produced by the millions of ants is blown out by convection through the «chimeney»; at the same time, oxygen-rich air is flowing into the hill by convection (see Figure). In this way, the ants are able to survive in their hills.

d) Ants starting to their wedding flight

At a particular time, all sexual animals belonging to a species swarme out of their colonies for the wedding flight. In this way, inbreading can be avoided. By emission of pheromones, the two opposite sexes attract each other.

The young queen is mated by 2 to 40 males and receives several millions of spermatozoa with which she fertilizes the eggs. Some hours after the wedding flight, the males are dying. They are then transported by the workers into the hill where they serve as nutrient.

330

7.6.2.4 Termites: Properties and Respiration

Subterranean Termites of Formosa (Taiwan)

Termites form a social insect order occurring in warm regions of the Earth. They are flying insects. They are not related to ants, which belong to hymenopterous insects (p. 330).

Many species have a white or white-yellow body colour. As a rule, the body-length of termites ranges between 2 and 20 mm. Queens of certain species having abdomens bulged with eggs reach body lengths as large as 140 mm.

Aboveground Temite Hills in Namibia

Termites are mixing sand grains, soil and pieces of wood with a secreation to forme clumps from which they construct huge hills! These hills can be higher than 8 meters.

The millions of termites living in such a fortress must be able to breathe. They need about 250 L of oxygen or more than 1'000 L fresh air per day. The exterior wall has a rib-like structure with ventilation pipes extending from the «floor» to the «basement». The warm air rising in the hill escapes in the floor and then slowly descends down through the tubes. During this flow, the air in the nest takes up oxygen from the exterior and simultaneously emits CO_2. The regenerated air accumulated in the «basement» starts for a new journey through the nest (circulation by external lungs).

331

7.6.2.5 Breathing of aquatic Insects - 1

Aquatic insects need oxygen too! They are equipped with a variety of adaptations that allow them to carry a supply of oxygen with them under water (I.e. by cuticular respiration) or to acquire it directly from the environment. In the following some adaptations are discussed and we illustrate how insects use them to obtain oxygen and maintain an aquatic lifestyle.

Biological gills

A biological gill is an organ that allows dissolved oxygen from the water to pass into the organism's body. In mayflies the gills are leaf-like in shape. Fanning movement of the gills keep them in contact with an instant supply of fresh water.

Mayflay larva with biological gills

Breathing tubes

Although many aquatic insects live underwater, they get air from the surface through hollow breathing tubes. In mosquitos larvae, for example, this «siphon»-tube is an extension of the posterior spiracles.

Mosquito larva with breathing tubes

Dissolved oxygen

Water contains usually a significant amount of dissolved oxygen (DO). Icy cold water (0^0C) can hold as much as 14.60 mg/kg oxygen (s. p. 6-A-3-1). With increasing temperature, the oxygen concentration in water decreases. In fresh and cold water, insects can usually rely on gills. In warm water, however, insects may need air bubbles or breathing tubes.

Temperature (Celsius)	Oxygen concentration (mg/kg)
0	14.60
10	11.27
20	9.07
30	7.54

Dissolved oxygen in water at different temperatures

332

Respiration of Aquatic Insects - 2

Air Bubbles

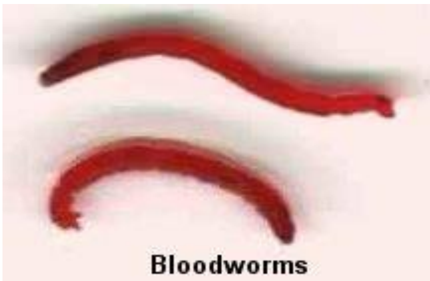
Some aquatic insects (diving beetles), for example), carry a bubble of air with them whenever they dive beneath the water surface. The bubble usually covers one or more spiracles so the insect can «breath» air from the bubble while submerged in water.
The picture shows a predacious diving beetle in water. The blue part at the back is the portion of the air bubble the beetle carries with it underwater that it exposes to the water. This allows the beetle to use the bubble as a physical gill.

Air bubble

Diving beetles with air bubbles for respiration

Larvae of midges (Blodworms)

Hemoglobin is a respiratory pigment that facilitates the capture of oxygen molecules. It is an essential component of al human red blood cells, but it occurs only rarely in insects – most notably in the larvae of certain midges known as bloodworms. These red «worms» usually live in muddy depths of ponds or streams where disolved oxygen may be in short supply. Under normal conditions, hemoglobin molecules in the blood bind and hold a reserve supply of oxygen. If conditions become anaerobic, the oxygen is slowly released for respiration.



Larvae of midges (Bloodworms) with respiratory pigment Hemoglobin

333

Appendix: Chapter 7

7-A-0

Systemic and Pulmonary Blood Circulation System

The main structures of the cardiovascular system are the heart, arteries, capillaries and veins. The function of the heart is to pump blood through the arteries to the organs of the body. The arteries branch out into a network of capillaries that carry blood with nutrients to the cells and remove their waste products. The capillaries murge to form the veins that circulate the blood back to the heart.

The pulmonary artery carries blood from the heart to the lungs. The function of the lungs is to exchange gases.The carbon dioxide (CO_2) produced from carbohydrates, ($C_m(H_2O)_n$) and fat metabolism is carried out in the bloodstream to the lungs where it is released to the atmosphere, and oxygen from the air is absorbed and stored in the hemoglobin of the red blood cells.

The aorta, which is the largest artery in the body, branches from the heart into the mesenteric (Eingeweide) and renal arteries that carry blood to the intestines (Därme) and the kidneys, respectively. The blood in the capillaries of the intestines absorbs carbohydrates, proteins, and fats from the foods processed by the digestive system. Blood from the intestines goes to the liver via the hepatic portal vein (Leberpfortader). The liver removes toxins from the blood. In the liver, the ammonia produced from protein metabolisms is combined with CO_2 to create urea. The blood from the liver flows back to the heart via the hepatic vein (Lebervene) and the interior vena cava (Hohlvene). The kidneys remove nitrogen waste products from the blood. Uric acid from nucleic acid metabolism and urea from protein metabolism are filtered out by the kidneys and extracted in the urine. Blood from the kidneys goes throhgh the renal vein, then to the inferior vena cava, and finally recirculates back to the heart.

Note:

The corony arteries are the blood vessels that deliver oxygen-rich blood from the heart to the tissues of the body (see p. 278).

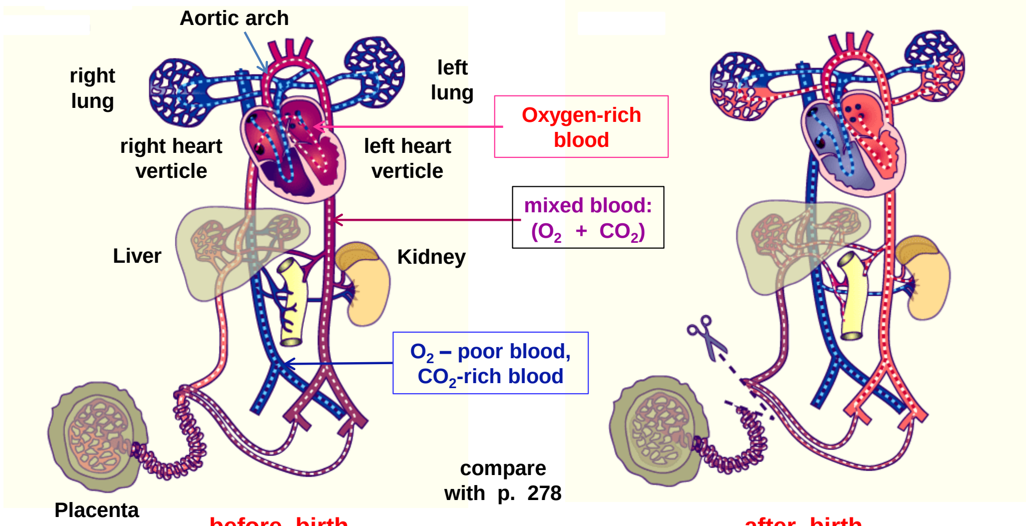
On the other hand, the pulmonary artesis carry oxygen-poor blood from the heart to the lungs under low pressure, making these arteries unique (see p. 278).

7-A-1-1

Prenatal and postnatal respiration system

During birth, two events are responsible for the functional adaptation to postnatal live:

- Interruption of the placentury circulation
- Unfolding the lungs with the first breath



compare with p. 278

before birth

after birth

7-A-1-2

From the fetal circulation to the first breath

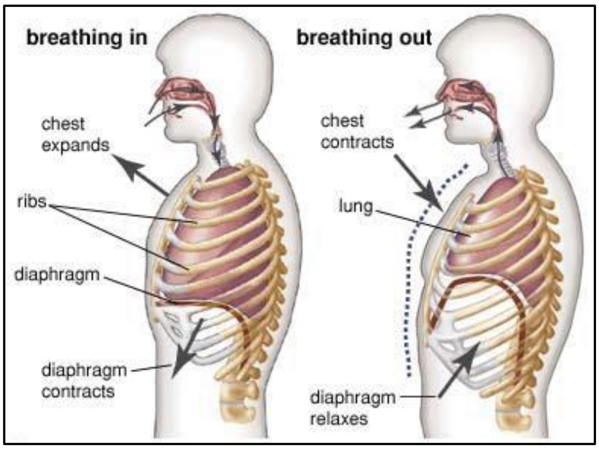
The pulmonary respiration of mammals and humans is discussed on pp 278 - 280).

Perfusing its body by breathing independently instead of utilizing placental oxygen is the first challenge of a newborn. At birth, the baby's lung are filled with lung liquid. When the newborn is expelled from the burth canal, its central nervous system reacts to the sudden change in temperature and environment. This triggers it to take the first breath, within about 10 seconds after delivery.
With the first breaths, there is a fall in pulmonary vascular resistance, and an increase in the surface area available for gas exchange. Over the next 30 seconds, the pulmonary blood flow increases and is oxygenated as it flows through the alveoli of the lungs. Oxygenated blood now reaches the left atrium and ventricle, and through the descending aorta reaches the umbilical arteries. Oxygenated blood now stimulates constriction of th umbilical arteries resulting in a reduction in placental blood flow.
As the pulmonary circulation increases there is an equivalent reduction in the placental blood flow which normally ceases completely after about 3 minutes. These two changes result in a rapid redirection of blood flow into the pulmonary vascular bed, from approximately 4% to 100% of cardiac output. The increase in pulmonary venous return results in left atrial pressure being slightly higher than right atrial pressure, which closes the foramen ovale.
The flow pattern changes results in a drop in blood flow across the «ductus arteriodus» and the higher blood oxygen content of blood within the aorta stimulates the construction and ultimately the closure of this fetal circulatory shunt.

[In the developing fetus, the «ductus arteriosus» is a blood vessel connecting the pulmonary artery to the aorta. The «ductus venosus» is the fetal shunt between the left hepatic portal vein and the inferior caval vein (s. Ref. 7-A-1-3 b)].

7-A-1-3

Breating in and breathing out of Humans



The mechanism of breathing: Air moves in and out of the lungs in response to differences in pressure. When the air pressure within the alveolar spaces falls below atmospheric pressure, air enters the lungs (inspiration), provided the larynx (Kehlkopf) is open; when the air pressure within the alveoli exceeds atmospheric pressure, air is blown from the lungs (expiration). The flow of air is rapid or slow in proportion to the magnitude of the pressure difference. Because atmospheric pressure remains relatively constant, flow is determined by how much above or below atmospheric pressure the internal pressure within the lungs rises or falls.

7-A-1-4

Breathing in modern airtight homes

We have discussed breathing of humans at pp 279, 280 and 7-A-1-4 (breathing in O_2 and breathing out CO_2). In the following we are concerned with the potential problems and dangers associated with breathing during sleeping, in particular with the problem of sleeping in an airtight room with and without ventilation by fresh air.

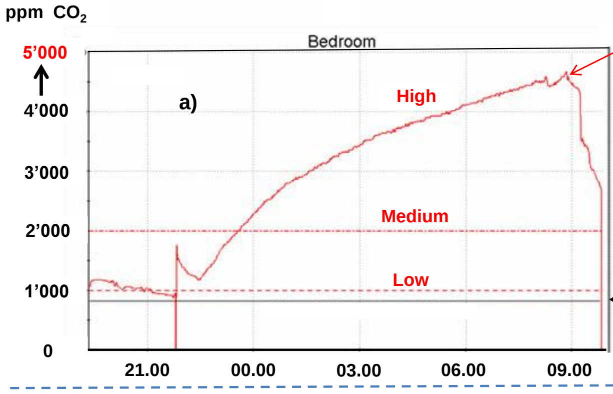
Adult time spent in bedrooms can be at least 8 hours per day. Children may additionally use their bedroom as a den in which case they could spend almost all their home time. Breathing in an airtight room decreases the oxygen concentration and increases the CO_2 concentration. It is therefore essential that airtight rooms and bedrooms are properly ventilated by fresh air. Based on European CEN Standards 13779, ventilation for «medium» air quality should be at least 10 L/s per occupant (15 L/s for high indoor quality). This equates to a steady state metabolic CO_2 concentration of no more than 800 ppm (see p. 7-A-1-6). It is now known that poorly ventilated spaces create adverse symptons. A night in an inadequately ventilated bedroom is likely to result in poor daytime health and, possibly, long term damage health.

Measurements of actual ventilation rates, based on CO_2 concentration, have consistently shown that bedroom ventilation rates are dangerously inadequate. The diagrams of p. 7-A-1-6 shows that a CO_2- concentration of 1’000 ppm is «Low performance» and that 2’000 ppm is «High performance». But it is not an untipical result in which the CO_2 concentration reaches a steady state rate of about 5’000 ppm [see diagrams at p. 7-A-1-6 a)]. This corresponds to an occupant ventilation rate of about 1 L/s.

At very high concentrations, CO_2 is a dangerous poison! Concentrations of 7 to 10% by volume (70’000 ppm to 100’000 ppm) may cause suffocation within a few minutes to an our, even in the presence of sufficient oxygen (see Chapter 5, p. 197).

7-A-1-5

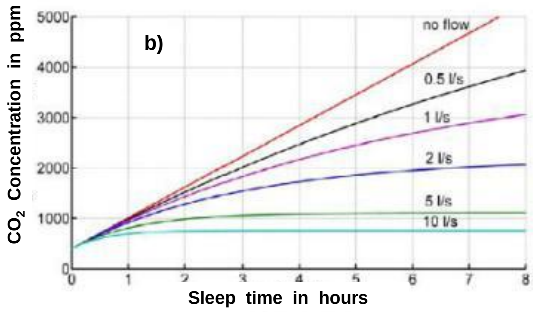
Sleeping in a Bedroom with different ventilations



Experiment (no ventilation)

CO_2 concentrations can reach a steady state approaching 5000 ppm. This corresponds to an occupant ventilation rate of about 1 L/s This is woefully inadequate but is typical of a bedroom with closed windows and doors.Such a low ventilation rate is simply not healthy but is probably quite common in the modern airtight home.

800 Maximum CO_2 for ventilation rate of 10 L/(s and person)



Theoretical model based on a simple differential equation.

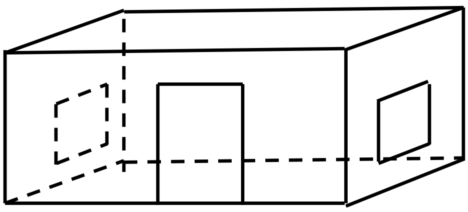
Initial concentrations (at time t = 0): ≈ 21% oxygen (O_2); ≈ 79% nitrogen (N_2); ≈ 0.04% CO_2 = 400 ppm.
The calculations have been performed on the basis of a simple differential equation [Reference 7-A-1-6 b)] with a room volume V of 21 m³ during a time of 8 hours. The CO_2-concentration curves have been evaluated for different outdoor air ventilation rates Q (Q = 10, 5, 1, 0.5 and 0 L/s). A more general model for including CO_2, O_2, and H_2O in breathing air of a sleeping room is discussed in the Reference of Appendix 7-A-1-7).

7-A-1-6

Sleeping in an absolutely airtight bedroom

The Publication of Markov (Reference 7-A-1-7) investigates the consequences of sleeping in airtight or in nearly airtight bedrooms. The present page contains a summary and an illustration worked out by P. Brüesch. I have confined the discussion to a completely airtight room.

Markov discussed the changes of the composition of air in an airtight bedroom with dimensions of 3.5 x 4.8 x 2.5 m³ = 42 m³ in which 4 persons are sleeping (the two parents with their 2 children) during a sleeping time of 9 hours.



Bedroom with airtight windows and door

Initial conditions: Atmospheric pressure = 94'000 Pa (corresponding to the atmospheric pressure at an altitude of 625 m), constant room temperature of 20 ^{0}C and relative air humidity of 30 %.

Based on mass-conservation equations, the consumptipn rate of oxygen (O_2) and the generation rates of both, carbon dioxide (CO_2) and water vapor (H_2O) due to breathing are evaluated and analytical solutions are presented. For the case of a completely airtight room, the initial volume fractions are $X_{in}(O_2)$ = 20'7884, $X_{in}(CO_2)$ = 400, and $X_{in}(H_2O)$ = 7'458 ppm (1 ppm = 1 part per million). After sleeping 9 hours, the final volume fractions are $X_{fin}(O_2)$ = 19'461, <u>$X_{fin}(CO_2)$ = 9'922</u> and $X_{fin}(H_2O)$ = 16'927 ppm, respectively. <u>Note that the CO_2- concentration in the bedroom has strongly increased, namely by a factor of almost 25 (!).</u>

From the medical point of view, all the investigated examples are dangerous for the occupants' health since almost in half the year during the night periods in their own bedrooms they would be exposed to indoor air with a very low quality. The present practical examples reveal the reason for the feeling of looseness and faintness experienced on the morning by the people sleeping in sealed spaces by the combined effects of reduced oxygen and, more importantly, by the drastic increased CO_2 concentration in the room air.

7-A-1-7

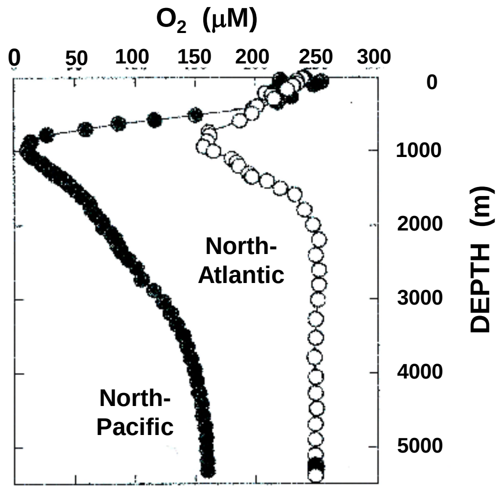
The O_2- content of Seawater close to the Sea surface is determined by the transition of O_2 from the air into water (by diffusion) as well as by the biological production of O_2 from CO_2 by means of the marine phytoplankton.

With increasing depth and the associated decrease of sunlight, the saturation of O_2 decreases in Seawater. In addition to respiration of O_2 by the zooplankton and by part of the bacterioplankton, the increased biological depletion of biomass also contributes to the decrease of the O_2- content.

The distribution of O_2 in the deep sea is not uniform: there exist so-called <u>Oxygen Minimum Zones</u> (OMZ's), zones at which oxygen saturation in the ocean is at its lowest level. In these OMZ's, anaerobic (*) ammonium oxidation and denitrification can take place (by means of anaerobic respiration of bacteria, molecular nitrogen (N_2) is generated which escapes into the air). OMZ's are often present in tropical regions. One example is the Arabian Sea where OMZ's are present in depths between 200 metres down to about 1'000 metres.

[(*) In anaerobic regions, life without oxygen is possible].

O_2- Depth profiles in Oceans



Remark: 1 μM = 10^{-6} mol/L

1 Mol O_2 = 32 g

→ 250 μM O_2 = 250 * 10^{-6} * 32 g/L O_2
= 8 mg/L O_2

7-A-5-1

Widespread deaths of Fish in oxygen- poor waters

Dead fish are bordering the cost of Salton Sea in California.

For living, fish need oxygen. In uncontaminated waters, there is sufficient dissolved oxygen (p. 7-A-5-1); In this case, fish have sufficient oxygen for gill breathing.

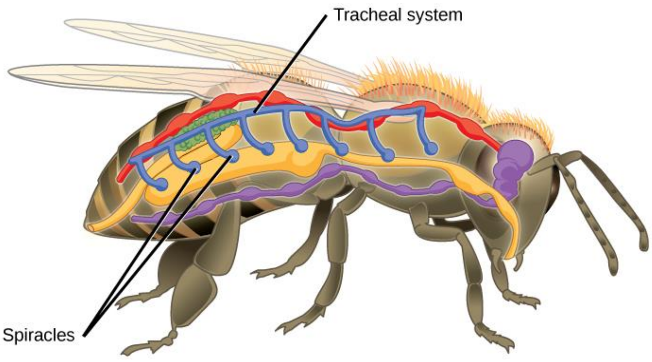
But if the discharge of nutrients into the sea is too large, the oxygen content is strongly reduced (< 4 mg/L, s. p. 314, left-hand Figure), and the fish are suffocating; In everyday language, this is referred to as the «dying of waters».

In stagnant waters or in slowly running waters, nutrients are continuously introduced, for example phosphates and silicates. If the growing season sets in, more algae are growing as previously. For energy generation, they use photosynthesis to produce oxygen. During night, however, they partly use up the oxygen and it can happen that so much oxygen is used up that the algea themselves are dying back; this is the case if the waters are completely deoxygenated.

In oxygen-poor waters, fish can try to swim just below the surface of the water, thereby benefiting that in this layer atmospheric oxygen is still desolved. If, however, the oxygen concentration is reduced too much this does not help either. The fish are dying by suffocation and are floating at the surface of the water.

7-A-5-2

Breathing of Insects



Tracheal Systems

Insect respiration is independent of its circulatory system. Therefore, the blood does not play a direct role in oxygen transport. Insects have a highly specalized type of respiratory system called the tracheal system, which consists of a network of small tubes that carries oxygen to the entire body. The tracheid system is the most direct and efficient respiratory system in active animals. The tubes in the tracheal system are made of a polymeric material called chitin.

Insect bodies have openings, called spiracles aiong the thorax and abdomen. These openings connect to the tubular network, allowing oxygen to pass into the body (Figure) and regulating the diffusion of CO_2 and water vapor. Air enters and leaves the tracheid system through the spiracles. Some Insects can ventilate the bracheal system with body movements.

When air reaches the tracheole, oxygen disolves into the tracheol liquid. Through simple dIffusion, oxygen then moves to the living cells and carbon dioxide enters the tracheal tube. Carbon dioxide, a metabolic waste, exits the body through the spiracles.

7-A-6-1

7.6.2.5 Aquatic Insect: Hyphydrus ovatus - Beetle

For certain water insects, adaptations have been developed, which allow breathing under water. Many water-scavanger beetles have body regions with special surfaces which are covered by an air bubble (physical gills).

The hyphydrus ovalus (Kugelschwimmkäfer) shown below has a length of about 5mm. This aquatic insect is relatively common in stagnant and sometimes also in running water.

Water-scavanger beetle - Hyphydrus ovatus (Kugelschwimm-Käfer) with an air bubble at the back of the abdomen.

The beetle is swimming rather rapidly in open water or if it is not swimming, it is sitting on a water plant.

As many other diving beetles, it gets fresh water from the surface of the air, whereby most often an air bubble at the back of the abdomen is present. The air in the bubble creates a strong buoyancy; only if the beetle is swimming it does not ascend to the water surface. For this reason, it often clinges to a water plant or to an algae.

If it is filling his air bubble upside down, it keeps his leggs close to its boddy. Viewed from above the water surface, it than looks indeed as a sphere.

7-A-6-2

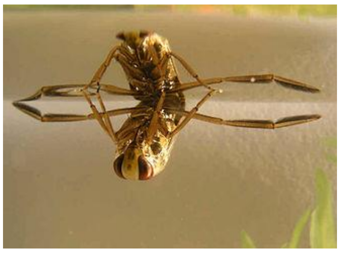
Aquatic Insects: Backswimmers

Backswimmers are a family of aquatic insects in the suborder of bugs. Their name is due to their preference to swim on their backs and view the world upside down. This is due to the fact that below their abdominal hair they have stored an air supply which shifts their centre of gravity towards the back. The middle- and forelegs support the animal by the surface tension of water; note that the animal is lighter than water because of their air supply.

Depending upon the season, backswimmers range from about 8 to 18 mm The animals are not only good swimmers but they also have wings and take flight which they often do in the late summer and fall to mate and populate new bodies of water.

A clear inspection of the tapered end of a backswimmer reveals tufts (Büschel) of fine body hairs. These hairs are used to penetrate the water surface to breath and gather the bubble of air these insects need to survive. They trap a bubble of air, called plastron along their bodies and under their wings, allowing them to survive beneath the surface. The backswimmer absorbs the air through spiracle pores along their bodies directly into their body tissue. This air bubble can be replenished to a degree by fanning their legs to diffuse oxygen dissolved in the surrounding water. Water temperature and the backswimmer's activity level dictates the dive times. Eventually, they must return to the surface to replenish their air supplies

Backswimmer swimming on his back



Backswimmer breathing at the water surface

7-A-6-3

References: Chapter 7

R-7-0

7.0 Introduction

R.7.0.1 p. 272 : Animal Classification

a) Classification of Animals - http://scitechblog.wordpress.com/2013/01/21/classification-of-animals
b) Vertebtate - https://en.wikipedia.org/wiki/Vertebrate
c) Wirbeltiere - http://www.tierschutz.org/tierwelu/tiergruppen/index.php
d) Invertebrate animals - http://en.wikipedia.org/wiki/Invertebrate
e) Wirbeltiere - http://www.tierschutz.org/tierwelu/tiergruppen/index.php

R.7.0.2 p. 273: Aeorobic and Anaerobic Respiration

a) Cellular respiration - http://en.wikipedia.org/wiki/Cellular_respiration
b) Breathing and Respiration - http://www.passmyexams.co.uk/GCSE/biology/aerobic-respiration.html
c) Atmung - http://de.wikipedia.org/wiki/Atmung
d) Aerobe Atmung - http://de.wikipedia.org/wiki/Aerobe_Atmung
e) Anaerobie - http://de/wikipedia.org/wiki/Anaerobic
f) Anaerobic respiration - http://en.wikipedia.org/wiki/Anaerobic_respiration
g) Anaerobic Respiration - Simple Definition of Aerobic and Anaerobic Respiration
http://www.anaerobicrespiration.net/general/simple-definition-of-aerobic-and-anaerobic-respirations
h) Gärung und anareobe Atmung
i) Prokaryote -- http://en.wikipedia.org/woki/Prokaryote
http://www.chemgapedia.de/vsengine/vlu/vsc/de/ch/8/bc/vlu/stoffwechsel/energiegewinnung.vlu/Page/
k) Prokayoten - http://wikipedia.org/wiki/Prokaryoten

R.7.0.3 p. 274 : Vertebrates - 1: Overview

a) Vertebtate - http://en.wikipedia.org/wiki/Vertebrate
b) The Five Classes of Vertebrates - http://www.davidinelson.md/Cacedero/FiveVertebrates.htm
c) Classes of Vertebrates - http://anthro.palomar.edu/animal/animal_4.htm
d) Wirbeltiere - http://de.wikipedia.org/wiki/Wirbeltiere
e) Wirbeltiere - http://www.tierlexikon.net/wirbektiere.htm
f) Wirbeltierklassen - Table from Google: Bilder - (Text translated from German to English by P. Brüesch)
g) see also References of Referenve R.7.0.1

R-7-1

R.7.0.4 p. 275: Vertebrates

a) Overview - 2 - http://anthro.palomar.edu/animal/animal_4.htm
Image from Google under «Cladogram of Vertebrates»
b) Wirbeltierklassen (Cladogramm der Wirbeltiere)
Paläontologie: Phylogenie - http://www,zum.de/Faecher/Materialien/beck/13/bis13.32.htm

R.7.0.5 p. 276: Invertebrates - Overview

a) Invertebrate animals: s. Ref. R.7.0.1 - p. 272 d)
bl Invertebrates - List, Characteristics of Invertebrates / Biology@TutirVista.com
http://biology.tutorvista.com/organism/invertebrates,html
c) Wirbellose: s. Ref. R.7.0.1 . p. 272 e)
d) Liste von Wirbellosen - List of Inverebrates - found under: Bilder zu «Wirbellose Tiere – Liste»

7.1 Respitation (General)

R.7.1.1 p. 278: Circulualory System and Lung

a) The Circulatory System
Figure from: http://www.scientificpsychic.com/blogentries//the-circulatory-system-html
b) Arterial blood - http://en.wikipedia.org/wiki/Arterial_blood
c) Venous blood - http://en.wikipedia.org/wiki/Venous_blood
d) Difference between Arterial and Venous Blood
http://www.differencebetween.com/difference-betweem-arterial-and-vs-versus-venous-blood/
- Arterial blood is the blood that runs through arteries, starting from the left chamber of the heart and lungs. Usually, it is oxygenated and bright red in colour therefore. However, pulmonary arteries carry deoxygenated blood from the heart to the lungs (s. Figure, p. 278).
- Venous blood moves through veins of the circulatory system. Veins take blood into the heart from the body organs. Usually, it is dark maroon in colour because of the deoxynated blood. However, the pulmonary veins carry oxygen rich blood from the lungs to the heart (s. Figure 278).

e) Welche Arterie führt venöses Blut und welche Vene arterielles Blut?
http://www.gutefrage.net/frage/welche-arterie-fuehrt-venoeses-blut-welche-vene-arterielles-blut
Definition von Arterie und Vene

R-7-2

R.7.1.2 pp 279 Pulmonary_Respiration_of_Humans – a)

a) Human Respiratory System Functions
http://www.buzzle.com/articles/human-respiratory-system-functions.html.
b) Human respiratory system
http://www.britannica.com/EBchecked/topic/499530/human-respiratory-system/66147/The-mechanics-of-breathing
c) How the Lungs and Respiratory System Work - http://www.webmd.com/lung/how-we-breath
d) Atmung - http://www.sign-lang.uni-hamburg.de/glex/konzepte717408.htm
e) Atmung - s. also: Atemfrequenz, Atemminutenvolumen und Totraumvolume
http://de.wikipedia/org/wiki/Atmung
f) Grundlagen der Atmung - DLRG
Informationen für Rettungsschwimmer - www.ogburscheid.de/infoboerse(download/Atmung.pdf
g) Remark to: Skin-breathing of humans:
http://www.hilfreich.de/stirbt-man-wenn-die_haut-nicht-atmen-kann_2585

R.7.1.3 pp 280 Pulmonary_Respiration_of_Humans – b)

a) MedicineNet - Definition of Pleura
http://www.medicinenet.com/script/main/art.asp?articlekey=4945
b) Lungs and circulation - Structure and function of the Alveoli
http://www.curoservice.com/parentsvisiters/lung_circulation/structue_alveoli.asp
c) Pleura: - http://de.wikipedia.org/wiki/Pleura
d) Lungenbläschen - http://de.wikipedia.org/wiki/Lungenbl%C3%A4schen
e) Atmung und Kreislauf - http://www.bio.vobs.at/physiologie/a-atmung-kreislauf.ht,

R.7.1.4 p. 281 Internal respiration & external respiration - (Innere und äussere Atmung)
http://biology12–lum.wikispaces.com/internal+respiration+%26+external+respiration

R.7.1.5 p. 282: Pulmonary Alveoli and Capillaries

a) Classification and Structure of Blood Vessels
http://training.seer.cancer,gov/anatomy/cardiovascular/blood/classification.html
b) Exchanging Oxygen and Carbon Dioxide
http://www.merckmanuals.com/home/lung_and_airway_disorders/biology_of_thr_lungs_and_airways/exchanging_oxygen_and.carbon_dioxide.html

R-7-3

R.7.1.5 (cont.)

c) Pulmomary alveolus: alveoli and capillaries in the lungs
http://www.britannica.com/EBchecked/media/107200/Tje-alveoli-and-capillaries-in-the-lungs-exchange-oxygen-for
d) Blood-air barriers - http://en.wikipedia.org/viki/Blood%E2%80%83air:barrier
e) Lungenbläschen (s. auch Ref. R-7-1-2, e) von p. 280 - www.de.wikipedia.org/wiki//Lungenbläschen
Picture under: «Lungenbläschen» - Images
f) Haargefässe - Kapillaren - Text: www.wissen.de/lexikon/haargefässe - Picture under: «Haargefässe»: Images

R.7.1.6 p. 283: Yawning and Snoring

a) Yawn - http://en.wikipedia.org/wiki/Yawb
b) Gähnen - http://de.wikipedia.org/wiki/G%C3%A4hnen
c) Element Luft - Atmung: Einatmen, Ausatmen, gähnen
http://www.kindernetz.de/infonetz/thema/luft/atemluft/-/id=128294/nid=12894/did=12860/hekg5g/
Pictures found in: www.google.ch/search - «Gähnen»
d) Snoring and Sleep
http://sleepfoundation.org/sleep-disorders-problems/other-sleep-disorders/snoring
e) Snoring - Definition - http://www.mayoclinig.org/diseases-conditions/snoring/basics/definition/con-20031874
f) Snoring - http://en.wikipedia.org/wiki/Snoring
g) Was ist Schnarchen? - http://www.smilestudio.de/schnarchen.html
Picture about: Breathing during day and Snoring at night
h) Schnarchen - http://de.wilipedia.org/wiki/Scharchen
(Wegen der Übersetzung auf Englisch wurde der Figurentext von P. Brüesch gekürzt und retouchiert)
i) Uvula (Gaumenzäpfchen) - http://de.wikipedia.org/wiki/Uvula

R.7.1.7 p. 284: Sleep Apnoea and Breath-hold_Diving

a) Sleep apnea - http://en.wokipedia.org/wiki(Sleep_apnea
b) Obstructive Sleep Apnea - http://imtheramedical,com/patients/obstructive-sleep-apnea/
c) What is Sleep Apnea Duing to your Sleep ?
http://www.end-your-sleep-deptovation,com/what-is-sleep-apnea.html
d) Schlafapnoe - Schlafapnoe-Syndrom - http://de.wikipedia.org/wiki//Schlafapnoe-Syndrom
e) Obstruktive Schlafapnoesyndrom
http://flexikon.docheck.vom/de/Obstruktives_Schöafapnoesyndro
f) Schlafapnoe-Syndrom (SAS)
http://www.lungenliga,ch/de/wallis/dienstleistungen/schlafapnoe-syndrom.html

R-7-4

p. 284: Breath-hold Diving
(cont.)

g) Free-diving - http://en.wikipedia.org/wiki/Free.diving
h) apneadiving.org - http://www.apneadiving.org/apnea-diving-records
i) Apnoetauchen - http://de.wikipedia.org/wiki/Apnoetauchen
(beim Aufstieg von Tauchern aus grosser Tiefe) - http://de.wikipedia.org/wiki/Dekompression

R.7.1.8 p. 285: The_most_important_pulmonary_diseases

a) Respiratory disease - http://wikipedia.org/wiki/Tespiratory_disease
b) Publications: Lung disease fact sheet - What is lung dosease?
http://womenashelth.gov/publications/our-publications/fact-sheet/lung-disease.html
c) Lung Dosease Aöphabetical Listing - http://www.org/lung-diseaselist.html
d) Lunge - http://de.wikipedia.org/wiki/Lunge
e) Lungenfibrose - http://de.wikipedia.org.wiki/Lungenfibrose
f) Asthma bronchiale - http://de.wikipedia.org/wiki/Asthma_bronchiale
g) Bronchialkarzinom - http://de.wikipedia,org/wiki/Bronchialkarzinom
h) Lungenemphysem - http://de.wikipedia.org/wiki/Lungenemphysem
i) Lungenödem - http://de.wikipedia.org/wiki/Lungen%C3%B6dem

R.7.1.9 p. 286: The lungs of a dog

a) Left-hand picture: A tog with Lung and Trachea
http://www.kleintierphysio.at/34.html
b Right-hand picture: Trachea, Pulmonary lobes , Larynx, Heart, Midriff and Liver
http://hundinfo.jimdo.com/k%C3%B6rperbau/organe/linge/
(Text and Figure text translated from German to English by P. Brüesch)

R-7-5

7.2 Respiration of Amphibians

R.7.2.1 'p. 288: Respiration of Apmphibians - General

a) Comparitive Animal Respiration - http://vetsi.co.uk.2010/02/28/comparative-animal respiration/
b) Amphibian - http://en.wikipedia.org/wiki/Amphibian
The young amphibians generally undergo metamorphosis from larva with gills to an adult air-breathing form with lungs. Amphibians use their skin as a secondary respiration surface and some small terrestrial salamanders and frogs lacks lungs and rely entirely on skin.
c) Amphibien - http://de.wikipedia.org/wiki/Amphibien
d) Atmung der Amphibien (pp 287 – 288) Amphibien – Uebersicht - http://de.wikipedia.org/wiki/Amphibien
Text zu p. 288 - Images to: 288 from Google unter Bilder
http://129.70.40.49/nawi/lernprogramme/Amphibien/index.php?schapter=B

R.7.2.2 p. 289: Respiration types of Amphibians

a) Forms of Amphibian Respiration
http://www.ehow.com/info_8513457_forms-of-amphibian_respiration.html - contains Text of p. 289
b) Respiration in Amphibians - http://www.de.slideshare.net/…/respiration-in-amphibians-and-reptiles
c) Respiration system - Anatomy - Amphibians - Written by: Ewaöd R. Weibel
http://www.brittanica.comEBchecked/topic/499584/respiratory-system/66211/Amphibians
d) Cutaneous respiration - http://en.wikipedia.org/Cutaneous-respiration
e) Breathing in amphibians - http://boundless.com/biology/respiratory-system-and gas-exchange/breathing-aerates-lungs/
f) Ralph Blauscheck - Amphibien und Reptilien in Deuschland
Mit 59 Abb., 158 S. / Landbuchverlag – Verlag 1985 / ISBN 3 7842 0317 5.
http://onlinelibrary.wiley.com/doi/10.1002/irho.19860710640/abstract - contains Table of p. 289
g) Atmung - Atmung der Amphibien - http://www.erdkroete.de/id290_m.htm - (contains Table of p. 289)

R.7.2.3 p. 290: Cutaneous respiration of Amphibians: Cross-section through skin

a) What is the process of amphibian respiration ?
http://www.ask.com/pets-animals/process-amphibian-respiration-401969fea1bbd978
b) Amphibian Skin
http://micro.magnet.fsu.edu/primer/anatomy/brightfieldgallery/amphibiansskin20xsmall.html
c) Amphibians . http://www.scienceclarified.com/Al.As/Amphibians.html

R-7-6

R.7.2.3 (cont.)

d) Merkmale und Eigenschaften der Amphibien - http://erdkroete.de/id292_m.htm

e) Hautatmung - http://129.70.40.49/navi/lernprogramme/Amphibien/index.php?chapter=B2 Text

f) Text aus Haut: Merkmale und Eigenschaften der Amphibien
http://www.erdkroete.de/id292_m.htm
Figure : Querschnitt durch Amphibien - Haut
from Google under «Skin of Amphibians» → Images
→ Diagram of amphibians skin, illustrated gas exchange
Contributers: Michigan Science Art

7.3 Reptiles

R.7.3.0 Overview of Reptiles
http://www.merckmanuals.com/vet/exotic_and_laboratory:animals/reptiles/overview_of_reptiles.html

R.7.3.1 p. 292: Reptiles: some Examples

a) Reptile - https://en.wikipedia.org/wiki/Reptile
b) Reptilien - http://de,wikipedia.org/wiki/Reptilien
c) Images from. Google under Google:
True lizard, Veranus giganteous, Chameleons, Crocodiles, Turtles, Snakes

R.7.3.2 p. 293: Reptiles: General Properties

a) Biology of Reptiles - http://borbl426-526.blogsüot.ch/2012/01/chalaza-cloacal-plates-and-ecdysis-oh.html
b) Most Venomous Snakes - http://www.enkicharity.com/most-venomous-snakes.html
(contains picture of the Inland Taipan)
c) Reptilien - http://www.tierplanet.de/reptilien.hrml
(Text of p. 293 - translated from German to English by P, Brüesch)

R.7.3.3 p. 294: Characterics of Reptiles

a) Characteristics of Reptiles - http://lifestyle.iloveindia.com/lounge/characteristics-of-reptiles-13984.html
b) Merkmale der Reptilien - http://www.digitalefolien.de/bilologie/tiere/reptil/reptmerk.html
(Sorce for pictures 1) to 4) of this page; picture Texts translated from German to English)
c) Reptilen - Reptilia:
http://www.wasseragamen.net/pages/terraristik/reptilien-allgemein.php?searchresult=1&sstring=lurche
(Source for pictures 5) (lungs of a Reptile) and 6) (lungs of Mammals); Texts translated to English)

R-7-7

R.7.3.4 p. 295: Respiration of Reptiles

a) Characteristics of Reptiles - www.csk12.com/lms/Content/.../MBIO_10H.pdf
b) Reptilien – Ein Leitfaden für Zoofachändler
[PDF] Reptilien - Bundesministerium für Reptilien-pdf
bmg.gv.at/cms/home/attachements/4/2/1/CH1125/…/reptilien.pdf
c) Blutkreislauf - http://www.mathematikundschule.de/projekte/fermi/Wiki/Blutkreislauf.htm
d) Figure from Google under: «Respiratory systems of Reptiles)

R.7.3.5 p. 296: Respiration of Lizards

a) Lizard Respiratory System - http://en.wikipedia.net/Lizard_Respiratory_System
b) [PDF] Biologie gk 12/1-Hoffmann.it - www.hoffmeister.it/biologie/02.04reptilien.pdf
(p. 7 of this Reference: Herz und Atmung von Echsen - translated to English by P. Brüesch)
c) Upper left-hand picture: Ref. R.7.3.3 c);: p. 7 (Figure of a Lizard);
[The names of the organs have been translated from German to Englisch by P. Brüesch]
d) Atmung: Vom Krokodil zum Dino - http://www.dinosaurier.org/2001/11/19/atmung-vom-krokodil-zum-dino
Upper right-hand picture: Figure of a crocodile: Inspiration and expiration
e) Lower left-hand picture: Crocodiles are Lizards
Eidechsen / Blindschleichen.net - http://blindchleiche.net/eidechsen

R.7.3.6 p. 297: Tortoises and Turtles - General

a) Turtoises vs. Turtle - www.diff.com/difference/Tortoise-vs-Turtle
(contains pictures of Tortoise and Turtle)
b) Turtle, Tortoise, or Terrapin: How to Tell the Difference
http://www.peteducation.com/article.cfm?c=17+1797&add=947
c) What is the difference between turtles, terrapins and tortoises ?
http://www.ncaquariums.com/ask-the-aquaurium/what-is-the-difference-between-turtles-terrapins-and-tortoises
d) Natur-Lexikon.com – Schildkröten - http://www.ausgabe-natur-lexikon.com/Schildkröten.php
e) Mediterrane Landschildkröten
http://www..mediterrane-landschildkröten.de/anatomie:und_physiologie_atmungssystem.php

R-7-8

R.7.3.7 p. 298: Tortoises

a) Tortoises - http://en.-wikipedia.org/wiki/Tortoise
b) Landschildkröten - http://de.wikipedia.org/wiki/Landschildkr%C3%B6ten
c) Left-hand picture:: Aegyptische Landschildkröte; Google – Bilder
d) Right-hand picture from: Galapagos Tortoise
http://anomals.nationalgeographic.com/animals/reptiles/galapagos/tortoise/
e) Aldabra giant tortoise - http://en.wikipedia.org/wiki/Aldabra_giant_tortoise
f) Dahms Tierleben - Reptilien
Die Seychellen.Riesenschildkröte (Dipsochelys hololissa)
http://www.dahmstierleben.de/unterwegs/national/Osnabruck/Reptilien

R.7.3.8 p. 299: Breathing of Tortoises (and Turtles)

a) Respiration System - http://www.quijano.net/tq/respiratory.html
b) Basic Tortoise Anatomy & Biology - http://www.thetortoishop.com/basic-tortoise-anatomy-biology
c) How did Tortoises breathing evolve?
http://www.techtomes.com/articles/19761/20141108(jow-did-tortoises-breathing-evolve.htm

R.7.3.9 p. 300: Freshwater and Seawater Turtles

a) Freshwater Turtles - http://www.wwfpak.org/species/Freshwater-Turtles.php - left-hand picture
b) Turtle - http://en.wikipedia.org/wiki/Turtle
c) Süsswasser-Schildkröten-Arten: Jede zweite ist vom Aussterben bedroht!
http://www.haz.de/Nachrichten/Wissen/Uebersicht/Suesswasser-Schildkroeten-Arten-Jede-zweite-ist-vom-Aussterben-bedroht
d) Sea turtle - http://en.www.org/wiki/Sea_turtle
e) Meeresschildkröten - Zwischen Wasser und Land
http://www.mmf.de/themen-projekt/bedrohte-tier-und-pflanzenarten/meeresschildkroeten/bedrohte-paddler/
(right-hand picture)
f) Planet Wissen Startseite - Schildkröten
http://www.planet-wissen.de/natur_technik/reptilien_und_amphibien/Schildkroeten/
g) 7 Species of Sea Turtles - http://marinelife.about.com/od/vertebrates/tp/seaturtlespecies.htm
h) Multi-celled animals (Metazoa) - http://www.starfish.ch/reef/marine-turtles.html

R-7-9

R.7.3.10 p. 301: Respiration of Turtles

a) Respiratory System of Turtles - http://www.ehow.com/info_8737876_respiratory-system-turtles.html
b) Respiratory System - http://campus.murraystate.edu/academic/faculty/tderting/anatomyatlas/respirat.htm
c) Mehrzeller - CHORDATERE, WIRBELTIERE, Reptilien
Meereschildkröten - http://www.starfish.ch/Korallenriff/Schildkroete.html
d) The Encyclopeia OF EARTH - http://www.eoearth.org/view/article/156745/
e) Schildkröten-Atmung aufgeklärt
http://www.scienceticker.info/2010/06/01/schildkroetenatmung-aufgeklärt/
(special discussion of «Common musk turtle» (Moschusschildkröte)) - left-hand picture
f) Kein Land in Sicht: «Schildkröte atmet unter Wasser»
http://www.dieuniversitaet-online.at/dossiers/beitrag/news/kein-land-in-sicht_schildkröte-atmet-unter wasser/655.html
«Die Moschusschildkröte kann rund sechs Monate lang unter Wasser verweilen, ohne zum Luftschnappen an die Oberfläche steigen zu müssen»
g) scienceticker.info - Wissenschaftsnachrichten
«Junge Herumtreiber mit Fleischhunger» - Suppenschildkröten - right-hand picture
Suppenschildkröte - Foto: Tommy Schultz
http://www.scienceticker.info/2007/09/19/junge-herumtreiber-mit-fleischhunger/
h) Schildkrötensuppe - klare Brühe aus den Fleisch der Suppenschildkröte
http://de.wikipedia.org/wiki/Schildkr%C3%B6tensuppe

R.7.3.11 p. 302: Snakes - Anatomy and internal Organs

a) Snakes - http://en.wikipedia.org/Dnakes - This Reference contains also the picture: «Anatomy of Snakes»
b) Schlangen . http://de.wikipedia.org/wiki/Schlangen

R.7.3.12 p. 303: Respiration of Snakes

a) Snake Respiratory System Anatomy - By Douglas Mader, M.S., DVM, DABVP
http://www.reptilesmagazine.com/Kid-Corner/Beyond-Beginners/Snake-Anatomy-Respiratory/
b) How do snakes breath? - http://wiki.answers.com/Q/How_do_snakes_breath
c) How do snakes breath? - http://www.ask.com/pets-animals/snakes-breath-59fc88c56c4680a0#
e) Hydrophiinae / Coral reef snakes or sea snakes - http://en.wikipedia.org/wiki/Hydrophinae
f) Atmung und Atemwege der Reptilien - http://www.uni-protokolle.de/showpage.php?pagenr=61
g) Seeschlangen - http://www.uni-protokolle.de/Lexikon/Seeschlangen.html

R-7-10

R.7.3.13 p. 304: Poisonous (or Venomous) Snakes (or Serpents)

a) Venomous snake - http://en.wikipedia.org/wiki/Venomous_snake
b) List of dangerous snakes - http://en.wikipedia.org/List_of_fangerous_snakes
c) Top 10 Most Venomous Snakes - http://listverse.com2011/03/30/top-10-most-venomous-snakes
d) Inland Taipan - http://en.wikipedia.org/wiki/inland_taipan
e) Getting in Touch with the Dangerous Side of Nature
http://www.laligant-photography.com/getting-in-touch-with-the-dangerous-side-of-nature/
f) Inlantaipan - http://de.wikipedia.org/wiki/Inlandtaipan
g) Giftschlange - http://www.wkipedia.org/wiki/Giftschlange
h) Schlangen aus dem Lexikon – wissen.de / - http://de.wikipedia.org(wiki(Fiftschlangen
i) Schlangengift - http://de.wikipedia.org/wiki/Schlangengift
Pictures: leftt: Google – Inland Taipan; middle: Google – Morphology of venosous snakes; right: Google – Sea snakes

R.7.3.14 p. 305: Snakes in Mythology and Snakes in Medicin

a) Adam and Eve - http://en.wikipedia.org/wiki/Adamü-_anf_Eve
b) Upper left picture: Verführung durch die Schlange - http://de.wikipedia.org/wiki/Adam_und_Eva
Picture from Michelangelo found in Google under «Bilder»
c) Medusa - http://en.wikipedia.org/wiki/Medusa
d) Picture of Medusa from Rubens found in Google under «Bilder» - http://de.wikipedia.org/wik
e) Rod of Ascalepius - http://en.wikipedia.org/wiki/Rod_of_Ascepios
f) Aeskulapstab - http://de.wikipedia.org/wiki%C3%84skulapstab
Bild von Aeskulap und Aeskulapstab aus Google unter «Bilder»
g) Aesculapian Snake - http://en.wikipedia.org/wiki/Aescuöapian_Snake
h) Äskupapnatter als Symbol - http://de.wikipedia.org/wiki/%C3%84skulapnatter
i) Snake venom - http://en.wikipedia.org/wiki/Snake_venom
k) Schlangengift - http://de.wikipedia.org/wiki/Schlangengift
l) Paracelsus - http://en.wikipedia.org/wiki/Paracelsus
m) Paracelsus: Overview - http://www.toxipedia.org/display/toxipedia/Paracelsus
n) Paracelsus - http://de.wikipedia.org/wiki/Paracelsus
o) Die medizinischen Lehren des Paracelsus - http://www.pro-natura.info/gesundheit/Paracelsus.html

R-7-11

7.4 Respiration of Birds

R.7.4.1 p. 307: Respiration of Birds . General

a) Birds: Adaption For Flight - http://sunny.moorparkcollege.edu/~econnoly/BirdI.htm
b) Figure of Bird from Lectures of W.M. Schaffer in:
EEB/MCB 182: Spring 2006 - Contains Figure: The avian respiratory system
http://www.bic.arizona.edu/courses/schaffer/183/Lecture-10.htm
c) Lung - http://en.wikipedia.org/wiki/Lung - (Contains a Section of Avian lungs)
d) Lunge - http://de.wikipedia.org/wiki/Lunge - (Text translated from German to English by P. Brüesch)

R.7.4.2 p. 308: Respiration of Birdsl – Lungs and Air sacs

a) The Avian Lung - http://www.dynamicscience.comau/tester/solutions/biology/respiratory/lungsavian.html
b) Air flow system, sacs provide efficient gas exchange: birds
http://www.asknature.org/stategy/36325543f2tt8c96dd2a8730a8bd2bbf#.VTT8JKZQXp8
c) Anatomie eines Wellensittichs - http://www.wellishomepage.de/anatomie.php - Bild des Papageien
d) Luftsack (Vogel) - http://de.wikipedia.org/wiki/Luftsack_(Vogel)

R.7.4.3 pp 309: Respiration Cycle of Birds – Synchronization and Air current in the Respiratory System

a) The avian respiratory system: adaptation for oxygen uptake at high altitudes ?
http://wiki.ggc.usg.edu/wiki/The_avian_respiratory_system:_adaptation_for_the_oxygen_uptake_at_high_altitude%3F
b) Respiratory System of Birds: Anatomy and Physiology - Holly Nash, DVM, MS
www.edb.utexas.edu/.../Pet%20Educatio-Bird.pdf
c) Wissenswertes über den Weissstorch - http://www.storchennest.de/phpBB/viewtopic.php?f=48t=1061&start=15
(contains Figure; Figure Texts from P. Brüesch; translated from German to English)

R.7.4.4 p. 310: Synchronization and Air current in the Respiration System

a) Birth Breathing - www.mytoss.com/airsacs.html
b) Mechanics of Respiration in Birds
http://www.vedmed.vt.edu/education/curriculums/vm8054/Labs/Lab26/NOTES/BIRDRESP.HTM
c) Felix Liechti: Biologie der Vögel . Morphologie und Physiologie
www.camarque.unibas..ch/Morphologie_Physiologie.pdf

R-7-12

7.5 Systematics, Physiology and Respiration of Fishes

R.7.5.1 p. 312: Systematics of Fishes

a) Fish - http://en.wikipedia.org/wiki/Fish
b) Fish anatomy - http://en.wikipedia.org/wiki/Fish_anatomy
c) Chondrichthyes or Cartilaginous fish - http://en.wikipedia.org/wiki/Chondrichthyes
d) Bony fish or Osteichthyes - http://www.britannica.com/EBchecked/topic/73261/bony-fish
e) Marine Education Society of Australasia - http://www.mesa,edu.au/fish/fish04.asp - Lobe-finned and Lungfish
f) Actinopteygii or Ray-finned fish - http://en.wikipedia.org/wiki/Actinopterygii
g) Fische - http://de.wikipedia.org/wiki/Fische
h) Knorpelfische - http://de.wikipedia.org/wiki/Knorpelfische
i) Knochenfische - http://de,wikipedia.org/wiki/Knochenfische
k) Fleischflosser - http://de.wikipedia.org/wiki/Fleischflosser
l) Strahlenflosser - http://de.wikipedia.org/wiki/Sreahlenflosser

R.7.5.2 p. 313: Physiology of Fish

a) Fish physiology - http://en.wikipedia.org/wiki/Fish_physiology
b) Physiologie der Fische (2. Systematik) - http://www.starfish.ch/Korallenriff/Physiologie.html
(Figure Text translated from Gernan to English by P. Brüesch)

R.7.5.3 p. 314: Dissolved Oxygen in Water – Empirical Equations

Dissolved Oxygen (DO)
How can I predict oxygen solubility in water?
Text: http://antoine.frostburg.edu/chem/senese/101/solutions/faq/predicting-DO.shtm
Left-hand Figure: found under Google.ch «Sauerstofflöslichkeit in reinem Wasser» – Bilder
(Figure Title translated from German to Englisch)
Right-hand Figure: found under Google.ch «Solubility of oxygen in seawater and freshwater» - Bilder

R.7.5.4 p. 314: Notes_Oxygen solubility in seawater: Better fitting equations

Limnol. Oceonagr., 37 (6), 1992, 1307 – 1312
[PDF] aslo.org/lo/vol_37/issue_6/1307.pdf

R-7-13

R.7.5.5 p. 315: Differences between bony fishes and cartiloginous fishes

a) Fish anatomy - http://en.wikipedia.org/wiki/Fish_anatomy#Skeleton
b) Pädagogische Hochschule Thurgau - Unterer Schulweg 3 – CH-8280 Kreuzlingen 2
[PDF] www.phtg.ch/.../koennen-fische-rueckwärts-schwimmen?

R.7.5.6 pp. 316, 317: Gill Breathing of Fishes

a) Fish gill - http://en.wikipedia.org/wiki/Fish_gill
b) How Do Fish Breath Underwater ? wonderopolis.org/.../how-do-fish-breathe-underwat…
wonderopolis.org/.../how-do-fish-breathe-underwat…
c) How do fish breath ? - What is the structure of gills ?
http://reptools.rutgers.edu/Functpage34.html // http://reptoosl.rutgers.edu/Functpage33.html
d) Kiemenatmung - (Text to Figure at p. 316) - http://de.wikipedia.org/wiki/Kiemenatmung
e) Das Aquarium im Biologieunterricht
Atmung – Bau und Funktion der Kiemen - (Figures of pp 316 / 317)
http://129.70.40.49/navi/lernprogramme/aquarium/atmung/bau_funktion.htm -(Text and Figures for pp 316, 317)
f) Kieme (Text to Figure 317) - http://de.wikipedia.org/wiki/Kieme
g) Atmung der Fische - S. Kastaun and L. Dettmann - (Text to pp 316. 317)
http://www.ibdoerre.com/aqua/lars/fischatmung.htm
h) Physiologie der Fische: 2. Systematik - http://www.starfish.ch/Korallenriff/Physiologie.html

R.7.5.7 p. 318: Sharks and Whales

a) Shark - http://en.wikipedia.org/wiki/Shark
b) Will a shark drown if it stops moxing ? - http://animals.howstuuworks.com/fish/sharks/shark-drown1.htm
c) Whale - http://en.wikipedia.org/wiki/Whale
d) How Do Whales Breathe ? - http://nmlc.org/2009/04/how-dowhales-breathe/
e) Haie - http://de.wikipedia.org/wiki/Haie
f) Natur & und Tiere / Eure Fragen / Haie (Atmung von Haien)
http://www.wasistwas.de/natur-tiere/eure-fragen/haîe/link//336361060d/article/stimmt-es-dass-die-haie-nir-atmen-koennen-…
g) Wale: http://de./wikipedia.org/wiki/Wale
h) Die Atmung von Walen und Delfinen: http://www.kinder-hd-uni.de/lufz/luft24.html
i) Atmung der Wale - http://www.medienwerkstatt.online.de/lws_wissen/vorlagen/showcard.php?id-1429
k) Killer whale: http://en.wikipedia.org/wiki/Koller_whale

R-7-14

R.7.5.8 p. 319: Lungfish - (Images from Google.ch)

a) Lungfish: http://en.wikipedia.otg/wiki/Lungfish
b) Lungfish - Adaptation of breathing
http://www.britanica.com/EBchecked//topic/351582/lungfish/63419/Adaptations-for-greathing
c) Lungenfische: http://de.(wikipedia.org/wiki/Lungenfische
d) Afrikanische Lungenfische - http://de.wikipedia.org/wiki/Afrikanische_Lungenfische
e) Australischer Lungenfisch - http://de.wikipedia.org/wiki/Australischer-Lungenfisch
f) The two Figures are found in: www.google.ch under: «Lungs of African Lungfish» - Bilder

7.6 Invertebrates

7.6.1 Invertebrates - General

R.7.6.1 p. 321: Invertebrates

a) Invertebrates - http://en.wikipedia.org/wiki/invertebrate
b) Invertebrates - Encycopedia. – com
http://eee.encyclopedia.com/topic/Invertebrates.ates.aspx
c) Wirbellose - http://de.wikipedia.org/wiki/Wirbellose
d) Wirbellose - http://www.tierschutz.9rg/tierwelt/tiergruppen/wirbellose/index.php
e) Die systematische Einteilung der Tierwelt: Wirbellose
www.israng.ch/downloads/presentationen.../systematik_wirbellose.pdf
f) Wirbellose Tiere - http://www.nationalgeographie.de/thema/wirbellose_tiere
g) Weichtiere - http://www.nationalgeographie.de/thema/wirbellose_tiere
h) Riesenkalmare - Giant Squid
i) Giant squid - http://wikipedia.org/wiki/Giant_squid
k) Text: http://de.wikipedia.org/wiki/Riesenkalmare
Image: http://de.godzilla.wikia.com/wiki/Riesenkalmare
l) Zwergwespe or Fairywasp / Faryfly (see also p. 127)
m) http://de.wikipedia.org/wiki/Zwergwespen
n) Image of fairy fly
upper picture: http://www.metroactive.com/papers/sonoma/09.07.05/sharshooter-0536-html
lower picture: Spektrum der Wissenschaften – Bildgalerie - gefunden unter: www.google.ch
http://www.spektrum.de/artikel/972679&template-d_sdww:bildergalerie&_z=798888&:aus=974090

R-7-15

R.7.6.2 p. 322: Invertebrates - Examples

a) Invertebrates - Science Clariefied - http://www.scienceclariified.com/He-In/Invertebrates.html (in English)
b) Examples of Invertebrates - animals.pawnation.com/examples-invertebrate-amim
c) Giant Squid - see Ref. R.7.6.1 h) - http://wikipedia.org/wiki/Giant_squid
d) Snail - http://en.wikipedia.org/wiki/Snail
e) Examples of 2 Invertebrates: The Snail and the Ant
http://www.frustfrei-lernen.de/biologie/wirbeltiere-wirbellose-tiere-biologie.html (in German)
left: from Images of Snails - www.google.ch - right: from Images of Ants – www.google.ch

R.7.6.3 p. 323: Respiration of two Molusces: Giant Squid and Snails

a) Giant squid - see Ref. R.7.6.1 , p. 321 and Ref. R.7.6.2 , p. 322
b) Kopffüssler - http://de.wikipedia.org/wiki/Kopff%C3%%BC%C3%9Fer
Bild links: In den Fängen des Riesenkalmars - Bild aus: Riesenkalmar - www.google.ch/search.
c) Cernuella virgata (Vineyard snail) - http://en.wikipedia.org/wiki/Cernuella_virgita
d) Weinbergschnecken; Atmung und Blutkreislauf
http://weichtiere.at/Schnecken/land/weinbergschnecken/seiten/atmung_kreislauf.html
Text and Picture right-hand side [red arrows added by P. Brüesch]

R.7.6.4 p. 324: Respiration of Insects

a) All Insects are invertebrates - http://www.ento.csiro.au/education/what_invertebrates.html
b) Insect . http://en.wikipedia.org/wiki/Insect
c) The Internal Anatomy of an Insect - Picture of Insect
http://www.robinsonlibrary.com/science/zoology/insects/general/anatomy2.htm
d) Insekten - http://de.wikipedia.org/wiki(Insekten

R.7.6.5 p. 325: Insects: Trachea - Tracheoids - Spiracles (Stigmas)

a) How do Insects breath ? - http://insects.abot.com/od/morphology/f/breathin.htm
b) Stigma - Definition of Stigma by the Free Dictionary
In Zoology, the Stigma are the spiracle of an insect - http://www.thefreedictionary.com/stigma
c) The Breathing System of Insects - http://www.saburchill.com/chapters/chap0021.html
d) Die Atmung (der Insekten - Breathing of Insects
(Contains Text and Figure of p. 325; Text translated from German to English by P. Brüesch)
http://www.aktion-wespenschutz.de/Wespenkoerper/Atmung.htm

R-7-16

R.7.6.6 p. 326: Trachea – Air sacs and Spiracles

a) Tracheal Breathing - http://users.rcn.com/ikimball.ma.uptranet/BioöogyPages/T/Trachea_Breathing.html
b) Insect Physiology - Respiratory System
http://www.cals.nscu.edu/course/ent425/tutorial/resüire.html
c) Text and Image from: Reference R.7.6.5 d)
(The Figure Text has been translated from German to English by P. Brüesch)

R.7.6.7 p. 327: Insects: Trachea, Tracheole and Spiracles

a) How do Insects breathe? - Outline of the Tracheal System
http://bioteaching.com/how-do-insects-breath-an-outline-ofthe-tracheal-system
b) Fine branching of the Trachea on Tracheole - Picture a) from Ref. R.7.6.5; p. 325 d)
c) Spiracles (Atemöffnungen oder Stigmen) - Picture from
http://www.faunistik.net/DETINVERT/PHYSIOLOGY/ATMUNG/atmung.html
d) Atmungswege - http://www,insektenbox.de/fibel/bau/atemhtm

R.7.6.8 p. 328: Butterflies (For Flies: see Chapter 4, pp 131 – 134)

a) Respiration of Butterflies - http://en.wikipedia.org/wiki/Butterfl
b) The Respiratory System of a Butterfly
http://www.ehow.com/info_8547723:respiratory-system-butterfly.html
c) Butterfly Anatomy – Enchanted Learning Software
http://www.enchantedlearning.com/subject/butterfly/anatomy
d) Schmetterlinge - http://de.wikipedia.org/wiki/Schmetterlinge
e) Wie atmet ein Schmetterling? (Tiere, Insekten)
http://www.cosmiq.de/qa/show/895629/Wie-atmet-ein-Schmetterling
f) Der innere Aufbau der Falter
http://www.weöt-der-schmetterlinge.de/schmetterlinge-der_innere_Koerperbau_der_faöter.html
g) left-hand picture: Orange-tip Butterfly - Aurorafalter
(aus: Alarm für seltene Schmetterlinge in Europa)
http://naturschutz.ch/news/alarm-für-seltene-schmetterlinge-in-europa/41526
6. Oktober 2011 / Biodiversität / Von Stefanie Pfefferli
right-hand picture: Peacook butterfly – Tagpfauenauge: aus: www.de.wikipedia.org/Schmetterlinge

R-7-17

R.7.6.9 p. 329: Butterflies in Art

a) A new beginning .. my journey through nat - Poem of Wilhelm Busch: A Butterfly in Love
http://guildwoodgardens.blogspot.ch/2008/01/gedicht-von-wilhelm-busch.ber-einen.html
b) Carl Spitzweg http://en.wikipedia.org/wiki/Carl_Spitzweg
c) Butterflies (Van Gogh series) - http://en.wikipedia.org/wiki/Butterflies_%28Van_Gogh_series%29
d) Butterflies in Art - http://www.artsology.com/butterfly-art.php
e) Der Schmetterling (Wilhelm Busch) - Poem: A Butterfly in Love (Reproduced at this page)
http://www.medienwekstatt-online.de/ws_wissen/vorlagen/showcard.php?id=12129
f) Wilhelm Busch - Zum 175. Geburtstag - Depiction of the Butterfly Hunter (Reproduced at this page)
http://www.aski.org/portal2/cms-askiev-kultur-lebendig/aski-ev---kultur-lebendig-1-07/askiev.wilhelm-busch-..
g) Schmetterlinge - http://de.wikipedia.org/wiki/Schmetterlinge
[This page contains depiction of «The Schmetterlingsjäger» - «The Butterfly Hunter» from Carl Spitzweg)]

R.7.6.10 p. 330: Ants: Breathing – Anthill and its Ventilation- (for flying of Bees, Ants and Terites: Chapter 4: p. 130)

a) Ant http://wikipedia.org/wiki/Ant
http://wikipedia.org/wiki/Ant
b) Ant http://simple.wikipedia.org/wiki/Ant
http://simple.wikipedia.org/wiki/Ant
c) Do Ants Breathe ? - http://www.sophisticatededge.com/d0-ants-breathe.html
d) How do ants breathe ?
http://sg.answers.yahoo/com/question/index?qid=20060720002027AAcfY1D
e) Results tagged «ant hill» - How does thermoregulation work in ants? - Figure c):Ventilation of an Anthill
http://www.antweb.org/egi-bin/mt/mt-search.egi?blog_od=1&tag=ant%20hill&limit=20
f) Ant colony - http://en.wilipedia.org/wiki/Ant_colony
g) Ameisen - Bild: Rossameisen und Text - http://de.wikipedia.org/wiki/Ameisen
h) Ants: Start to Honeymoon flight - Hochzeitsflug - Picture and Text in Ref. g)
i) Ameisenhügel - aus: www.google.ch

R-7-18

R.7.6.11 p. 331: Termites (for flying Bees, Ants and Termites: Chapter 4, p. 130)

a) Termite : http://en.wikipedia.org/wiki/Termite
b) Formosan subterranean termite - http://en.wikipedia.org(wiki/Formosan_subterranean_termite
c) Termiten - http://de.wikipedia.org/wiki/Termiten
d) Termiten - Heft: Begabte Baumeister – Ceruttis Wunderwelt: Begabte Baumeister
http://www.konradin.de/sixcms/detail.php?id=90563
e) Das Wunder der Termiten : Harun Yahya / Adnan Oktar
http://harunyahya.de/de/Bucher/4614/das-wunder-der-termiten/chapter/8763
[Text and Figures from References c), d), and e) - Text translated from German to English by P. Brüesch]

R.7.6.12 pp 332, 333: Respiration in Aquatic Insects - 1 – 2

a) Respiration in Aquatic Insects - http://www.cals.ncsu.educourse/ent425//tutorial/aquatic.html
(contains Text and pictures of pp 332 and 333)
b) Common aquatic insects - The Encyclopedia of Earth - http://www.eoearth.org/view/article/151318&/
c) Better Breathing Underwater in Aquatic Insects .
http://thedr.agonflywoman.com/2010/02/24/aqrespefficiency/
d) Aquatic insects - http://en.wikipedia.org/wiki/Aquatic_insects
e) Atmung von aquatischen Insekten
http://www.schule-bw.de/unterricht/faecher/biologie/project/bach/atmung_hintergtund.html

R-7-19

References to Appendix - Chapter 7

7-A-1-1 p. 7-A-1-1: Systemic and Pulmonary Blood Circulation System

a) Text from Ref. R.7.1.1 a) (p. 278)
b) Heart Health Center - Image Collection: Human Anatomy
http://www,webmd.com/heart/picture-of-the-arteries
c) Circulatory System: Facts, Function % Diseases
http://www.livescience.com/22486-circulatory-system.html
d) The Circulatory System - Part II: The Heart and Circulation of Blood
http://sa.colorado,edu/essence/texts/heart.html
e) Blutkreislauf - DocCheck Flexikin
Definitionen: Grosser und kleiner Blutkreislauf
http://flexikon.doccheck.com/de/Blutkreislauf

7-A-1-2 p. 7-A-1-2: Prenatal and postnatal circulation system

a) Blood curculation in the Fetus and Newborn - University of Rochester Medical Center
http://www,urmc,rochester.edu/encyclopedia/content.aspx?ContentTypeID=90&ContentID=?02362
b) CH19 Blood Flow - Exam1 Review: Chapter 19: Blood Flow
http://apbrwww5.apsiu.edu/thompsonj/Anatomy%20&208%20Physulogy/2'20&2020%20Exam%
20Review/Exam%201/CH19%20Blood%20Flow.htm
c) 16.9 Enbryo-fetal circulation system – changes at birth
Changes at birth - http://www.embryology.ch/anglais/pcardio/umstelling02.hrml
d) Control of Respiration in the Fetus and Newborn Lung - by P.J, Fleming and Jose Punte (1983)
link.Springer.com/…/10.1007%2F978-1-4684-1487-…
e) Enbryo-fetaler Kreislauf – Umstellung bei Geburt
Einführung – Der fetale Kreislauf (Text und Bild der geschlossenen Nabelschnur)
http://www.embrology.ch/allemand/pcardio/umstellung01.htmk
(Beschriftung des Bildes von P. Brüesch)

R-7-20

7-A-1-2 (cont.)

f) Umstellung bei Geburt – Kreislaufsystem
http://www.embryology.ch/allemand/respiratory/geburt01.html

g) Wissen.de
Welche Bedeutung hat der erste Atemzug des Kindes?
http://www.wissen.de/bildweb/geburt-welche-bedeutung-hat-der-erste-atemzug-des-kindes

7-A-1-3 p. 7-A-1-3: From fthe fetal circulation to the first breath (Vom fetalen Kreislauf bis zum ersten Atemzug)

a) Adaptation to extrauterine life
http://en.wikipedia.org/Adaptation-to-the-entruteric-life

b) Translation of the latin «ductus arteriosous», «ductus venosus», «Foramen ovale» and «Umbilical» vein:
b1) Ductus arteriosus: is a blood vessel connecting the pulmonary artery to the proximal descending aorta. Anatomical terminology
http://en.wikioedia.org/wiki/Ductus:arteriosus
b2) Ductus venosus: Fetal shunt between the left hepatic portal vein and the inferior caval vein. Allows oxygenated blood from the placenta to bypass the liver, Ductus venus
http://en.wikipedia.org/wiki/Ductus_venosus
b3) Foramen ovale: In the fetal heart, allows blood to enter the left atrium from the right atrium. Foramen ovale.
http://en.wikipedia.org/wiki/Foramen_ovale_%28heart%29
b4) Umbilical vein: (Nabelvene) is a vein present during fetal development that carries oxygenated blood from the placenta to the growing fetus.
Umbilical vein - http://en.wikipedia.org/wiki/Umbilical_vein

7-A-1-4 p. 7-A-1-4: Picture from: Human respiratory system - Encyclopedia Britannica
Physiology - Written by Arthur A. Siebens, M.D.
http://www.britannica.com/EBchecked/topic/499530/human-respiratory-system/66147/The-mechanism-of-breathing

7-A-1-5 p. 7-A-1-5: Physiological Responses to Oxygen and Carbon Dioxide in the Breathing Environment
W. Jon Williams, Ph.D. National Institute for Occupational Safety and Health, USA (2009)
http://www.cdc.gov/niosh/...//9cO202PresentWJW-pdf

R-7-21

7-A-1-6 p. 7-A-1-6: Badly ventilated beedrooms

a) Ventilation Energy and Environmental Technology - http://www.veetech.org.uk/Bedroom%20Ventilation.htm
b) Dynamics of Changes of Carbon Dioxide Concentrations in Bedrooms
Piotre Batog and Marek Badura - Departement of Heating and Air Conditionning, Faculty of Environmental Engineering, Wroclaw University of Technology, Wybrzeze - Wyspianskiego St., 50 – 370 Wroclaw, Poland
ELSEVIER - SciVerse ScienceDirect - Procedia Engineering 57 (2013) 175 - 182
www.elsevier.com/locate/procedia

7-A-1-7 p. 7-A-1-7: Evaluation of indoor air composition time variation in air-tight occupied spaces during night periods
Detelin Markov in: AIP Conf. Proc. **1497**, 61 (2012)
https://www.researchgate.net/publication/258573843_Evaluation_Of_Indoor_Air_Composition_Time_Variation_in Air-tight_Occupied_Spaces_During_Night_Periods

7-A-4-1 Respiratory Sysrem
Figur showing Inspiration and Expiration of Birds
Birds: Adaptations for Flight - http://sunny.moorparkcollege.edu/~econnolly/Bird.htm

7-A-5-1 Oceans: Oxygen Minimum Zones (OMZ's)

a) Oxygen minimum zone - http://en.wikipedia.org/wiki/Oxygen_minimum_zone
b) Ozean - Text: http://de.wikipedia-org/wiki/Ozean

7-A-5-2 Oxygen deficiency in Seawater

a) Dissolved Oxygen (DO) in Water - Lowest DO at which fish survived for 24 hours (Summer)
http://www.water-research.ch,net/index.php/dissolved-oxygen-in-water
b) Dem Meer fehlt der Sauerstoff - Peter Ruegg: Veröffentlicht am 12.1.2012
http://www.ethlife.ethz.ch/archive_articles/120112_sauerstoffarme_meere_per
c) Fischsterben - http://de.wikipedia.org/wiki/FISCHSTERBEN

7-A-6-1 Breathing of Insects

a) Biology - http://enx.org/contents/185chf87-c72e-48f5-b51e-f14f1275eabd@9.45:204 – (Picture and Text to Insect) - Picture and Text to Insect
b) How do Insects Breathe ? - http://insects.about.com/od/morphplogy/f/breathing.ht

R-7-22

7-A-6-2 Aquatic Insects – Glatter Kugelschwimm – Käfer

a) Aquatic insects - http://en.wikipedia.org/wiki/Aquatic_insects
b) Insekten - http://de.wikipedia.org/wiki/Insekten
c) Glatter Kugelschwimmer - Hyphydrus ovatus - http://de.wikipedia.org/wiki/Glatter_Kugelschwimmer
d) Glatter Kugelschwimmer, Käfer von Hyphydrus sp: http://www.hydro-kosmos.de/winsekt/hyphkaef.htm
e) Gefleckter Schnellschwimmer - http://www.submers/index.php?-Gefleckter_Schnellschwimmer
f) Wasserkäfer und Wasserkäferlarven - http://www.hydro-kosmos.de/klforsch/wkaefer.htm

7-A-6-3 Backswimmers

a) Backswimmers - http://www.flycraftangling.com/index.asp?p=118
b) Notonectidae - http://en.wikipedia.org/wiki/Notonectidae (contains picture of «Backswimmer swimming on his back» and «Breathing backswimmer at water surface»
c) Rückenschwimmer - http://de.wikipedia.ofg/wiki/R%C3%BCckenschwimmer
d) Rückenschwimmer - http://www.hydro-kosmos.de/winsekt/waskaef2.htm

R-7-23

8. Selected Atmospheric Phenomena

334

8.1 Thunderstorm - clouds Lightnings and Thunder

[See also Chapter 3: pp. 71, 77,78; pp 93 – 99]

335

8.1.1 Development and Structure of Thunderstorm Cells

A thunderstorm is a complex meteorological phenomena which is associated with a discharge of electrically charged air (lightnings and thunder). On average, about 1'600 thunderstorms exist simultaneously on the Earth which take place over an area of 0.3% of the surface of the Earth. It is estimated that there are as many as 40'000 thunderstorms occurrences during one day world-wide. For introductionary remarks about thunderstorms, hails, lightnings, tornados and hurricanes s. Chapter 3, pp 71, 77, 78; and pp 93- 99.

Thunderstorms can develop if a sufficiently large vertical temperature decrease is present in the atmosphere. In this case, a parcel of air becomes instable by condensation (i.e. by the formation of small water droplets) and starts to rise. This is only possible if the temperature decrease is larger than 0.65 ^{0}C per 100 meters in altitude. A rising parcel of air which is condensed out, cools down by more than 0.65 ^{0}C/100 m (saturated adiabatic ascent).

← Thunderstorm of a strong Hailstorm at the «Bodensee»

But due to the released condensation heat, the parcel of air cools down less rapidly than the ambient air. For this reason it becomes warmer and due to the associated decrease of density it becomes ligther than the ambient air: a lift is generated. For the formation of a lightning, the existance of a humid air layer near the ground is necessary. The latent heat of this humid air layer is the energy supplier for moisture convection. This is the basic necessary condition for the formation of a thunderstorm. The latent heat is the hidden energy contained in the water vapour, and this energy is released as heat during the process of condensation.

336

Processes of development of a Thunderstorm cloud

A rising parcel of air will initially cool down (1.0 ^{0}C/100 m) until its dew point temperature is reached. At and below this temperature, the water vapour contained in the parcel of air starts to condense and a Cumulus cloud is formed. Under appropriate conditions, this Cumulus cloud can increase and grow by forming a thunderstorm cloud, a so-called Cumulonimbus cloud. At the condensation point, the energy stored in the water vapour is released in the form of thermal energy giving rise to a temperature increase. This causes a decrease of the density of the parcel of air relative to the ambient air and leads to an additional buoyancy. In the presence of a so-called conditionally unstable stratification, the parcel of air rises up to an altitude where the difference of temperature per unit height (the temperature gradient) decreases again. This causes again a decrease of the temperature- and density differences relative to the ambient air. If the density of the parcel of air is equal to the density of the ambient air, the buoyancy force disappears and the buoyancy of the air is stopped.

Cumulonimbus cloud

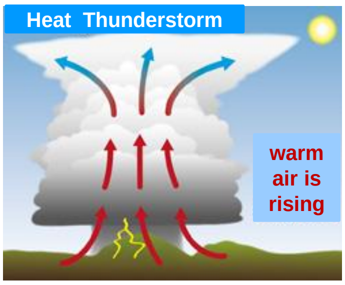
Usually, the equilibrium level is located in the vicinity of the Tropopause (Chapter 1, pp 7 and 9). In Central Europe, the altitude of the Tropopause is between 8 km in winter and 12 km in summer. In the Tropics, the Tropo-pause is at about 16 km.

Because of their inertia, the parcels of air can overshoot the equilibrium level. Such «overshooting tops» can reach altitudes up to 20 km. [see alsp picture in Chapter 3, p. 71].

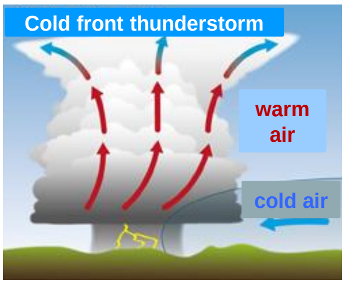
337

Convection currents in Heat- and Cold front Thunderstorms

Basically, there are two kinds of thunderstorms: The air-mass thunderstorm such as the heat thunderstorm, and the multicell storm such as the cold front thunderstorm. The characteristica of these two types of thunderstorms are discussed below.



In Middle Europe, heat thunderstorms occur almost exclusively in the summer half-year. The strong solar radiation heats up the air (lower red arrows) and much water vapor is leaving the ground (evapotranspiration). The temperature is increasing strongly, mainly near the ground, while in larger altitudes it essentially remeins constant. At a certain temperature (trigger temperature), warm air bubbles start to rise into the altitude, since these air bubbles are warmer and lighter than the air in their surroundings. With increasing altitude, the air bubbles are cooling down and finally, they reach the condensation level. If the atmospheric levels above are humid and unstable, thermal thunderstorms are formed. Heat thunderstorms are most common in the afternoon or in the early evening hours.



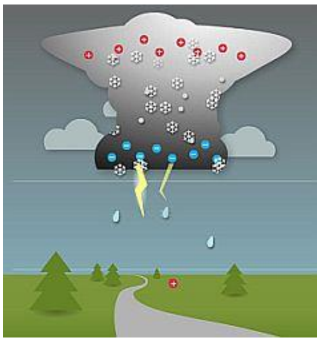
The cold front thunderstorm is initiated by the contact of humid air with a cold air front. The effect is similar to that of the heat thunderstorm as shown in the Figure at left. If a cold front is formed, the cold air is sliding similar to a wedge below the moist warm air so that the latter is lifted. In a certain altitude, the gaseous water vapour is condensed and Cumulus clouds are formed. At suitable conditions, these Cumulus clouds can grow and create thunderstorm clouds.

338

8.1.2 Formation of electrical charges in a Thunderstorm cloud

In nature a lightning is a spark discharge between a cloud and the ground (cloud-to-ground discharge), within a cloud (intra-cloud), between two clouds (cloud-to-cloud discharge) or from the ground to a cloud (upward lightning) (s. p. 340). As a rule, a lightning is generated during a thunderstorm caused by electrostatic charges of the cloud generated by water droplets or by raindrops. It is accompanied by thunder and it belongs to the so-called «electro-meteors». In this process, electical charges (electrons or gaseous ions) are seperated, i.e. electrical currents are flowing. Most often, lightnings are observed in the presence of Cumulonimbus clouds (s. p. 337 and picture below; in addition, see also the Figure at p. 77, Chapter 3).

The mechanism of charge separation within a cloud is not realy understood. One theory assumes that the friction between snow crystals generates a charge separation. Another theory advocates that falling water droplets are electrically charged. In a third theory it is supposed that during their fall and the associated deformation, larger raindrops are ruptured and that the larger fragments aquires a positive, the smaller a negative charge («water fall electricity»). This latter mechanism could be mainly responsible for the lower part of the thunderstorm cloud. A further theory is associated with the freezing process: Here, it is postulated that during the freezing of water droplets, positively charged hydrogen ions H^+ (protons) together with the ice crust are fragmented. In all theories, charges are separated and by means of ascending and descending winds are carried along; in this way, a large electrical field is established.



Cloud-to-ground discharge between a cumulonimbus cloud and the ground

The discharge of lightning occurs if the charge separation is sufficiently large so that the breakdown potential is reached. In practical situations, this breakdown potential is substantially smaller than 1 MV/m.

339

The Anatomy or Types of Lightnings

a) Cloud-to-Ground Lightning: CG

b) Cloud-to-Cloud Lightning: CC

c) Intra-Cloud Ligtning: IC

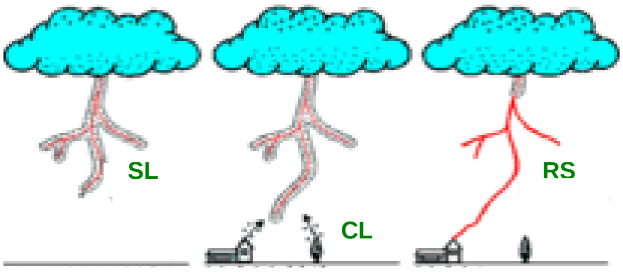
d) Ground-to-Cloud Ligtning: GC

340

Stepped Leader, Upward connecting Leader and Return Leader

The lightning discharge is proceeded by a series of predischarges which are directed against the ground. Thereby, a charge channel, the so-called «Stepped Leader» (SL) is generated (Figure a) . This stepped leader is formed by impact ionisation of the air molecules, i.e. by «Runaway-electrons». The ionized lightning channel is formed step by step (hence, it is known as the step leader) until it has nearly reached the ground. Although the predischarges, also known as «dart leaders» are directed towards the ground, their directions are slightly changed within some meters and they can split off sporadically. This gives rise to their zigzag form and for their branching.

Shortly before the dart leaders have reached the ground, one or more faint upward «Connecting Leaders» (CL) start from the ground (Figure b). An upward connecting leader usually occurs at pointed objects (trees, masts, church towers). In most cases, one of the stepped leaders coincides with an upward connecting discharge thereby forming a closed charge channel, the so-called «Return Stroke» (RS), between cloud and ground (Figure c). The «Return Stroke» (or main lightning) has a maximum diameter of 12 mm. This is the principle lightning discharge, which is very bright and is the observed lightning. The intense radiation is caused by the formation of a plasma.



a) Stepped Leader (SL) v_{SL} ≈ 300 km/s

b) Upward Connecting Leader (CL)

c) Return Stroke (RS) v_{RS} ≈ 100'000 km/s

Stepped Leader from cloud to ground with upward Connecting Leader

341

Properties of Lightnings

Temperature: The highest yet measured temperatur of a lightning is about. 30'000 ^{0}C (!) and has been obseved in a lightning channel for a period of about one micro second (10^{-6} s). This temperature exceeds the temperature at the surface of the Sun by more than a factor of four!

Diameter: The visible diameter of a lightning is several centimeters to about 10 centimeters but an exact determination by photographic methods is very difficult.

Lengts of Ligthnings: Cloud-to-ground lightnings have lenghts varying between 5 and 7 km while the average length of a cloud-to-cloud lightnings is about 8 km (s. p. 340). By means of radar equip-ments, lengths of clouds as large as 140 km have been detetected.

Velocity: The velocity v of a lightning is about one-tenth to one-third of the velocity of light c (c ≈ 300'000 km/s). Let v_1 = 30'000 km/s and v_2 = 100'000 km/s. The circumference of the Earth is U ≈ 40'000 km. This means that within τ = 1 s, the lightning would travel 0.75 times and 2.5 times around the Earth, respectively.

Main lightning discharge: An average ligtning contains about 4 discharges, and the duration of each is about t = 40 μs. For a voltage of U = 30 MV the current is I ≈ 20 kA. The electrical energy E per discharge is given by E = U*I*t. By substituting the above values one obtains an energy E ≈ 26 kWh for the 4 discharges. This is an energy which is consumed by a four-person household in about 2 to 3 days. Since 1 litre of fuol contains about 10 kWh, the lightning energy of 26 kWh is equivalent to 2.6 L of fuel. A very strong lightning is able to discharge about 10 times this energy (≈ 260 kWh → ≈ 26 L fuel) [s. also p. 96, Chapter 3].

Light emission: The extremely high temperatures and electric fields in a lightning channel ionizes the air (oxygen and nitrogen), i.e. their electrons are pulled off and become free and mobile. In addition, the atoms are highly excited and form a plasma. As the energy of a plasma drops, the free electrons recombine and the internally excited electrons relax to their ground state. The transition of the electrons to lower states causes the emission of photons or radiation – ultraciolet – visible or infrared light which propagates with the velocity c. This explains the yellow-light colour of lightning channels.

342

8.1.3 Development and Properties of Thunder

Thunder is caused by a sudden expansion of air, which is due to the sudden increase of temperature associated with the passage of a lightning (25'000 to 30'000 ^{0}C, s. p. 342). This process starts only in the case of an adequate supply of atmospheric humidity. The air expands with a velocity u which is larger than the speed v of sound by breaking the sound barrier: $u > v = 340$ m/s. A pressure wave of condensed air molecules is generated. The very hot air plasma around the lightning channel (a few meters) generates the shock wave and the lightning bang.

The intensity of a lightning bang decreases with increasing distance since the energy of the pressure wave is spread over larger areas. The bang is peceptible by the sense only in close vicinity of the lightning (about 5 km). At larger distances, a permanent murmer or rolling sound without peak clipping is perceptible. This «stretching» of the pressure wave is due to dispersion, i.e. to the fact that the lightning bang is composed of a large number of waves with different frequencies and different speeds. In addition, reflexion and refraction of the sound waves as well as winds present in the traversed air play an important role. For all these reasons, the pressure wave reaches the observer at different times. If the distance between observer and lightning is too large, the thunder can not be detected acoustically and only a heat lightning can be observed.

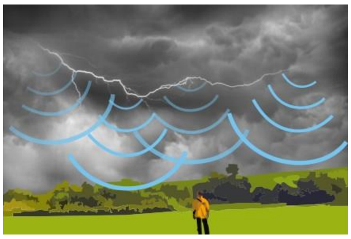
Zeus, the Greek God
of heaven and thunder

In the absence of all the complications mentioned above, the distance between the observer and the lightning can be evaluated in a simple way: Let t be the time in seconds, which elapses between the observation of the lightning and the perception of the bang. The distance d between the lightning and the observer is then simply given by $d = v*t$. As an example we assume that $t = 10$ s; then the distance is given by $d = 340$ m/s * 10 s = 3'400 m = 3.4 km.

343

Acoustic emmisions of Lightnings

In the case of a Cloud-to-Ground lightning (CG), the lightning starts from the cloud and propagates perpendicularly to the ground, (p. 340, Figure a)). In this case, the direction of the lightning is essentially perpendicular to the observer who hears a fierce bang.



If the direction of the lightning is approximately parallel to the line of sight (p. 340, Figure b)), the observer hears the well known rolling of thunder. This situation prevails in the case of a Cloud-to Cloud lightning (CC).

In case of a combination of a CG and a CC-lightning, the observer hears both, a fierce bang as well as a rolling thunder.

344

8.1.4 Dangers of lightnings and lightning protection

Dead cows after a lightning strike

Victim of a lightning strike

Bearning house
after a lightning strike

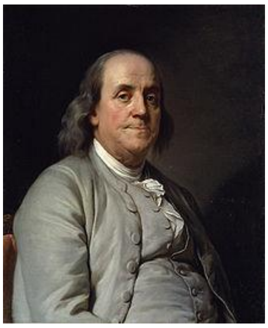
Venezuela: Refinery burns
after a lightning strike

345

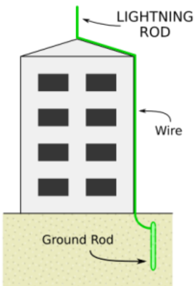
Lightning protection by lightning conductors and earthing

Benjamin Franklin (1706 – 1790) is considered as the inventor of the lightning conductor. He found that electrical charges are attracted by metal tips. In April 1749 he described his observations as follows: : «An iron rod being placed on the outside of a building from the highest part continued down into the moist Earth, …, following the form of the roof or other parts of the building, will receive the lightning at its upper end, attracting it so as to prevent it's striking any other part; affording it a good conveyance into the Earth, will prevent its damaging any part of the building». As lightning protectors, he installed iron rods on the top of high towers.

A lightning rod is an earthed electrical conductor (aluminum- or copper conductor with diameters between 8 and 10 cm). In the first place, a lightning rod avoids the impact of a lightning into a protected building. The impact rather takes place into the lightning protection system. In the case of an impact, this lightning protection system represents a low-resistance current path, whereby damages of the protected building can be avoided. In order that the high currents can be conducted safely into the ground, the concrete-footing ground electrode must have a low impedance. The probability, that lightning rods attract additional lightnings is so small that it can not be statistically detected.



a) Benjamin Franklin

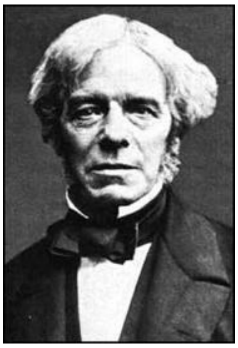


b) Diagram of a simple lightning protection system

c) Lightning rod mounted at a Statue of the «Landtag of Bavaria»

346

Lightning protection by the Faraday cage

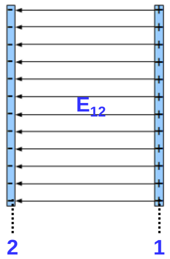


Michael Faraday

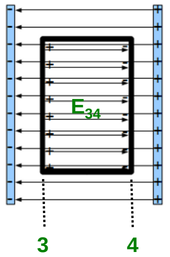
Michael Faraday (1791 - 1867) was an eminent natural scientist and a most distinguished experimental physicists.
Among other things, he is the discoverer of «Faraday's law of induction» on which the «Faraday cage» is based (s. left-hand pictures below). The external electric field E_{12} of the capacitor plates 1 and 2 causes an opposit displacement of charges in the metal walls of the cage. The opposing field in the inner of the cage, E_{34}, cancels the external field E_{12}: $E_{12} + E_{34} = E = 0$.

In the ideal case of a fully enclosed Faraday cage consisting of an electrically conducting material, no mobile telephony or radio reception would be possible. In the case of a lightning, persons sitting in the interior of a closed car are in a safe place because it is relatively field-free (s. right-hand picture below). For the same reasons, airplanes are usually well protected from the dangers of lightning strikes.

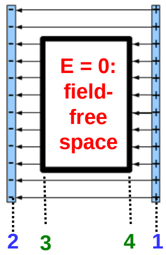
Electric field E_{12} in a plate capacitor



Opposing field E_{34} in Faraday cage in plate capacitor



Resulting field $E_{12} + E_{23} = E = 0$ in Faraday cage



Lightning strike on the cage of a car

347

8.1.5 Fractal structures of lightnings and electric discharges

The word fractal is derived from Latin and stands for fractured (in medicine, a similar word is known: fracture). Fractal structures are characterized by a high degree of self-similarity. This is, for example the case, if an object consists of several small copies of itself. Thereby, the self-similarity must not be complete, i.e. substantial deviations are tolerated: it is only necessary that the smaller structures have similarities with the larger structures.

The left-hand image shows the fractal structure of a cloud-to-ground lightning. The right-hand structure illustrates impressively artificially produced discharges.

Fractal structure of a lightning.

Electrical discharges (Lichtenberg-Figures), which shows the natural beauty of fractal structures.

348

8.1.6 Ball Lightnings - Observations

This form of lightning is observed very rarely. It has the appearence of a slowly moving sphere. The diameters are usualla in the range between 20 to 40 cm. It has been claimed recently that a ball lightning has been captured on video for the first time.

Not only famous people such as the roman philosopher Seneca, Pliny the Elder, Charlemagne or Henry II of England, and in more recent times the Nobel Prize winners of physics, Niels Bohr and Piotr Kapitza claim to have observed the phenomena. Also many less famous people are reporting unexpected encounters with ball lightnings. In Internet, more than a million of reports can be found (such as the ball lightning of Neuruppin in Brandenburg, Germany). On the other hand, this atmospheric phenomenon is very rare, and so far the subject is still controversal.

According to reports of eyewitnesses, ball lightnings can have different colours, including blue, yellow, pink and orange. These lightning spheres occur usually immediately after a thunderstorm.

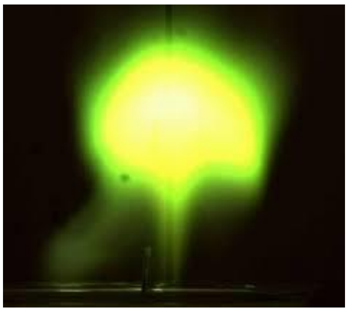
The duration of a ball lightning can vary from some seconds to one minute, but usually they do not cause damages. A characteristic feature is the mobility of the balls: within 2 to 8 seconds, at the maximum after 30 seconds, they often change their direction; obviously, they are not carried by the wind but rather orient themselfs by visible objects. They also can penetrate solid obstacles without deformations and without leaving any traces and the rain can penetrate the ball lightnings unaffected. Many witnesses also report about the appearence of spark discharges or about a loud bang at the end of their existence. It is claimed that the latter phenomenon can also cause injuries and damages.

Description of a ball lightning of the 19th century

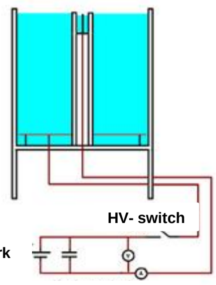
Scientifically, the existence of ball lightnings is controversal. Despite many efforts, no mechanism has been found which is able to unify all observations. But the lack of an understanding is no counterproof. Effectively, the existence of ball lightnings is increasingly accepted.

349

Ball Lightning Experiments



Plasma ball similar to a ball lightning generated in the Laboratory



Experimental set-up

Scientists of the Max-Planck Institute for Plasma Physics (IPP) in Garching near Munich and of the Humboldt University in Berlin (HUB) have produced plasma balls which are similar to ball lightnings. By producing an underwater discharge, luminous plasma balls have been generated at the surface of the water. The lifetime of these plasma balls is nearly a half-second and the diameters are 10 to 20 cm.

In parallel with these experiments, a research group in St. Petersburg was able to produce ball-shaped light sources which are distinctly more similar to the natural ball lightnings. These experiments strongly suggest that during the birth of ball lightnings, thunderstorm lightnings and water must act together.

The experimental set-up for producing ball-shaped light sources is rather simple: A capacitor battery (U = 5 kV, C = 0.5 mF) provides the energy supply. In a beaker filled with salt-water there are two electrodes where one of the electrodes is electrically isolated from the surrounding water by a clay tube. If a high voltage is applied, a current up to 60 A is flowing through the water By an electric flashover, this current is flowing from the water into the clay tube whereby the water contained in the clay tube evaporates. After the current puls, a luminous plasmoid consisiting of ionized water molecules (H_3O^+ and OH^- ions) is produced (see upper picture).

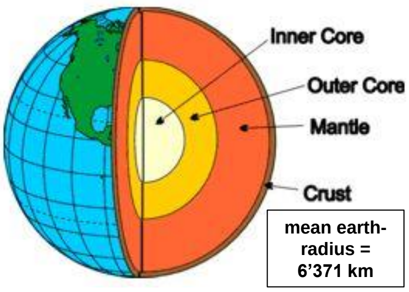
350

8.2 Earth's magnetic field, Solar wind, Magnetosphere, and Polar lights

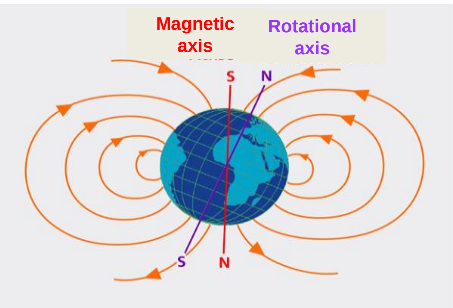
Without the shielding of the Solar wind
by the Earth's magnetic field,
no life would be possible on Earth !!

351

8.2.1 Internal structure of the Earth and Earth's magnetic field



Earth's internal structure



Undistorted magnetic field of the Earth
(for details s. Appendix p. 8-A-2-1)

The Inner Earth core extends from 5'100 km to 6'371 km below the surface of the Earth. [The average radius of the Earth is <R> = 6371 km]. Presumably, it consists on a solid nickel-iron alloy. The Outer Earth Core is located in a depht between 2'900 km and about 5'100 km below the surface of the Earth. This part of the core is a liquid nickel-iron alloy and its temperature varies between 3'000 ^{0}C and about 5'000 ^{0}C. The magnetic field of the Earth is generated by the electrically conducting iron melt in the outer core which is set in motion by the rotation of the Earth.

The magnetic field is very weak (0.2 bis 0.7 Gauss). It is also subjected to short- and long-term variations. The notion «Magnetism of the Earth», refers to the magnetic field in the close vicinity of the Earth and in the absence of extenal perturbations by the solar wind (undisturbed magnetic field). In a first approximation it is the field of a magnetic dipole. This field strongly decreases with increasing distance from the Earth but it extends far into the space. This space region is also called magneto-sphere and is strongly distubed by the solar wind (pp 353-356). As to the generation of the magnetic field (geodynamo) as well as to its possible pole reversal see the discussion given in Appendices 8-A-2-1 and 8-A-2-2.

[For comparision, the magnetic field of a small bar magnet in a distance of 20 cm is about 0.1 Gauss].

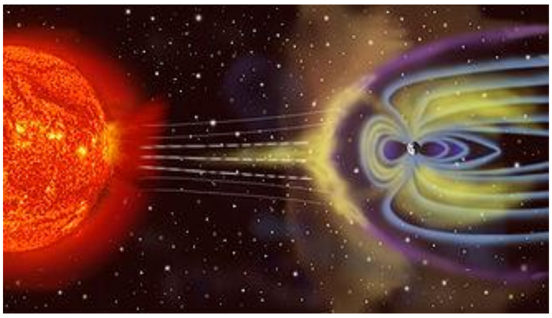
352

8.2.2 Solar wind and Magnetosphere - 1

The solar wind is a particle stream emanating from the surface of the Sun in all directions.

The solar wind is composed on high-energy charged particles, namely on protons and electrons as well as on alpha-particles (He^{2+} - ions consisting on two protons and two neutrons); other particles such as atoms and non-ionized (electrically neutral) atoms are essentially absent; for this reason, the solar wind is a so-called Plasma.

In the proximity of the Earth, the solar wind has a density of about $5*10^6$ particles per cubic meters. Its velocity is very large, about 300 to 700 km/s! The Sun loses about one million tons of its mass per second (the mass of the Sun is about $1.99»10^{27}$ tons). Without the shielding of the solar wind by the Earth's magnetic field, no live would be possible on Earth !! (s. Ref. R.8.2.4, e)).

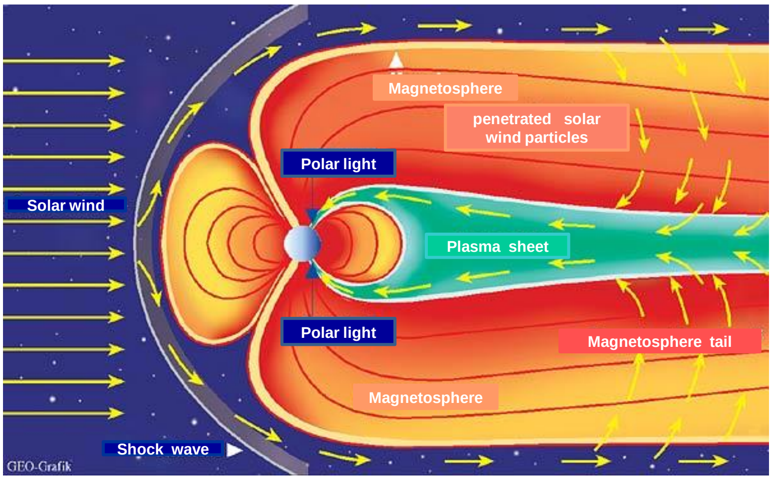


Shielding of the solar wind by the magnetic field of the Earth (Figure not to scale)

353

Solar wind and Magnetosphere - 2

Since the solar wind is a plasma, it deforms both, the magnetic field of the Sun as well as that of the Earth (s. Figure below). The terrestrial magnetic field screens the Earth to a large part from the dangerous particle shower of the Sun. Only in the case of a intensive solar wind, its particels can penetratrate into the high layers of the Earth's atmosphere. By penetration into the plasma sheet, they can produce the so-called . polar lights or aurora polaris (pp 358-361). Strong polar winds can also perturbe the High Frequency radio (HF radio) (s. Section 8.3).



Deformation of the terrestrial magnetic field by the Solar wind

354

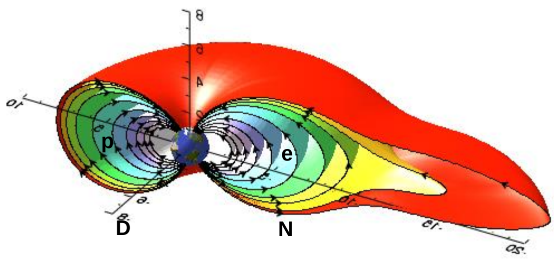
Solar wind and Magnetosphere - 3

If the the solar wind propagates through the space towards the Earth, it encounters an obstacle, namely the huge magnetic field of the Earth (s. pp 353, 354). This charged particle straem approaching the Earth compresses the magnetic field of the Earth on the Sun-facing side and expands it on the opposite side where it forms a long tail (pp 353-356 and picture below). In this way, the Magnetosphere of the Earth is formed.

The boundary or outer edge of the elongated cometary body facing the interplanetary space, is a mantel having a depth of about 100 km which is called the Magnetopause (s. p. 354). Due to its high kinetic pressure, the solar wind compresses the Magnetosphere at the dayside to a distance of about $6*10^4$ km from the Earth, while at the nightside, the magnetic field is elongated to a tail having a length of about $6»10^6$ km (s. p. 354, 356 and picture below).

At the sun-facing side, the solar wind exhibits a transition from a supersonic to a subsonig flow, which causes a shock wave or a so-called bow shock wave. The distance between this bow shock wave and the magnetopause is about 18'000 km. Due to the strong retardation of the solar wind within the bow shock wave, the solar wind exhibits a so-called thermalization. i.e. a conversion of a large part of its kinetic energy into thermal energy; this thermalization heats up the solar wind.

During the collision of the particles of the solar wind with the Magnetopause, a separation between the protons and the electrons takes place; this is due to the so-called Lorentz force: As observed from the Earth, the protons (p) are deflected to the right while the electrons (e) are deflected to the left. Due to this separation, a positive pole is formed at the dayside (D) and a negative pole at the nightside (N). In this conducting plasma of the magnetosphere, an electrical current can flow between these two poles.

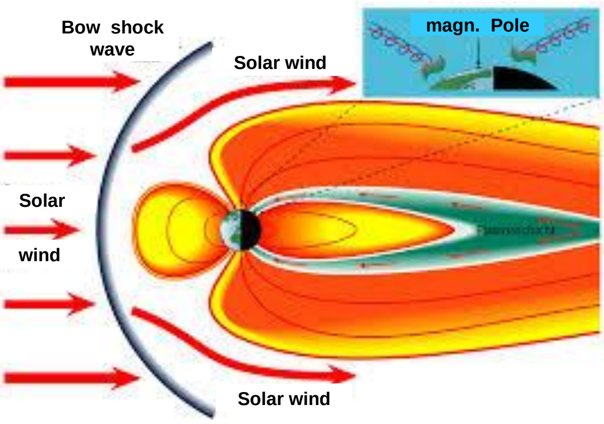


3 D- Representation of the Magnetosphere

Solar wind and spiral paths of charges near the poles

Here we show a complementary picture to that of p. 354. In addition to the deformation of the magnetic field by the solar wind, the picture shows also the electrons penetrating into the atmosphere in the surroundings of the North Pole (blue Section at upper right side). This Section shows schematically how the electrons are moving around the magnetic field lines and penetrate into the atmosphere of the Earth. By chemical reactions with oxygen and nitrogen of the air, they are generating the polar lights (pp 358 – 361).

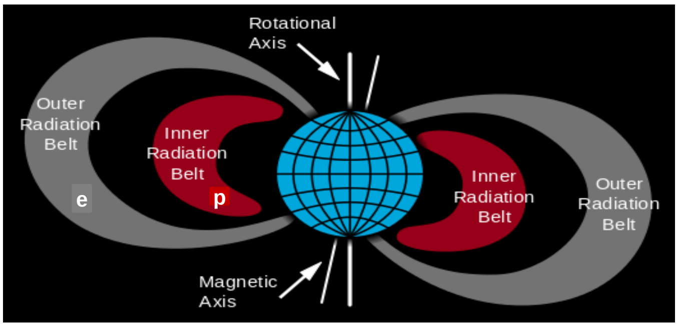
According to the older perceptions, it is assumed that the charged particles are predominantly generated by the solar wind and the cosmic radiation. However, more recent investigations have shown that the particles originate mainly in the so-called Van-Allen belt itself (see p. 357).



Spiral path of charges around the magnetic field

Van Allen radiation belt

A Van Allen radiation belt (named after James Van Allen) is one of at least two layers of energetic charged particles (plasma) that is held in place around the planet's magnetic field (see Figure below). So far it has been assumed that these particles originate predominantly from the solar wind and from cosmic radiation (see p. 365). Newer investigations from the orbiters «Van-Allen A» and «Van-Allen B» have shown, however, that the predominant portion of the particles originate in the belts themselves: In these belts, the atoms are effectively ruptured by very strong electromagnetic fields whereby electrons and protons are liberated.



The belt essentially consist of two radiation zones: The inner radiation belt extends over low latitudes in an altitude range between 700 to 6'000 km above the Earth's surface and it contains mainly high-energy protons (p). The outer radiation belt is located in an altitude between 15'000 to 25'000 km and contains mainly electrons (e).

Importance for Space Flights: Depending on the spatially and temporally regions, the intensity of the radiation within the Van_Allen belts can potentially be dangerous to health. For this reason, the aspect of radiation protection for manned space missions in the Earth's orbit can not be neglected.

357

8.2.3 Formation of Polar Lights

Since the electromagnetic processes of the formation of polar lights are complicated, we confine ourselves to a qualitative description.

The Polar lights known as «Northern lights» at the North Pole, scientifically denoted as «Aurora borealis», and the Southern Lights «Aurora australis»), are luminous phenomena (more precisely «Electrometeors»). They are generated by the impact of charged particles of the solar wind (pp 353 – 355) into the Earth's atmosphere of the polar regions. The Photo below shows a Polar light in Northern Norway (Reference R.8.2.7 c)).

The particles of the solar wind (electrons and protons) have an average velocity of 500 to 830 km/s (up to about 3 millions km/h) and their density is about 5 millions of particles per m^3. The particles of the solar wind are directed by the magnetic field towards the magnetic Poles (pp 354, 356). In the vicinity of the magnetic Poles, the direction of the magnetic field is practically perpendicular to the surface of the Eaerth and therefore, the particles can penetrate into the Earth's atmosphere (yellow arrows in the plasma sheet of the Figure at p. 354). In the atmosphere above the poles of the Earth, the particles of the solar wind are colliding with the gas molecules of the Earth (O_2 and N_2) thereby exciting the air molecules to glow (partially via complex reaction chains). These reactions take place in an altitude between 100 and 300 km above the surface of the Earth; these are the areas where the polar lights are generated. Concerning the formation of the different colours see Appendix 8-A-2-4.

358

Polar lights: Types and Colours - 1

1) Polar lights: «Corona» in full glory

A Corona (not to be confused with the Sun-Corona) is a form of a polar light which can be seen by an observer located exactly in the Zenith.

The different rays of the Corona seem to converge in a centre .

Northern light bow stretsching over Kattfjordeidet near Tromsø - Norway

2) Polar lights: «Bows»

For quiet conditions, i.e. in the absence of intensive streams of the solar wind, it is possible to observe the so-called «quiet bow».

It extends in the east-west direction over the sky and can remain at a fixed position for more than 10 minutes.

359

Polar lights: Types and Colours - 2

3) Polar lights: «Bands»

If there are perturbations in the solar wind, the «quiet» bow is deformed. In this case, bumbs and folds can be formed.

This is referred to as «bands», because this phenomenon resembles luminous rows flowing above the sky.The bands are rapidly changing their colour, form and brightness.

4) Polar lights: «Curtains»

«Curtains» are flimsy and hazy Polar lights which extend up to several 100 km into the sky.

It is often possible that the light of stars is able to penetrate the Curtains (not observed in the present Foto).

360

Polar lights: Types and Colours - 3

a) Aurora over Otertind (Norway)

b) Northern light in Canada

c) Polar light in Iceland

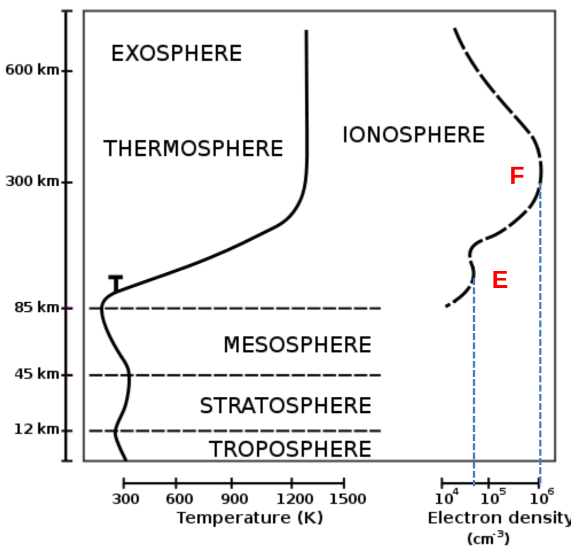
d) Polar light near Munich

361

8.3 The Kennelly – Heaviside Layer and High frequency Radio

362

8.3.1 The Ionosphere and the Kennelly - Heaviside - Layer



Temperature of the atmospheric layers and electron densities (E- and F-Layers) of the Ionosphere

The Ionosphere is a part of the Thermolayer. It contains a large concentration of ions and free electrons (s. Figure). It starts above the Mesosphere at an altitude of about 100 km and extends finally into the interplenatory space (s. Chaper 1, pp 7, 9; Chapter 2, pp 35, 44).

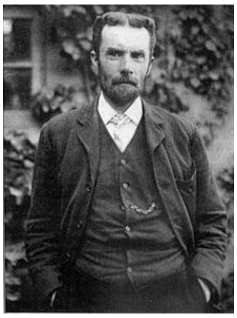
The Ionosphere originates by absorption of ionizing solar radiation, mainly by energy-rich electromagnetic waves (UV- and X-ray radiation) but also by particle radiation, mainly by electrons and protons (p. 354).

The practical importance of the Ionosphere of the Earth is associated with the world-wide radio communication: The Ionosphere reflects short-waves and therebye it enables global connections; in addition, their free electrons and ions are damping the propagation of radio waves with increasing wave-lengths .

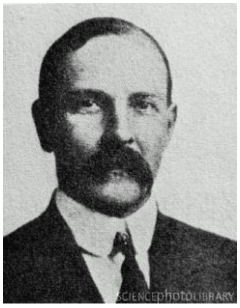
The Figure also illustrates the E-Layer, the so-called Kennelly-Heaviside-Layer of the Ionosphere. It is located at an altitude between 110 and 130 km. This is of great practical importance for the global radio communication because the E-layer reflects short-waves (s. p. 364).

363

8.3.2 Kennelly- Heaviside – Layer and Short-wave Transmitter

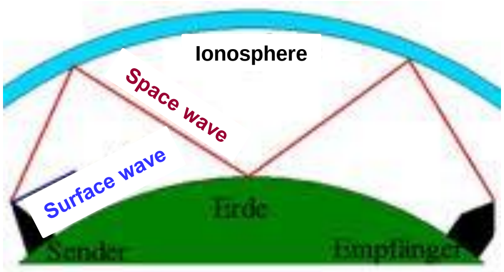


Oliver Heaviside



Arthur Edwin Kennelly

Arthur Edwin Kennelly (1861 – 1939) and Oliver Heaviside (1850 – 1925) have discovered the so-called Kennelly-Heaviside-Layer, which is also denoted as E-Layer. At 1902 the E-Layer has been discovered independtly by the two scientists. In addition, there exists also the prominent F-Layer (s. pp 363 and 365). At this page, we consider only the reflexion of waves at the E- Layer.



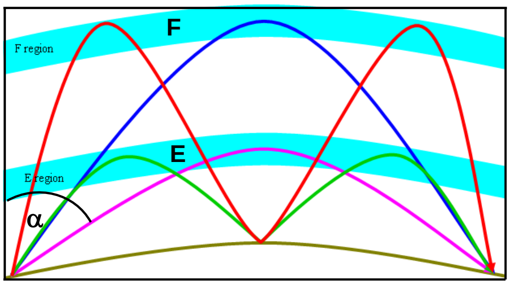
Reflection of short waves of the E-Layer of the Ionosphere

Radio waves in the short-wave band having frequencies between 3 MHz to 30 MHz, i.e. in the wavelength region between 100 m to 10 m are reflected at the E-Layer. After multiple reflections on the soil, they can cover long distances around the Earth. [If f is the frequency in Hz = 1/s and λ the wavelength in m, then λ = c/f, where c = 3*10⁸ m/s is the velocity of light].

Reflection of short-waves at the E- and F- Layers

The Figure at p. 363 shows that a maximum of the E- Layer is present at about 120 km and that the maximum electron density is about 6*10⁴ electrons per cm³. The F- Layer has its maximum at about 300 km where the electron density is about 10⁶ electrons per cm³.The refractive indices in the Tropo-, Strato- and Mesospheres (p. 363) are practically 1, n ≈ 1. Due to the comparatively high electric conductivity in the E- and F- Layers (caused by the quasi-free electrons and ions), the refractive indices n_E and n_F are smaller than 1 within these layers.

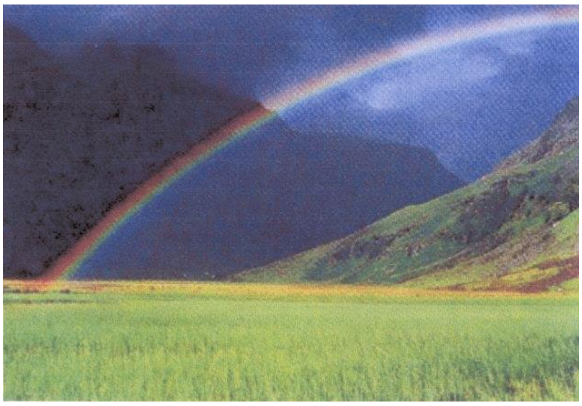
If the angle of incidence α of the short-waves is larger than the criticel angle α_C, the wave is reflected at the conducting layers because n_E and n_F are smaller than 1. After a certain propagation length, the short-wave returns to the surface of the Earth. A large part of the ground absorbs the radiation very weakly, i.e. the soil has a low loss; this is particularly true for the reflection of the waves at the surface of the electric conducting sea, but also at humid soil (groundwater). For these reasons, and because of multiple reflections, short-wave signals can often propagate very long (worldwide) distances. This fact has already been used intensively in World Wars 1 and 2 for the sake of propaganda and information exchange. In World War 2, this has been used both, by the Germans (Nazi- propaganda-Minister Dr. Joseph Goebbels) as well as by the Allies.



8.4 Weitere Atmosphärische Phänomene

366

8.4.1 Der Regenbogen



Ein Regenbogen ist ein Phänomen der atmosphärischen Optik, das als kreisbogenfarbiges Lichtband mit vielen Spektralfarben in einer charakteristischen Farbreihenfolge wahrgenommen wird.

Ein Regenbogen entsteht durch das Wechselspiel annähernd kugelförmiger Wassertropfen mit dem Sonnenlicht, welches bei Ein- und Austritt aus dem Tropfen wellenlängenabhängig gebrochen und an der rückwärtigen inneren Oberfläche des Tropfens richtungsabhängig reflektiert wird.

Regenbogen: ausführliche Darstellung in «WASSER» von P. Brüesch; Ref. R.0.B, Abschnitt 7.2

367

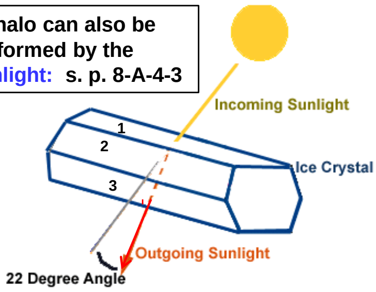
8.4.2 Halos: Origin and Appearence

A halo, also known as a nimbus, icebow or gloriole is an optical phenomenon produced by light interacting with ice crystallites suspended in the atmosphere, resulting in a wide variety of colour or white rings, arcs and spots in the sky. Most halos are near the Sun or Moon. Among the most well known halo types are the circular halo (properly called the 22^0 halo), light pillars and sun dogs, but there are many more: some of them are fairly common, others extremely rare.

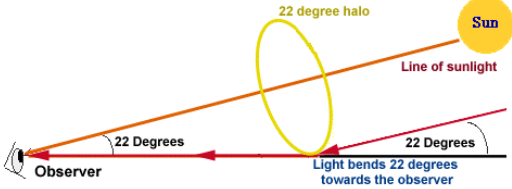
Phantastic Sun-halo at Sunset over Stockholm

The ice crystals responsible for halos are typically suspended in cirrus or cirrostratus clouds (5 – 10 km) in the upper troposphere, but in cold whether they can also float near the ground, in which case they are referred to as diamond dust. The particular shape and orientation of the crystallites is responsible for the type of halo observed. Light is refracted and reflected by the ice crystals and may split up into colours of dispersion (see left-hand Figure below). A mathematical derivation of 22^0 halos is given in Appendices 8-A-4-1 and 8-A-4-2.

A halo can also be formed by the Moonlight: s. p. 8-A-4-3



Light refraction at a single crystal



22 Degree Halo by light-reflection at a single crystal

368

8.4.3 St. Elmo's fire: General and History

St. Elmo's fire (also St. Elmo's light) is a rare weather phenomenon in which luminous plasma is created by a corona discharge from a sharp or pointed object in a strong electric field in the atmosphere.

St. Elmo's fire is named after St. Erasmus of Formiae (also called St. Elmo, one of the Italien names for St. Erasmus, the other being St. Errasmo), the patron saint of sailors. The phenomenon sometimes appeared on ships at sea during thunderstorms and was regarded by sailors with religious awe for its glowing ball of light, accounting for the name (right-hand picture).
Elmo or Erasmus (left-hand picture) was born in the Roman city Formiae in Campagna, Southern Italy under the rule of the Roman Emperor Diocletian. Elmo became a bishop of Formiae and converted to Christianity. He was subsequently arrested, terribly tortured and finally he was behaeded.

St. Elmo or St. Erasmus

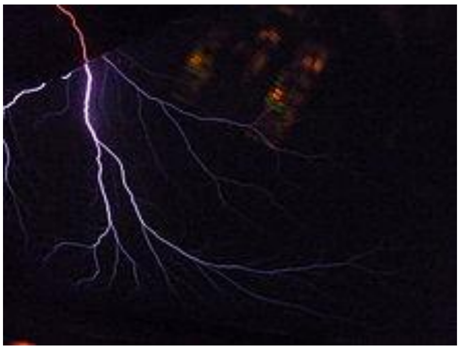
St. Elmo's fire on ship's masts

369

St. Elmo's fire: Physical Aspects

St. Elmo's Fire is a plasma. A normal gas is composed of molecules (air is composed of oxygen- (O_2) and nitrogen molecules (N_2)). The electric field around the objects in question causes ionization of the air molecules producing a faint glow easily visible in low-light conditions. Roughly, 1'000 volts per centimeter induces St. Elmo's fire; the voltage depends greatly on the geometry of the object, so discharges are more intensive at the ends of pointed objects such as lightning rods, masts, spires and chimneys, and on aircraft wings. St. Elmo's fire can even appear on leaves, grass, and even of cattle horns. Often accompanying the glow is a distinct hissing sound. It is sometimes confused with ball lightning (s. pp 349, 350).

Conditions that can generate St. Elmo's fire are present during or after thunderstorms, when high voltage differentials are present between clouds and ground. The nitrogen and oxygen in the Earth's atmosphere cause St. Elmo's fire to fluoresce with blue or violet light (see Figure below).



St. Elmo's- fire observed from an airplane

370

8.4.4 Purple light at twilight

The purple light is a twilight phenomenon, causing a purple colour before sunrise or after sunset. It starts about 15 minutes after sunset at the western horizon if the sun is about 2^0 below the horizone. It is due to scattering and reflection of light at small dust particles and dust in the atmosphere. During twilight, the angle of light incidence is very favorable, because no direct Sunlight is present and scattered. Therefore, the light scattered by dust particles is undisturbed by Sunlight and is directly visible.

The appearence, the visibility and the intensity of purple light are strongly dependent on weather and on the observation conditions; it also depends on the air pressure and the wind conditions in both, the stratosphere and troposphere. For the occurance of purple light, there are several origins such as forest fires, volcanic eruptions and atmospheric pollution.

The purple light is caused by the superposition of both, the scattered red light of the lower hazy layers as well as of the scattered blue light of the higher layers of the atmosphere. By Rayleigh scattering (s. Ref. R.8.4.5 e)) of the white Sunlight at the air molecules, the blue spectral contributions are observed. The hazy particles in the lower layers are causing Mie-scattering (s. Ref. R.8.4.5 g)).

The purple light is a twilight phenomenon

Purple and violet are similar, though purple is closer to red. In optics, there is an important difference; purple is a composite color made by combining red and blue, while violet is a spectral color, with its own wavelengths λ on the visible spectrum of light: 400 nm $< \lambda <$ 450 nm.

371

8.4.5 Airglow or Nightglow

Airglow (also called nightglow) is the very weak emission of light by a planetary atmosphere. In the case of the Earth's atmosphere, this optical phenomenon causes the night sky never to be completely dark, even after the effects of straylight and diffused sunlight from the far side are removed.

The Airglow phenomenon was first identified in 1868 by the Swedish scientist Ångström. It is caused by various processes in the upper atmosphere, such as the recombination of atoms, which are photoionized by the sun during the day, luminescence caused by cosmic rays striking the upper atmosphere and chemiluminescence caused mainly by oxygen and nitrogen reacting with hydroxyl ions at heights of a few hundred kilometers. It is not noticeable during daytime because of the scattered light by the sun. The airglow at night may be bright enough to be noticed by an observer and is generally bluish in colour.

One airglow mechanism is when an atom of nitrigen combines with an atom of oxygen to form a molecule of nitric oxide (NO). In the process, a photon is emitted. This photon may have any of several different wavelengths characteristic of nitric oxide molecules. The free atoms are available for this process, because molecules of nitrogen (N_2) and oxygen (O_2) are dissociated by solar energy in the upper reaches of the atmosphere and may encounter each other to form NO.

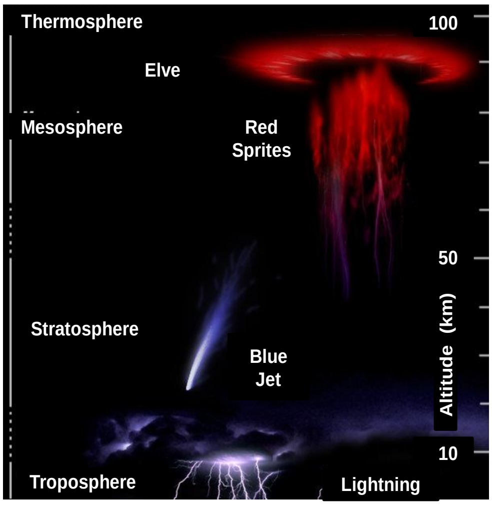
Satellite observation of an «Airglow»

«Airglow»: Science and Analysis Laboratory / NASA

372

Red Sprites, Blue Jets and Elves are all related to strong lightnings

Red Sprites are very brief, luminous glows that occur in the middle atmosphere. Sprites ofteh start at a height of about 72 km and extend upwards to the edge of the Ionosphere. The portion of the event that might be visible to the naked eye often lasts less than one hundredth of a second. Sprites are caused by lightnings. They result from extremely powerful discharges, sometimes occurring with thunderstorms. They are almost always triggered by a powerful positive cloud-to-ground (CG) flash (s. pp 339, 340) which lowers massive amounts of electrical charge to the Earth. It is believed that sprites result when the electrons in the thin atmosphere are accelerated by the sudden change in electric field strength. When the electrons slam into molecules of nitrogen, they cause the nitrogen to glow. Certain energies result in primarily red optical emissions, hence **the red colour of sprites**.



Red Sprites – Blue Jets - Elves

373

Blue Jets appear to spurt upwards from cloud tops at speeds of abour 80 to 160 km per second, reaching heights of up to 40 km before fading. They last generally less than a quarter of a second, but it is possible to perceive their upward motion with the unaided eye. They are generated by storms with high lightning rates. They do not appear to be related to specific cloud-to-ground lightning discharges .

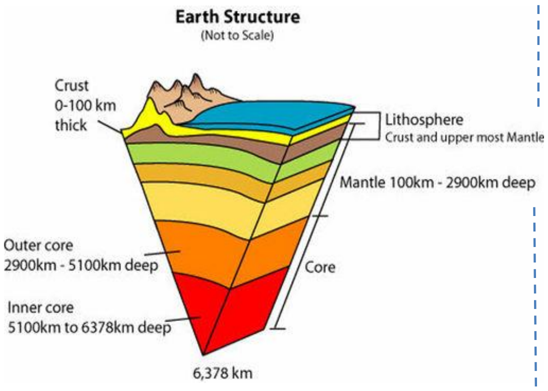
Elves result from an especially powerful electro-magnetic radiation puls that emanates from certain lightning discharges. As the energy passes upwards through the base of the Ionosphere, it causes the gases to briefly glow. Though as brite as a sprite, the elve only lasts for less than a thousandth of a second. They are most likely **red in colour** and look like giant expanding doughnuts. They occur at heights between 96 to 105 km.

Appendix: Chapter 8

8-A-0

Earth's magnetic field: Magnetic and geographical Poles

a) Cross-section through Earth



Liquid outer core: 2'900 – 5'100 km

Temperature: 3'700 – 4'600 ^{0}C; Density ≈ 12.1 g/cm^3

Pressure: 1'500 – 3'400 kbar;

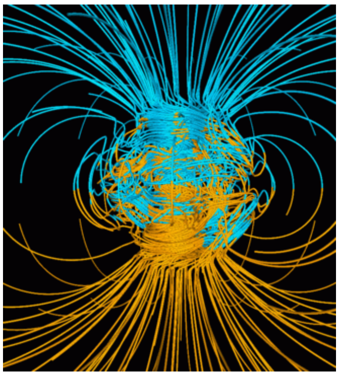
Solid inner core: 5'100 – 6'378 km

Temperature: 4'600 – 6'000 ^{0}C; Density ≈ 12.5 g/cm^3

Pressure: 3'400 – 3'600 kbar

[3'600 kbar = 3.6 Million bar !]

b) Earth's magnetic field

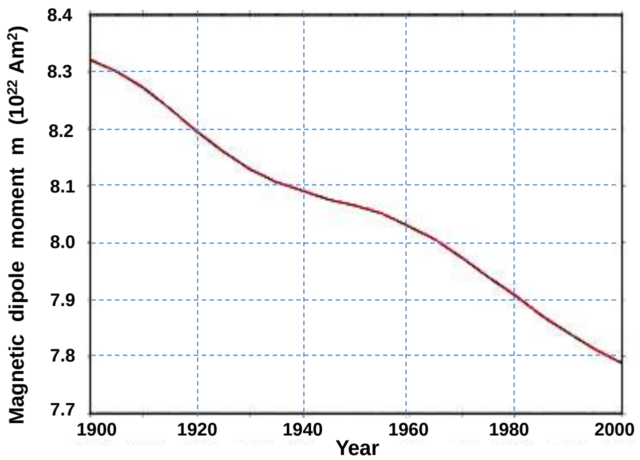


Earth's magnetic field that extends from the Earth's inner core to where it meets the solar wind (s. pp 353 – 356).
The above picture is a Computer simulation of the Earth's magnetic field in a period of normal polarity (s. pp 8-A-2-2, 8-A-2-3). The lines represent magnetic field lines, blue when the field points towards the center and yellow when away. The rotation axis of the Earth's is centered and vertical. The dense cluster of lines are within the Earth's core.

8-A-2-1

Decrease of the magnetic field and Pole reversal - 1

On the basis of the reconstruction of the paleomagnetic field and the magma of the oceanic crust, it is kwown that the Earth's magnetic field is reversed about every 250'000 years. The last time this happened is, however, about 780'000 yeas ago. The magnetic pole jump, i.e the magnetic field reversal, took about 4'000 to 10'000 years (Computer simulations suggest about 9'000 years).
Since the magnetic field is decreasing, it is possible that in the not too distant future a pole reversal could take place (estimates: in the years between 3'000 to 4'000); This conjecture is, however, not scientifically validated. In general, it should be noted, that within the last 120 miillion years, the frequency of such pole reversals has increased.



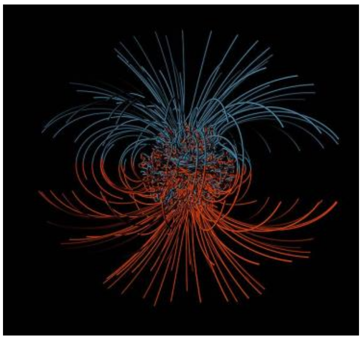
Decrease of the magnetic dipole moment in the last 100 years.

There are some indications for an imminent polar reversal: There are certain locations in the core-mantle zone in which the direction of the magnetic field has reversed its direction with respect to that common for this hemisphere. These regions are measurably increasing and are moving on and on continuously. Based on this phenomenon, the decrease and subsequent reversal of the dipole moment can be explained. The Figure on the left shows that the dipole moment m has decreased by 6.4% between 1'900 und 2'000. In the year 2014, m was about $7.72 \cdot 10^{22}$ Am^2. Geological investigations of ceramic specimens have shown that within the last 4'000 years, m has decreased by about 50%.

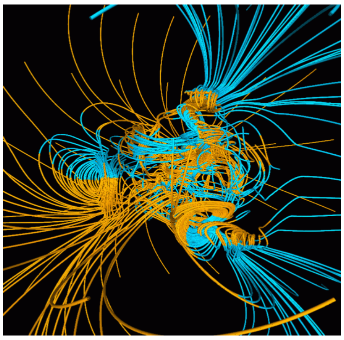
8-A-2-2

Decrease of the magnetic field and Pole reversal - 2

During the phase of pole reversal, the Earth would be more strongly exposed to the solar wind (pp 353-355; p. 8-A-1-1). This corresponds to the observation that in the respective sediment layers a species turnover has been detected. It is possible that the oscillation of the Earth's magnetic field and the associated DNA mutation caused by high-energy radiation was a pacemaker and at the same time a significant impetus of the evolution. Moreover, it can be assumed that due to the interaction of the ions of the solar wind in the ionosphere , magnetic flux lines are created which are leading from the sun-facing side to the opposite side of the Earth. This self-magnetization creates a magnetic screening of the Earth from the solar wind and has a similar protecting effect to live on Earth as the present magnetic field.



Simulation of the Earth's magnetic field. The simplified dipole approximation is only valid in the immediate outside area of the Earth.



Chaotic perturbation of the Earth's magnetic field. The field in larger distances from the Earth is quite different from a dipole field.

The magnetic field of the Sun reverses much more rapidly its direction, about every 11 years. During the reversals it does not, however, vanish completely, but it becomes more chaotic.

8-A-2-3

The coulours of Polar lights

The origin of the differnt colours of polar lights is relatively complex. As a supplement to p. 358 we content ourselves with a qualitative discussion.

The solar wind particles from the magnetosphere penetrating into the atmosphere are colliding with the oxygen- and nitrogen atoms or molecules of the air. Therebye, the latter are excited, i.e. as a result of the collision, an electron of an air paricle is excited to a higher quantum state. As a result of relaxation of the electrons into the ground state, the absorbed energy is emitted in the form of light.

Polar lights are thus generated if electrical charged particles of the solar wind collide with oxygen- or nitrogen atoms or molecules in the upper layers of the atmosphere and cause ionization. The colour of the emitted light depends on the species of the excited atoms or molecules. Oxygen emits green and red light, whereas nitrogen emits blue and violet light. Since the light emitted by oxygen is particularly intensive, polar lights often show a green colouring. Thereby, the green light is most intensive at an altitude between 120 and 140 km while the red light is most intensive at an altitude above 200 km

Polar light over Iceland

Depending on the actually prevailing circumstances, one or more ground colours or combination coulours can be observed. The Fotos depicted at pp 358 – 361 and the present Foto give an impression of the variety and beauty of the resulting colours produced by the polar lights.

8-A-2-4

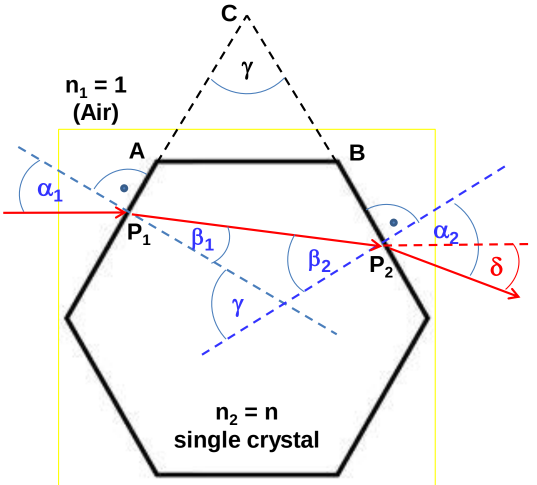
Some Birds can sense the magnetic field of the Earth

Some birds can sense the Earth's magnetic field and orient themselves with the ease of a compass needle. This ability is a massive boon for migrating birds, keeping frequent flyers on the straight and narrow. But this incredible sense is closely tied to a more mundane one – vision. Thanks to special molecules in their retina, birds like the European robins (see picture) can literally see magnetic fields. The fields appear as patterns of light and shade, or even colour, superimposed onto what they normally see. Katrin Stapput from the Goethe University in Frankfurt has shown that this «Magneto-reception» ability depends on a clear image from the right eye.

8-A-2-5

Halo: Refraction of Light at a hexagonal Ice crystal - 1

The Figure below shows the refraction of a light beam of the Sun at a hexagonal Ice crystal (s. p. 368) (the triangle ABC has been added for didactical reasons). The angle γ is 60^o. In the Figure it has been assumed that the (red) lightbeam (paralle to the side AB) impinges horizontally on the crystal and is refracted the first time at the point P_1. After traversing the crystal, the beam is refracted a second time at the point P_2.



Refraction of light at a hexagonal Ice crystal

α_1: angle of incidence
β_1: refractice angle at point P_1
β_2: refractive angle at point P_2
α_2: refractive angle after exit at P_2
δ: angle of deflection:

Refractive indices:

$n_1 = 1$ (Air); $n_2 = n = 1.310$ (Ice [(*)])

$$\delta = (\alpha_1 + \alpha_2) - (\beta_1 + \beta_2)$$

$$\beta_1 + \beta_2 = \gamma \qquad (1)$$

$$\rightarrow \quad \delta = \alpha_1 + \alpha_2 - \gamma \qquad (2)$$

Law of refractions:

$$\sin(\alpha_1) = n \sin(\beta_1) \qquad (3)$$

$$n \sin(\beta_2) = \sin(\alpha_2) \qquad (4)$$

8-A-4-1

Halo: Refraction of Light at a hexagonal Ice crystal - 2

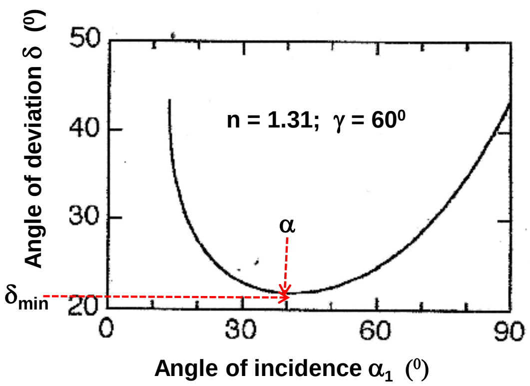
Based on the equations (1) to (4) of p. 8-A-4-1 we calculate the angle of deflection δ as a function of α_1, γ and n: From $\sin(\gamma-\beta_1) = \sin\gamma \cos\beta_1 - \cos\gamma \sin\beta_1$ and from $\cos\beta_1 = (1 - \sin^2\beta_1)^{1/2}$ we obtain after some rearrangements:

$$\alpha_2 = \arcsin(n \sin\beta_2) = \arcsin[\sin\gamma\, (n^2 - \sin^2\alpha_1)^{1/2} - \cos\gamma \sin\alpha_1] \qquad (5)$$

[Definition of the arc function: if $y = \sin(x)$ then $x = \arcsin(y)$]

Substituting equation (5) into equation (2) we obtain the following relation:

$$\boxed{\delta(\alpha_1,\gamma,n)) = \alpha_1 - \gamma + \arcsin[\sin\gamma\, (n^2 - \sin^2\alpha_1)^{1/2} - \cos\gamma \sin\alpha_1]} \qquad (6)$$



8-A-4-2

It can be shown that the angle of deviation δ is minimal if $\alpha_1 = \alpha_2 = \alpha$ and $\beta_1 = \beta_2 = \beta$, i.e. for the case of a symmetrical path for which the light path from P_1 to P_2 in the Figure of p. 8-A-4-1 is parallel to AB. The <u>minimum deviation angle</u> is then given by

$$\delta_{min} = 2 \arcsin[n \sin(\gamma/2)] - \gamma$$

For hexagonal Ice crystals , i.e. for $\gamma = 60^0$ and $n = 1.310$ (yellow Na-D line) it follows: $\delta_{min} = 21.8^0$ and $\alpha = 40.9^0$. The maximum intensity of the Halo is then at δ_{min} (s. present Figure and the Halo shown at p. 368).

A Moon Halo in Mandan, North Dakota – Februrary 2015; by Marshall Lipp

For the Origin and Appearence of Hallows s. p. 368

8-A-4-3

Night clouds or Noctilucent clouds

Night clouds or Noctilusent clouds (NLC) are made of crystals of water ice. Noctilucent roughly means night shining in Latin. They are most commonly observed in the summer months at latitudes between 50^0 and 70^0 north and south of the equator. They can be observed only when the Sun is below the horizon.

They are the highest clouds in Earth's atmosphere, located in the Mesosphere at altitudes of around 75 to 85 km (s. Chapter 2, p. 44). They are formally too faint to be seen , and are visible only when illuminated by sunlight from below the horizon while the lower layers of the atmosphere are in the Earth's shadow. NLC's are not fully understood and are a recently discovered meteorological phenomenon; there is no record of their observation before 1885.

NLC's can form only under very restrictive conditions; their occurrence can be used as a sensitive guide to changes in the upper atmosphere.

Clouds in the Earth's lower atmosphere form when water collects to particles (Chapter 3, Section 3.3. pp 68 – 78), but mesospheric clouds may form directly from water vapour in addition to forming on dust particles. The sources of both the dust and the water vapour in the upper atmosphere are not known with certainty.

Noctilucent cloud observed at 04.07.2014 over Germany

Noctilucent clouds photographed by the crew of ISS

8-A-4-4

References: Chapter 8

R-8-0

8.1 Formation and Properties of Tunderstorms and Lightnings

R.8.1.0 p. 335: Thunderstorm clouds - Lightnings and Thunder

R.8.1.1 p. 336: 8.1.1 Development and Structure of Thunderstorm Cells

a) Life Cycle of a Thunderstorm - http://www.nc-climate.ncsu.edu/climate/tstorms/lifecycle.php
b) Thunderstorms - Introduction - Map of Thunderstorms in the U.S.
found under: Thunderstorms - Introduction (Images)
c) Latent heat (Definition) - http://www.thefreedictionary.com/latent +heat
d) Entstehung eines Gewitters - Nationale Plattform Naturgefahren PLANAT – Swiss confederation
www.planat.ch/de/wissen/gewitter/entstehung-gw
e) Gewitter: http://de.wikipedia.org/wiki/Gewitter: [contains picture of «Thunderstorm cloud of a strong Hailstorm»]

R.8.1.2 p. 337: Processes of Development of a Thunderstorm Cloud

a) Thunderstorm - http://en.wikipedia.org/wik/Thunderstorm
b) Cumulonimbus_Cloud - Picture from Gabrielle De Santi and Tiffany Maenner - (Google)
c) Gewitter - http://de.wikipedia.org/wiki/Gewitter
d) see also Chapter 3, p. 71

R.8.1.3 p. 338: Heat Thunderstorms and Cold front Thunderstorms

a) References R.8.1.2 a) and R.8.1.2 c)
b) Informationen über die Entstehung von Gewittern, Hagel und Tornados
http://www.sturmwetter.de/texte.gewitterinfos.htm
(Figure Texts translated from German to English by P. Brüescj)

R.8.1.4 p. 339: Formation of electrical charges in a Thunderstorm cloud

a) Lightning - http://en.wikipedia.org/wiki/Lightning
b) Blitz - http://de.wikipedia/org/wiki/Blitz
c) Wissen + Schulungsforum >> Blitz und Donner – Wie entsteht er eigentlich ?
http://www.stormhunters-germany.de/t67f37-Blitz-und-Donner-Woe-entsteht-er-eigentlich.html
d) see also Chapter 3, p. 77
e) Die Entstehung von Gewittern - 10 .06. 2008/ Autor: Alexandra Doll – on June 16 2008
Letzte Aktualisierung Juli 09 2013 - suite 101.de/article/die-entstehung-von-gewittern-146220

R-8-1

R.8.1.5 p. 340: The Anatomy or types of lightnings

a) Cloud-to_Ground Lightnings: CG
b) Cloud-to_Cloud Lightnings: CC
c) Intra-Cloud Lightning: IC
d) Ground-to_Cloud Lightning: GC
e) Wie entädt sich ein Blitz bei einem Gewitter?
http://www.asklubo.com/de/garten-natur/wie-entlädt-sich-ein-blitz-bei-einem-gewitter
[All pictures from Google – Images]

R.8.1.6 p. 341: Stepped Leader, Upward connecting Leader and Return Leader

a) Reference R.8.1.4 a)
b) Reference R-8-1-4 b)
c) Lightning Discharge - http://www.aldis.at/en/lightning-research/lightning-physics/lightning-discharge
[contains picture about: The three phases of cloud-to-ground-lighning discharge]
d) Thunderstorm and Lightning - http://globalsailingweather.com/thunderstorm.php
e) Lightning flashes and strikes - http://en.wikipedia.org/wiki/Lightning
f) Fangentladung - http://de.wikipedia.org/wiki/Fangentladung
g) Bild: Die drei wesentlichen Phasen einer Blitzentladung - http: kurios.at/wetter/entl.html

R.8.1.7 p. 342: Properties of Lightnings

a) Lightning Part 3: The Lightning Bolt
http://sciexplorer.blogspot.ch/2013/01/lightning-part-3-lightning-bolt.html
b) Characteristics of lightning current - www.dehn.org/wiki/Lightning
c) Characteristics of Lightning Strokes - http://electrical-engineering.portal.com/characteristics-of-lightning-strokes
d) Dauer, Stromstärke und Polarität von Blitzen - http://de.wikipedia.org/wiki/Blitz
e) Blitz und Gewitter - http://www.ping.de/schule/pg-herne/p-wetter/bkutze/internet.htm
f) Wärmeenergie von Heizöl www.erdgas.ch/fileadmin/customer/…/Data/…/umrechnungsfaktoren.pdf
Eidgenössisches Departement für Umwelt, Verkehr und Kommunikation (UVEK)
[PDF] Umrechnungsfaktoren / Facteur de conversation-
www.erdgas.ch/fileadmin/customer/…/Data/…/umrechnungsfaktoren.pdf

R-8-2

R.8.1.8 p. 343: Development and Properties of Thunder

a) Thunder - http://en.wikipedia/org/wiki/Thunder
b) What causes the sound of thunder ? - http://www.loc.gov/rr/scitech/mysteries/thunder.html
c) Donner - http://de.wikipedia.org/wiki/Donner

R.8.1.9 p. 344: Acoustic emission of Lightnings

Environment Canada – Weather and Meteorologogy
The Sound of Thunder - contains three pictures of different thunders
http://ec.gc.ca/foudre-lihghtning/default.asp?lanng-En&n=4EFD3A52-1

R.8.1.10 p. 345: Dangers of lightnings and lightning protection

a) New tank burns at Venezuela refinery; death toll revised down
http://edition.cnn.com/2012/08/28/world/americas/venezuela-refinery-ölast/
b) First three images from: www. Google.ch
c) Oelraffinerie in Venezuela - Speichertank steht nach Blitzeinschlag in Flammen
http://www.spiegel.de/panorama/venezuela-raffinerie-brennt-nach-blitzeinschlag-a-915996,htm

R.8.1.11 p. 346: Lightning protection by lightning conductors and earthing

a) Benjamin Franklin - http://wikipedia.org/wiki/Benjamin_Franklin
b) Benjamin Franklin - http://www..todayinsci.com/F/Franklin_Benjamin/FranklinBenjamin-Quotations.htm
c) Lightning rod - http://en.wikipedia.org/wiki/Lightning_rod
d) Benjamin Franklin - http://de.wikipedia.org/wiki/Benjamin_Franklin
e) Blitzableiter - http://de.wikiprdia.otg/wiki/Blitzableiter (mit Bild von blitzableitender Statue)
f) Der Blitzableiter / Benjamin Franklin - http://www.gymmuenchen.ch/stalder/klassen/sa/rev_d/blitz.html
g) Bkitzschutzerdung - http://de.wikipedia.org/wiki/Blitzschutzerdung

R.8.1.12 p. 347: Lightning protection by the Faraday cage

a) Michael Faraday - http://en.wikipedia.org/wiki/Michael_Faraday
b) Faraday cage - http://en.wikipedia.org/wiki/Farady_cage
c) The Invention of Faraday Cage - http://eee.juliantrubin.com/bigten/faradaycageexperiments.html
d) Michael Faraday: http://de.wikipedia.org/wiki/Michael:Faraday

R-8-3

R.8.1.12 (cont.)

e) Elektrische Ladung / Feld: http://fehertamas.com/2009/elektrische-ladung
(contains part of the Text to Faraday cage - translated from German to English by P. Brüesch)
f) Faradayscher Käfig - http://www.abi-physik.de/buch/das-elektrische-feld/faradayscher-Käfig/
g) Elektronik Kompendium - http://www.elektronik-kompendium.de/sites/grd/0205141.htm
(Faraday cage in the field of a plate condensor)
h) Elektrisches Feld und elektrische Spannung
http://www-med-physik.vu-wien.ac.at/physik/ws95/w95e0dir/w95e2000.htm
i) Faraday – cage: Figure from www.google.ch.search under «Faraday – Käfig im Feld des Plattenkondensators
(The Figure has been slightly modified by P. Brüesch by adding the external field E_{12} and the opposite inner field E_{34} : $E_{12} + E_{23} = E = 0$, where E = 0 is the vanishing resulting field in the cage).
k) Figure of «Lightning strike on the cage of a car»: found in Internet - images: «Blitschlag auf Auto-Käfig»

R.8.1.13 p. 348: Fraktale Eigenschaften von Blitzen

a) Fractal Dimension of Dielectric Breakdown
L. Niemeyer, L. Pietronero, and H.J. Wiesmann
Physical Review Letters, Vol. 52, 19 March 1984, pp 1033 – 1036
b) Fraktal: http://de.wikipedia.org.wiki/Fraktal
c) Fractal: http://en.wikipedia.org/wiki/Lichtenberg/Fractal
d) Fractal dimension of lightning discharches - Nonlinear Processes in Geophysics (1995) 2: 101 – 106
e) Jacket Interview - Ben Lerner - (right-hand Figure) - http://jacketmagazine.com/26/john-lern.html
f) Bild links auf p. 348: Fraktale Struktur eines Blitzes
Fraktale in der Natur - http://www.natur-struktur.ch/fraktale/fraktalnatur.html

R.8.1.14 p. 349: Ball lightnings - Existence and Observations

a) Ball Lightning - http://en.wikipedia.org/wiki/Ball_lightning
b) The Question of the Existence of Ball Lightning - Plenum Press, 1971
http://amascj.com/tesla/ballext.bt
c) Does ball lightning really exist ?
http://science.howstuffworks.cim/nature/climate-weather/atmospheric/ball-lightning.htm
d) Periodically, I hear stories about ball lightnings. ….. - Scientific American - July 18, 1997
https://www.scientificamerican.com/article/periodically-i-hear-stori/
e) Scientists accidently record ball lightning in nature for the first time - by Nick Statt – January 17, 2014
http://www.cnet.com/news/scientists-accidentally-record-ball-lightning-in-nature-for-the-first-time

R-8-4

R.8.1.15 p. 349: (cont)

f) Kugelblitz - http://de.wikipedia.org/wiki/Kugelblitz
g) Arten von Blitzen – Library - library.thinkquest/org.03oct/01352/gr_ForkedLightning.htm
h) Kugelblitz über Neuruppin - http://www.met.fu-berlin.de/~manfred/Kugelblitz.html
i) Kugelblitz trifft deutschen Turistenbus
http://www.t-online.de/nachrichten/panorama/id_48816992/kugelblitz-trifft-deutschen-touristenbus-.html

R.8.1.16 p. 350: Ball Lightnings - Laboratory Experiments

a) Ball lightning . http://7www.ipp.mpg.de2977926/kugelblitze
b) Ball-lightning in the laboratory - https://www.ipp.mpg.de/ppcms/eng/presse/archiv/05_06-pi
c) How to make a Stable Plasmoid (Ball Lightning) with the GMR v1.0 (Graphite Microwave Tesonator)
http://jlnlabs.online.fr/plasma/gmr/
d) Kugelblitze im Labor IPP: Max-Plank Institut für Plasmaphysik
http://www.ipp.mpg.de/ippcms/de/presse/archiv/05_06:pi.html
e) Max-Planck Forschung - enthält Abschnitt über «Kugelblitze aus dem Wasserbecher»
Das Wissenschaftsmagazin der Max-Planck-Gesellschaft
[PDF] Plasma – Max – Plank Gesellschaft
https://www.mpg.de/905905/MPF_2008_1.pdf
f) Im Labor erzeugte kugelblitz-ähnliche Plasmawolke
gefunden unter «Kugelblitz im Labor»: www.google.ch - Bild

R-8-5

Earth's magnetic field – Solar wind – Magnetosphere and Polar lights

R.8.2.0 p. 351: Earth's magnetic field, Solar wind, Magnetosphere and Polar lights

R.8.2.1 p. 352: Internal Structure of the Earth and Magnetic Field

a) Earth's magnetic field - http://en.wikipedia.org/wiki/Earth's_magnetic:field
b) Magnetic field - http://en.wikipedia.org/wiki/Magnetic_field
c) Measuring the Strength of a Magnet - http://www.wired.com/2014/01/measuring-strength-magnet/
d) Order of magnitude (magnetic field)
http://en.wikipedia.org/wiki/Order_of_magnitude_%28magnetic_field%29
e) Upper picture to: The inner structure of the Earth's
f) Text to inner structure of the Earth - http://de.wikipedia.org/wiki/Innerer_Aufbau:der_Erde
g) Lower picture and Text in: Einfluss des Erdmagnetfeldes auf Lebewesen
Das Magnetdeld der Erde - http://www.vitatec.com/grundlagen/einfluss-erdmagnetfeld
h) europhysicsnews - The Magazine of the European Physical Society – EPN 45/4 – 2014 - pp 16 - 19
Unravelling The Mystery of THE EARTH'S MAGNETIC FIELD - Author: Henri-Claude Nataf (Grenoble)

R.8.2.2 p. 353: Solar wind and magnetic field of the Earth – 1

a) Solar wind - http://en.wikipedia/wiki/Solar:wind
Weltraumwetter - PDF] www.mps.mpg.de/dolumente/.../pa/pa_0107_Weltraumwetter.pdf
b) Sonnenwind - http://de.wikipedia.org/wiki/Sonnenwind
c) Sonnenwind und Weltraumwetter - Rainer Schwenn und Kristian Schlegel
[PDF] www.mps.de/dokumente/.../pa/-0107_weltraumwetter.pdf

R.8.2.3 p. 354: Solar wind and magnetic field of the Earth – 2

a) Magnetosphere - http://en.wikipedia.org/wiki/Nagnetosphere
b) Magnetsturm – Kosmos- GEO.de
Eine Beule im Magnetfeld der Erde - A bulge in the magnetic field of the Earth
http://www.geo.de/GEO/natur/kosmos/neue-explosionen-auf-der-sonne-1686.html?p=2
(In the picture of GEO reproduced by Stefanie Peters, the Figure Text has been translated from German to English by P. Brüesch)

R.8.2.3 (cont.)

c) Die Magnetosphäre der Erde
Max.Planck-Institut für Sonnensystemforschung
[PDF] www.mps.mpg.de/dolumente/.../pa/pa_0110_Weltraumwette

R.8.2.4 p. 355: Solar wind and magnetic field of the Earth – 3

a) Magnetosphere: Reference R.8.2.3 –a)
b) Earth's magnetic field - Bild: more realistic model of Earth's Magnetosphere
[The designations p for proton, e for electrons; D for «Dayside» and N «Nightside» have been added by P. Brüesch] - http://www.ucalgary.ca/above/science/mag:field
c) The Earth's Magnetosphere
http://www.enchantedlearning.com/subjects/astronomy/planets/eart/Magnetosphere.shtml
d) Die Magnetosphäre - www.pluslucis.univie,ac.at/FBA/FBA99/Biemat/4.pdf
e) Lorentzfeld - http://de.wikipedia.org/wiki/Lorentzkraft
f) Das Magnetfeld der Erde - Bodensee-Sternwarte
http://www.bodensee-sternwarte.de/grundlagen/das-magnetfeld-der-erde.htm
Without Earth's magnetic field which protects us from the Solar wind, no life would be possible on Earth !

R.8.2.5 p. 356: Solar wind and spiral paths of charges near the poles

a) Text and Reference: R.8.2.7 d) - Early theory: origin of particles is due to solar wind
(The Figure Text has been translated from German to English by P. Brüesch)
b) 3.5 Bewegte Ladungen im Magnetfeld - [PDF]
e3.physik.uni-dortmund.de/~suter/.../3.5_Ladungen_im_B-Feld.pdf
Text und Figur rechts; mit Erklärungen zur Lorentzkraft
(Zur besseren Lesbarkeit wurde der Figurentext von P. Brüesch retouchiert)
c) Umwelt im All: Weltraumwetter
http://www.erkenntnishorizont.de/raumfahrt/weltraumwetter.c.php?screen=800
d) Entstehung der Polarlichter
http://home.arcor.de/klaus.lampen/endstehung.html
e) Van Allen Gürtel - Van-Allen belt - www.de.wikipedia.org/wiki/Van-Allen-Gürtel
In this article it is emphasized that according to more recent studies, most of the charged particles in the Van-Allen belts do not originate from the solar wind but are rather produced inside the Van_Allen belts by very strong electromagnetic fields acting on the atoms thereby producing electrons and protons (see p. 357).

R.8.2.6 p. 357: Van Allen belt

a) Van Allen radiation belt
www.en.wikipedia.org/wiki/Van_Allen_radiation_belt
b) Mystery of Earth's radiation belts solved
«Van Allen belts accelerate their own particles rather than trapping them» - Ron Cowen - 25 July 2013
http://ww.nature.com/news/mystery-of-erth-s-radiation-belts-solved-1.13452
c) Forces on a Moving Charge in a Magnetic Field: Examples and Applications
on pages 67 of this contribution; Short discussion with two Figures of magnetic field of the Earth including the «Inner and Outer Van Allen belt - cnx.org>Content>College Physics
d) Van Allen radiation belt
http://www.britanica.com/science/Van-Allen-radiation-belt
e Van-Allen-Gürtel - www.de.wikipedia.org/wiki/Van-Allen_Gürtel/
f) Van-Allen-Gürtel: Forscher lösen Geheimnis der irdischen Strahlungsringe
SPIEGEL ONLINE – WISSENSCHAFT (26. 06. 2013)
http://www.spiegel.de/wissenschaft/weltall/van-allen-guertel-lokale-teilchen-sind-quelle-fuer-strahlung-um-erde-a-91325…
- Laut der neuen Theorie sind es elektrische Felder innerhalb des Gürtels, die umherwandernde Atome zerreissen und ihre Elektronen abtrennen. Diese werden bis zu 99% der Lichtgeschwindigkeit beschleunigt.
- According to the new theory, the very strong electromagnetic fields within the belts are ruptering the atoms and produce electrons (and protons). The electrons are accelerated to about 99% of the velocity of light.

R.8.2.7 p. 358: Formation of Polar Lights

a) Aurora (Astronomy) - http://en.wikipedia.org/wiki/Aurora(astronomy
b) Polarlicht - http://de.wilipedia.org/wiki/Polarlicht
c) Polarlichtseite: Foto shown at p. 358) - from Katja Gottschweski (2002)
http://home.online.no/~/khgott(Polarlichseite.html
d) Deutsche Physikalische Gesellschaft – Fachverband Didaktik der Physik
Beitrag aus der Reihe; Karl-Heinz Lotze, Werner B. Schneider (Hrsg)
Wege in der Physikdidaktik - Band 5 - Naturphänomene und Astronomie
[PDF] Schlegel Kristian_ Polarlicht - Solstice
www.sokstice-de/cms/upload/wege/band5/wege5-p2-70-81.pdf

R-8-8

R.8.2.8 pp 359 – 361: Fotos of Polar lights: Forms and Colours

a) Aurora - https://en.wikipedia.org/wiki/Aurora
b) pp 359, 360: Fotos found in Internet under: Polar lights – Forms and Colours
p. 360: Foto 4): - «Curtain - Vorhang» - Nordlicht: Nordlicht aus den Lofoten: Erleben Sie das Nordlicht aus den Lofoten - www.rundstykke.com/nordlicht-auf-den-lofoten
c) p. 361: Foto a): Aurora over Otertind (Norwegen) from: www.gogle.ch – Polarlichter – Polar lights
Foto b): Northern light of Canada – from: www,google.ch – Northern light
d) p. 361: Foto c): Polarlicht in Iceland (from BLOG!)
www.davidkoester.de/.../bild-des-monats-polarlichter-ueber-joekulsarien...
e) p. 361: Foto d): Polar light near Munich – Sonnenwinde wenden sich von Erde ab
http://www.swissinfo.ch/spa/index/Sonnenstürme_wenden_sich_von_Erde_ab.html?cid=3602258

R.8.2.9 pp 358 – 361: Polar lights (Text)
von Dr. Otto Braumandle; Verein Antaras. NÖ Amateurastronomen
[PDF] Polarlichter – Verein Antras
www.noe-sternwarte.at/best/lib/exe/fetch.php?media...polarlichter
[This article contains a very good summary of the most important aspects of Northern lights: translated from German to English by P. Brüesch]

R-8-9

8.3 Kennelly-Heaviside-Layer, Short-wave Transmitter - Varia

R:8.3.0 p. 362: Kennelly – Heaviside and High frequency radio - Introduction

R.8.3.1 p. 363: The Ionosphäre and the Kennelly – Heaviside – Layer

a) Ionosphere - https://en.wikipedia.org/wiki/Ionosphere
b) Kennelly – Heaviside Layer - https://en.wikipedia.org/wiki/Kennelly%E2%80%93Heaviside_layer
c) Kennelly – Heaviside Layer - http://ethw.org/Kennely-Heaviside_Layer
d) Die Ionosphäre und Plasmasphäre der Erde
[PDF] webdoc.sub.gwdg.de/ebook/diss/2003/fu-berlin/2002/273/kap2.pdf
e) Ionosphäre - http://de.wikipedia/wiki/Ionosph%C3%A4re
f) Kurzwelle - http://de.wikipedia.org/wiki/Kurzwelle
g) Der Beginn des Kurzwellen-Rundfunks - http://www.wabweb.net/radio/radio/kw_beginn.htm

R.8.3.2 p. 364: Heaviside-Layer and Short-wave transmitter

a) Oliver Heaviside - https://en.wikipedia.org/?title=Oliver_Heaviside
b) Arthur E. Kennelly - https://en.wikipedia.org/wiki/Arthir_E_Kennelly
c) The Ionosphere and Radiowave Propagation
http://www.radio-electronics.com/info/propagation/Ionospheric/ionosphere.php
d) Kennelly – Heaviside – Schicht - http://de.wikipedia.org/wiki/Kennelly-Heaviside-Schicht
e) Text: from References of R.8.3.1
f) Figure from www.google – pictures: Figure Text translated f rom German to English by P. Brüesch

R.8.3.3 p. 365: Reflection of short-waves at the E- and F- Layers

a) Introduction to HF Radio Propagation - http://www.ipx.gov.au/Educational/5/2/2
Picture of Reflection (Propagation modes and paths) of short-waves at the E- and F- layers
b) Ionospheric Wave Propagation
by Professor David Jenn): Departement of Electrical and & Computer Engineering / Monterey, California
Naval Postraduate School - www.dejenn.com/EC3630/Ionosphe(v1.5).pdf
c) Kurzwelle - http://de.wikipedia.org/wiki/Kurzwelle
d) Kurzwellenrundfunk - http://de.wikipedia.org/wiki/Kurzwellenrundfink
e) L. Bergmann und C. Schaefer: Lehrbuch der Experimentalphysik
Editor: De Gruyter - Band 2: Elektrizitsilehre
s. auch unter: books.google.ch/books?isbn_3111442881 ; p. 382

R-8-10

8.4 Other Atmospheric Phenomena

R.8.4.1 p. 367 : Rainbows - http://sol.sci.uop.edu/~jfalward/physics17/chapter12/rainbowmeadow.jpg
A detailed discussion about Rainbows can be found in «WASSER» from P. Brüesch,
Chapter 7, Section 7.2, pp 327 – 339, (s. Ref. R.0.4 of this work about «The Atmosphere of our Planet»

R.8.4.2 p. 368: Halos: Origin and Appeareance

a) Halo (optical phenomenon) - https://en.wikipedia.org/wiki/Halo_(optical_phenomenon)
b) 22^0 halo - https://en.wikipedia.org/wiki/220C2%B0-hato
c) Ice Crystal Halos - http://www.atoptics.co.uk/haosim.hrm
d) Halo (Lichteffekt) - http://de.wikipedia.org/wiki/Halo_(Lichteffekte)
e) Halo (optical phenomena) - http://en.wikipedia.org/wiki/Halo_(optical:Phenomenon)
[enthält physikalische Grundlage für minimalen Winkel von 22^0]
f) 22 Degree Halo: A ring of light 22 degrees from the sun or moon
http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/opt/ice/halo/22.rxml
[Images from 22 degree Halo; second picture; Refraction at hexagonal single crystals
g) Beautiful sun halo over Stockholm today - Photo of Sunset with Halo; Foto of Tomas Oneborg
http://www.ufoeyes.com/2010/08/beautiful-sun-halo-over-stockholm-today - see also:
https://www.pinterest.com/josieannmcbride/sun-dog-parthelion-they-are-wunderful-and-magical-t/

R.8.4.3 p. 369: St. Elmo's fire: General and History

a) St. Elmo's fire - http://en.wikipedia.org/wiki/St._Elmo's_fire
b) Erasmus von Antiochia - Bild von St. Elmo - http://de.wikipedia.org/wiki/Erasmus_von_Antiochia
c) Elmsfeuer - http://de.wikipedia.org /wiki/Elmsfeuer:
Bild von Schiff in Not mit Elm's Feuer an den Mastenspitzen
d) Saint Elmo - http://www.catholic-saints.info/patron-saints/saint-elmo.htm

R.8.4.4 p. 370: St. Elmo's fire. Physical Aspects

a) What causes the strange glow knowm as St. Elmo's Fire?
Is this phenomenon related to ball lightning?
http://www.scientificamerican.com/article.cfm?id=quotwhat-causes –the-stran
b) Was ist das Elmsfeuer ? http://www.pm-magazin.de/r/gute.frage/was-ist-das-elmsfeuer
c) Am Rhein - Elmsfeuer: http://www.marnach.info/masurenrein/rhein/elmsfeuer.html
d) What is St. Elmo's Fire? - http://science.howstuffworks.com/nature/climate-weather/atmosphere-elmo-fire.htm

R-8-11

R.8.4.5 p. 371: Purple light at Sunrise and Sunset

a) Purple Light and Twilight Arch
http://epod.usra.edu/blog/2009/12/putple-light-and-twilight-arch.htm
b) Measuring and modelling twilight's purple light - http://www.ncbi.nim.nih.gov/pubmed/12570266
c) Purple light - http://glossary.ametsoc.org/wiki/Purüle_light
d) Purpurlicht - http://de.wikipedia.org/wiki/Purpurlicht
[Text translated from German to English by P. Brüesch; contains also the Figure]
e) Rayleigh scattering - http://en.wikipedia.org/wiki/Rayleigh_scattering
[Rayleigh scattering is the elastic scattering of light by particles with diameters d much smaller than the wavelength λ of light, i.e. scattering of visible light by oxygen- and nitrogen molecules of the air. For purple light this condition is satisfied because $\lambda \approx 400$ nm and $d(O_2) = 0.121$ nm, $d(N_2) = 0.11$ nm].
f) Rayleigh-Streuung - http://de.wikipedia.org/wiki/Rayleigh.Streuung
g) Mie-scattering - http://en.wikipedia.otg/wiki/Mie_scattering
[Mie scattering suggests situations where the size d of the scattering particles is comparable to the wavelength λ of the light. A reasonable condition is $0.2\,\lambda < d < 2\,\lambda$. For $\lambda = 400$ nm (purple light) the diameters of the dust particles are in the range 80 nm to 800 nm].
h) Mie-Streuung - http://de.wikipedia.org/wiki/Mie-Streuung

R.8.4.6 p. 372: Airglow or Nightglow

a) Airglow - http://en.wikipedia.org.wiki/Airglow
b) Airglow - http://de.wikipedia.org/wiki/Airglow
c) Foto (left-hand-side): Astro Bob - Is there true darkness ?
http://astrobob.areavoices.com/2009/02/25/is-there-true-darkness/
d) Foto (right-hand side) aus: Science and Analysis Laboratory / NASA
in: Frankfurter Allgemeine: «Globale Erkältung (in der Mesosphäre»
e) Airglow - http://www.britanica.com/science/airglow

R.8.4.7 p. 373: Red Sprites, Blue Jets and Elves

a) Sprites, Blue Jets, Elves and «Superbolts»
http://www.sky-fire.tv/index.cgi/spritesbluejetselves.html#18
b) Red Sprites and Blue Jets - http://elf.gi.alaska.edu#vhy
c) Sprite (Wetterphänomene) - Text und Bild aus http://de.wikipedia/org/wiki/Nlue:Jet

R-8-12

References to Appendix – Chapter 8

R-A-1-1 p. 8-A-2-1: Earth's magnetic field: Magnetic and geographical Poles

a) Left-hand picture: Cross-section through Earth - from: www.google.ch
b) Right-hand picture: Earth's magnetic field - http://en.wikipedia.org/wiki/Earth's_magnetic_field

R-A-2-2 pp 8-A-2-2 – 8-A-2-3: Decrease of magnetic fields – Pole reversal – 1 and 2

a) Geomagnetic reversal - https://en.wikipedia.org/wiki/Geomagnetic _reversal
b) Earth's Magnetic Poles May Be About To Switch - http://www.rense.com/general26/poles.htm
c) Magnetic Flips - Written and assembled by William Hamilton III (2005)
http://www.astroscjence.info/magflips.htm
d) Reversals: Magnetic Flip - http://www.geomag.bgs.ac.uk/edication/reversals.html
It is the oppinion of the present Author, that this short summary is written very clearly, differentiated and objectively. In addition, it also contains the Figure of p. 8-A-2-2
e) Erdmagnetfeld - http://grographie.ch/index.php/Erdmagnetfeld
(contains Texts for pp 8-A-2-2 and 8-A-2-3 - translated from German to English by P. Brüesch)
f) Erdmagnetfeld - http://de.wikipedia.org/wiki/Erdmagnetfeld
(contains pictures for p. 8-A-2-3 / Figure Text translated from German to English by P. Brüesch)
g) Polsprung – Erdachse verschiebt sich nach Osten
http://www.pravda-tv.com/201207/polsprung-erdachse-verschiebt-sich-nach-osten
h) Paläomagnetismus und die Umpolung des Erdmagnetfeldes - http://www.hak-vk.at/index.php?d=2527

R.A.2.3 p. 8-A-2-4: The Colours of Polar lights

a) Colours of the Aurory - http://www.webexhibits.org/causesofcolor/4D.html
b) Polarlichter (engl, Aurora) - http://www.schreiben10.com/referate/?hysik/7/Polarlichter---Aurora.reon.php

R.A.2.4 p. 8-A-2-5: About the Mechanisms of Magnetic Orientation in Birds

a) «Robins can literally see magnetic fields, but only if their vision is sharp»
http://blogs.discovermagazine.com/notrocketscience/2010/07/08/robins-can-literally-see-magnetic-fields-but-only-if-their-vision-is-sharp/#.VX1_erY983g
b) Mechanisms of Magnetich Orientations in Birds - http://icb.oxfordjournalsorg/content/45/3/565.full
c) Warum verlieren Zugvögel nicht die Orientierung ?
http://www.simolyscience.ch/teens-liesnach-archiv/articles/warum-verlieren-zugvögel-nicht-die-Orientierung.html

R.A.4.1 pp 8-A-4-1 and 8-A-4-2:

R.A.4.2
a) Chapter 1 - Reflection and Refraction - http://www.astrowwww.phys.uvix.ca/~tatum/goptics/geomop1.pdf
b) Prisms - http://www. hyperphysics.phy-astr.gsu,edu/hbase/.../prism.html
c) The 22^0 Halo - http://www.hyperphysics.phy-astr.gsu.edu/hbase/.../halo22.html
d) Lichtbrechung in der Atmosphäre - «Light refraction in the Atmosphere»» - Universität Regensburg von Florian Albrecht zum Seminar «Phänomene der klassischen Optik» - (Sommersemester 2008)
www.physik.uni-regensburg.de/forschung/schwarz/1-Atmosphäre.pf...
e) Die Brechung des Lichtes – Chemgapedia - «The refraction of Light» - Chemgapedia
http://www.chemgapedia.de/vsengine/vlu/vsc/de/ph/14/ep/einfuehrung/geooptik/brechung.vlu/Page/vsc/de/...
Die Arbeit enthält die grundlegenden Gleichungen zur Berechnung der Brechung am hexagonalen Eiskristall
[This work contains the baisic equations for the evaluation of the refraction of light at a hexagonal Ice-crystal]
Figur des hexagonalen Eiskristalls mit Dispersionsprisma von p. 8-A-4-1 erstellt von P. Brüesch
[Figure of hexagonal Ice crystal with dispersion prism shown at p. 8-A-4-1 from P. Brüesch]
f) Halo - [PDF] Lie. «Ein Halo ist ein heller Ring um die Sonne» - [«A Halo is a bright ring around the Sun]
physik.li/beispiele/Halo/Halo.pdf
Enthält Figur des Ablenkungswinkels als Funktion des Einfallswinkels (p. 8-A.4.2)
[Contains the Figure showing the angle of deviation as a function of the angle of incidence (p. 8.A.4.2)]

R.A.4.3 p. 8-A-4-3 - A Moon Halo in Mandan, North Dakota (by Marshall Lipp. February, 2015)
http://earthsky.org/space/what-makes-a-halo-around-amoon

R.A.4.4 p. 8-A-4-4: Noctilucent clouds or Night clouds

a) Noctilucent cloud - http://en.wikipedia-otg/wiki/Noctilucent_cloud
(right-hand picture: Photograph by the crew of the ISS)
b) Leuchtende Nachtwolken
http://www.deutscher-wetterdienst.de/lexikon/index,htm?ID=L&DAT_Leuctende_Nachtwolken
(left-hand picture)
c) Leuchtende Nachtwolken - http://www.meteoros.de/themen/nlc
d) Leuchtende Nachtwolke - http://de.wikipedia.org/wiki/Leuchtende_Nachtwolke

9. Breathing in Psychology, Philosophy and in World Religions

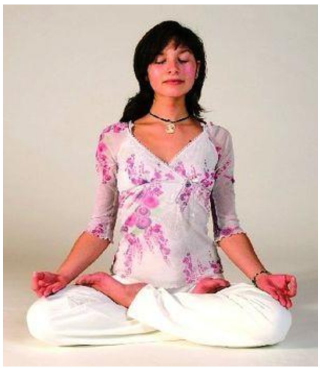
374

9.1 Breathing in Psychology

Physiological and Psychological Aspects of Breathing

The notion «Psychology» is composed on the words «Psycho» and «logos». The Greek word «logos» means science, word or doctrin. The word «Psycho» also derives from Greek and signifies «Life», «Soal», «Breath» or «Respiration».

The breathing rhythm and the heart rhythm are coupled together. At rest and during sleep, the ratio of respiration and heart rhythm is 1: 4: for 15 to 20 breaths per minute there are about 60 – 80 heartbeats. During physical stress, the number of breaths increases while during physical relaxation it decreases. More rapid breathing accelerates the heartbeat becaus more oxygen must be transported to the organs. Conversely, the heartbeat slows down at slower breathing. A higher heartbeat at rest, coupled with fears can cause a panic attack. The shallower the breathing, the faster is the breathing rhythm, and as a rule, the higher is the heart rate.



Spirit and breathing are often regarded as similar notions. But while spirit and consciousness are abstract concepts, respiration as well as heartbeat are physiologically real; they are the physiological counterpart to spirit and consciousness.

Picture: «Square» Respiration:

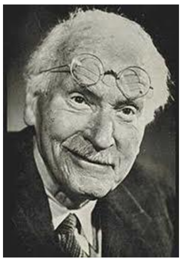
Respiration is divided into 4 equal phases:

1) Inspiration
2) Holding one's breath with the lungs fully filled
3) Expiration
4) Holding one's breath with the empty lungs

Animus, Anima and Breath

Animus and Anima are concepts of the analytical psychology of Carl Gustav Jung (1875 - 1961). Animus and Anima are two basic Archetypes residing in the collective unconscious. Archetypes are prototypes of the soal which are independend on individual experiences. The notions animus and anima are derived from the Latin. «Animus» has a variety of meanings such as soal, spirit, memory, courage, high spirit, temper , passion, etc. On the other hand, «Anima» is assigned to Air as an element, to breath of air, to wind, to soal, breath, etc. Both concepts, animus and anima, are summarized by Jung by the generic term soal. For Jung, soal is the archetypical internal and unconscious personality.

According to Jung, breath does not belong to the personal unconscious but rather to the collective unconscious. For Jung, the collective unconscious comprises in itself the psychic life of our ancesters right back to the earliest beginnings. Similar to the biological body, the collective unconscious has developed throughout the evolution and has been shaped by different experiences.



Carl Gustav Jung

Respiration belongs to Anima

377

The Breath Soul

In many cultures the perception exists that the breath is the life force and the breath is identified with the «breath soul». Therefore, the breath is also called the «breath of life» which reflects the spiritual state and is even identical with it.

In many cultures, the notion of the breath soal is only one aspect of the soal, the other being the «free soal» which corresponds to the shade.

There is the perception that the last breath or dying breath, corresponds to the escape of the life force or of the soal from the body and signifies the end of life. On the other hand, life begins with the «first breath», the first inhalation.

As mentioned above, the perception of «breath soal» is intimately related to the notion of the breath of life (in Old High German: «Odem»). In Latin, «anima» has a dual meaning, namely «soal» and «breath».

The ancient Greek word for «butterfly» was «Psyche», which is equivalent to «breath», «whiff» or «soal»

378

9.2 Respiration in Philosophy

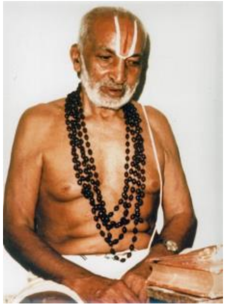
379

Respiration in Philosophy - Yoga

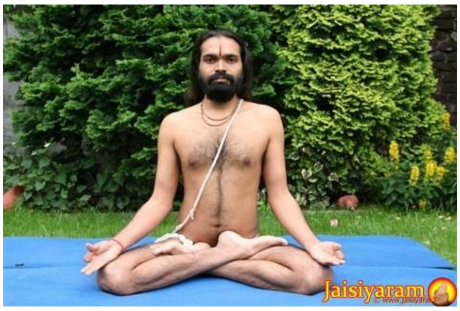
In philosophy, the aspiration of human reasoning concerning the «existential» queastions have priority. In particular, the question of the role of humans in the world is of prime importance.

In Indian philosophy, respiration plays a central role, especially in the Yoga-philosphy, one of the six orthodox Indian philosophical systems.

The Yoga philosophy declares: «Life is Respiration and Respiration is Life». The propre respiration is of paramount importance for everybody in all aspects of life; this is because respiration, body and mind are in mutual interaction. A Yogi counts its lifespan according to the number of his breaths. The sages of Indian Yogis were able to prevent many diseases; they have developed their mind and have developed a high level of conciousness.



Sri T. Krishnamacharya (1888-1989): Founder of Yoga philosophy in Europe



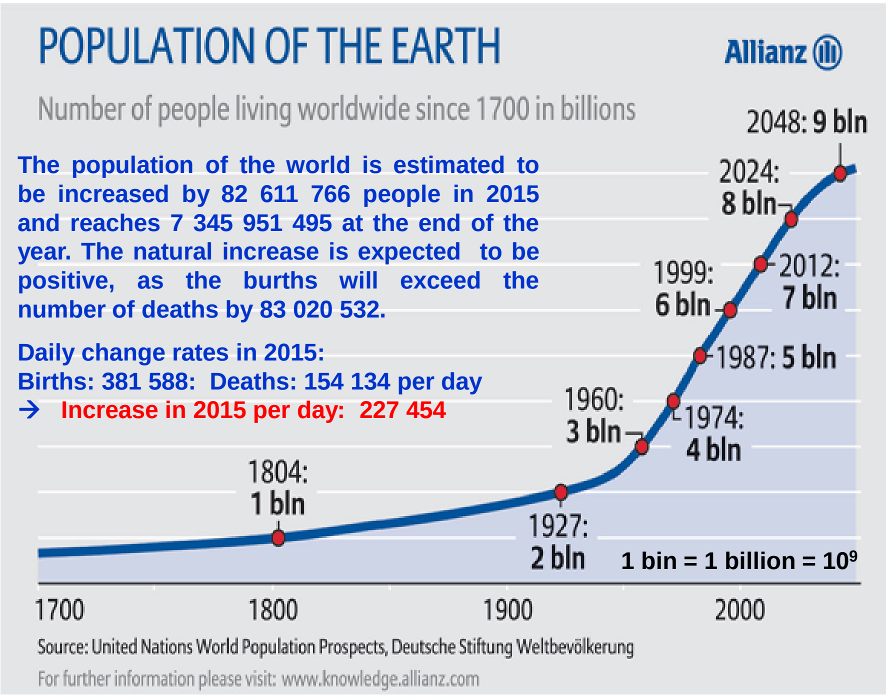
Dirgha Pranayama: Full Yogy respiration

380

9.3 World Population and World Religions

381

9.3.1 World Population



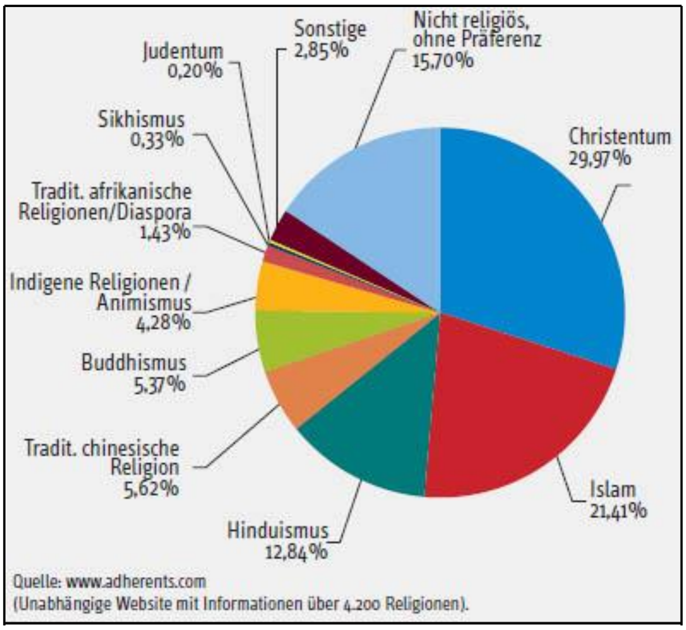
The population of the world is estimated to be increased by 82 611 766 people in 2015 and reaches 7 345 951 495 at the end of the year. The natural increase is expected to be positive, as the burths will exceed the number of deaths by 83 020 532.

Daily change rates in 2015:
Births: 381 588: Deaths: 154 134 per day
→ Increase in 2015 per day: 227 454

1 bin = 1 billion = 10^9

382

9.3.2 Die Weltreligionen - 1



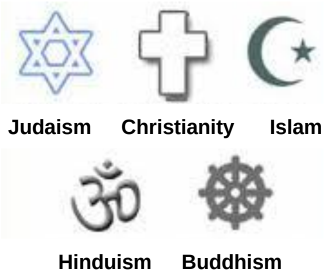
Die beigefügten Prozent-Zahlen beziehen sich auf die Weltbevölkerung (Am 1. 1. 2014 lebten 7.202951 Milliarden Menschen auf der Erde !).

383

The five World Religions - 2

The following Religions are referred to as the «Five World Religions». (The number of followers have been found in «Encyclopedia Britanica» 2005).

- **Christianity (about 2.1 billions)**
- **Islam (about 1.5 billions)**
- **Hinduism (about 900 millions)**
- **Buddhism (about 376 millions)**
- **Judaism (about 14 millions)**



Symbols of Religions

Despite of its universal self-conception, the number of Jewish followers is very small in comparison with those of the other World Religions quoted above (s. also p. 383). While both, Christianity and Islam missionize actively, this is not the case in Judaism for different historico-cultural reasons. Despite this fact, the Jewish belief has an important cultural significance, since both, Christinity and Islam are based on the Abrahamitic monotheism. A conversion to Jewish belief is, however, in principle possible. Also in Buddhism and in Hinduism there is no active missionary work. In Hinduism, the religion is characterized by a narrow social structure (caste system). Despite of the large number of followers, Hinduism depends strongly on regional conditions.

In a very narrow view, only Buddhism, Christianity and Islam would be true World Religions. This universal claim of validity exsisted already at the foundation of these Religions. The condition includes a worldwide dissemination, a ver large number of followers as well as the fact that these Religions are very old.

384

The five World Religions: Table

Religion / Characterisitics	Judaism	Christianity	Islam	Hinduism	Buddhism
Founder	Mose (Ezra)	Jesus Christ	Mohammed	Various teachers	Siddharta Guatama: Buddha
Holy Scriptures	Thora (= 5 Books Mose) – «Old Testament»	Bible (Old and New Testament	Koran	Vedas Upanishads	Tipikata (Pali Canon)
Sanctuary	Synagogue (previously Temple)	Church	Mosque	Temple	Temple
Church leader	Rabbi (Father of each Family)	Pastor Priest (Pope)	Imam (Teacher) Muozzin (Prayer leader)	Priest (Brahmin)	Monks / Nuns (teachers)
What are they believing ?	In One God He is Creature and Liberator	God approaches us in the person of Jesus	One God (Allah): (He is merciful but also Judge)	Reincarnation Salvation from external cycle	Reincarnation Salvation from Cycle → Nirvana
How should one behave ?	10 Commandmans Love God and neighbour	Act out of Love Love enemy (10 Commands)	Confession of faith – worship pay poor rate	Worship Gods Worship of cows Rules of castes	Do not kill, steel, lie, no alcohol; Live in chastity
Holy places	Jerusalem	Any place is secret Jerusalem …	Mecca, Medina, Jerusalem	Varanasi (earlier Benares)	Bodh Gaya Sarnath, Kushinagara
Religious festivals	Paschal fest – New Year - Yon Kipper Feast of Booths	Easter – Pentecost – Christmas	Ramazan Bayran Feast of sacrifice	Holi Diwali	Bodhy Parniivana + Hanamatsuni
Special characteristics	Orthodox Jews have special clothing	There are different confessions	Muslima often wear a headscarf	Hinduism is very diverse !	2 priniple direc-tions: Mahayana and Hinayana

385

9.4 Respiration in the five World Religions

Judaism Christianity Islam

Hinduism Buddhism

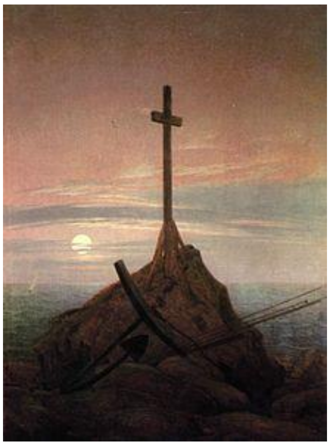
386

9.4.1 Christianity

387

Christianity - General

The founder of Christianity is Jesus of Nazareth, who was born more than 2'000 years ago in Galilee, a part of Palestine. Jesus was a Jew. In his younger years he was a carpenter. At about the age of thirty, he walked as a itinerant preacher through the country. During that time he took great care to sick people, to poors and to lawbreakers. The followers of Jesus conceived him as the Messiah who was announced by the prophets. From the holders of power at that time he was, however, considered as an insurrectionist and finally he was even sentenced to death by crucification. His followers were, however, convinced that Jesus rised from his grave .



Caspar David Friedrich:
Cross at the Baltic Sea

Christianity is based on the Old Testament (s. Section 9.4.5), the Holy Book of Judaism) as well as on the New Testament. Among others, the latter contains the four Gospels which have been written down by the four Evangelists St. Mathew, St. Mark, St. Luke and St. John between 70 and 120 years A.D.

Christianity is a monotheistic religion which achknow-ledges a single God. The Chrstian God appears, however, in three essential forms: in God the Father, in the Son of God, and in the Holy Spirit.

Similar to Judaism and Islam, Christianity is based on the ten Commandments. For Christianity, however, the commandment of Love in the form «Love your next one like yourself» is of prime importance.

Today, the three denominations are the following:

1. The Catholic Church - 2. The Orthox Churches, and
3. The Evangelical Church.

388

The Breath of the Holy Spirit

In Christianity, the Holy Spirit is the «The Lord». That means: It is God. There are three symbols of the Holy Spirit: Often, the Holy spirit is compared with the «Fire». Another symbol is «living Water». A third symbol of the Holy Spirit is the «Breath of God». In the present context we consider the third symbol, the Holy Spirit as the «Breath of God».

When the resurrected Jesus appeared to his disciples, «he breathed upon them and said to them: Receive the Holy Spirit! For those whose sins you forgive, they are forgiven; for those whose sins you retain, they are retained (not forgiven)» (Joh. 20, 22f).

Just as the air makes possible our physical life, the Holy Spirit sustains our spiritual life. Only where the Holy Spirit is breahed in, humans can live as Christians.

The Breath of God

The one who let me breathe:
Humans receive the Breath of God

389

The Holy Spirit

What is the Holy Spirit? For Spirit and Breath the Bible knows only one word. In order to symbolize the stimulating force of the Holy Spirit onto human beings, almost all classical languages use the word Breath, Whiff or Air: «Ruach» in Hebrew, «Pneuma» in Greek, «Spiritus» in Latin, «Atman» in Sanscrit and «Chi» in Chinese. In the original language of the Bible, the Holy Spirit has the significance of Wind, Whiff or Breath. In the Holy Gospel it is said that at his baptism, Jesus saw how the Holy Spirit was descending onto him as a pigeon.

The Christian church celebrates Pentecost as the feast of the arrival of God's spirit and identifies the Spirit of God with God itself. The Outpouring of the Holy Spirit at Pentecoast is often symbolized by the descending of a pigeon.

God's Breath of Life

The pigeon as a symbol of the
Holy Spirit

390

Citations about Breath and Spirit in the New Testament

Joh. 3,5: Jesus answered, «Truly, truly, I say to you, unless one is born of water and the Spirit he cannot enter into the kingdom of God».

Joh. 3.8: Jesus said: «The Wind blows where it whishes, and you hear the sound of it, but cannot tell where it comes from and where it goes. So is everyone who is born of the Spirit».

Joh. 20, 19 – 22: Jesus appears to the disciples: 19. On the evening of that day, the first day of week, the doors being locked where the disciples were fear of the Jews, Jesus came and stood among them and said to them, «Peace be with you». 20. When he said this, he showed them his hands and his side. The disciples were glad when they saw the Lord. 21. Jesus said to them again, «Peace be with you. As the Father has sent me, even so I am sending you». 22. And when he said this, he breathed on them and said to them, «Receive the Holy Spirit».

An angle comes for the soal of a dying and the soal is leaving the body.

(Woodcut from the fifteenth century)
Author not known

391

9.4.2 Islam

392

Islam - General

Similar to Christianity and Judaism, the Islam is a monotheistic and Abrahamic Religion articulated by the Qur'an, a book considered by its adherents to be the verbatim word of God (Arabic Allah) and by the teaching and normative example of Muhammad, (570-632 AD), considered to them as the last prophet of God. An adherent Islam is called a Muslim.

At the age of 40, Muhammed had a visionary experience in a stone cave near Mecca which initiated a profound transubstantiation in his live. While he was sleeping, the Archengel Gabriel appeared to him and he called upon him to cite Verses (which today are the first 5 Verses of the 96th Surahs of the Koran. In the following years, the prophet obtained further revelations and divine inspirations which he associated with God. All these revelations are summarized in the Koran. In the present form, the Koran is subdivided into 114 Surhas (Sections).

Symbol of the Islam:
The Half-Moon with a Star

Allah-Calligraphy

The prophet
Muhammed

393

Holy Spirit, Breath and Wind in Koran

The Holy Spirit, also known as Jibrayi, described in the Islamic faith is mentioned several times in the Qur'an, and is generally interpreted by Muslims as being the same Holy Spirit that is referred to in both the Old and the New Testaments of the Bible. Here we content ourselves to site just two surahs of the Koran

«So when I have proportioned him and breathed into him of My soul, then fall down to him in prostration»

Surah 38, 72

«And it is Allah who sends the winds, and they stir the clouds, and We drive them to a dead land and give life thereby to the Earth after its lifelessness. Thus is the resurrection»

Surah 35, 9

«Nafas al Rachman», breath of the Merciful, experienced daily by those taking part in Al-Qijamah (The Resurrection).
(Photo taken 1st August 2008 in Russia of the Nafas al Rachman which, though invisible to the naked eye, can be felt as Cool Breeze of Wind of the Resurrection flowing from hands, head and other parts of the body).

394

9.4.3 Hinduism

395

Hinduism - General

Hinduism is a very old religion. It is not possible to determine a date of formation, but the religion goes back to the so-called «Indus culture», which developed about 6’000 years ago in India. It is a bundle of religions because Hinduism is affected by a variety of diverse streams. One of these streams led to the foundation of Buddhism (s. 9.4.4).

The Hinduism contains monotheistic, dualistic and polytheistic directions. Hindus believe on an external soal. After death, this soal reappers in another living being on the Earth (reincarnation). In this way, an external cycle is established: Samsara. The deeds in the past life is judged by the «Dharma». This judgement determines his «karma». The karma is the sum of good and bad deeds in the life of a Hindu. It determines the reincarnation in a specific caste. A good karma has the effect that the soal is reborn in a better life or is even released from the external cycle. A prominent representative was Mahatma Gandhi (1869 - 1948).

The symbol Om embodies the basic idea that the Creator of the World is omnipresent, infinite, all-wise and infallible.

For Hindus, the Cow is sacred and in a figurative language it appears as a Goddes.

396

Breath or Prana in the Upanishads

Breath in Hinduism is called Prana. Next to the Self and Supreme-Self, the most important entity frequently mentioned in the Upanishads is prana. (The Upanishads are a collection of texts which contain the central religious contexts of Hinduism).

The prana that the Upanishads extol is not just the air we breath. It is the life-energy which circulates in a being from the time of its conception until its death. While the body is mortal, prana is immortal. What sustains and supports the body during its existence upon earth is prana.

Prana nourishes the organs in the body, protects them and at the time of death absorbs their subtle aspects into itself and then releases them in the region above the Earth, from where they return to their source.

Prana is superior to all the organs of the body for three reasons: First, because prana is beyond the control of the mind and body and tireless. Second, prana cannot be corrupted by evil desires, whereas the organs in the body are vulnerable to desire and sinful intensions. Third, prana keeps the body alive and free from evil. While the body can survive without the presence of other organs, without the breath it dies.

Hindu breathing meditation

Breatihng meditation from Indian Jainas

9.4.4 Buddhism

The Symbol of Buddhism
(s. p. 400)

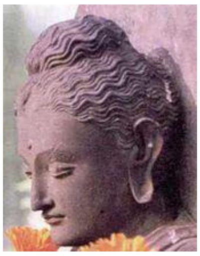
398

Buddhism: General

Buddhism is a <u>nontheistic</u> religion to about 300 million people around the World. The word comes from «budhi», «to awaken». It has its origin about 2'500 years ago when Siddharta Gottana, known as Buddha, has himself awakened (enlighted) at the age of 35. He was born into a family in Lubini, now located in Nepal, at 563 BC. He was not a God but rarher a man who taught a path to enlightment from his own experience,

<u>To many, Buddhism goes beyond religion and is more a philosophy or «way of life».</u> It is a philosophy because philosophy «means love or wisdom» and the Buddhist path can be summarized up as: (1) to lead a moral life; (2) to be mindful and aware of thoughts and actions; and (3) to develop wisdom and understanding.

The basic concepts of Buddhism can be summarized by the Four Noble Truths and the Noble Eightfold Path (s.p. 400). The first truth is that life is suffering, i.e. life includes pain, getting old, diseases and ultimately death. The second truth is that suffering is caused by craving and aversion. The third truth is that suffering can be overcome and happiness can be attained. The forth truth is that the Noble-8-fold path is the path which leads to the end of suffering. The Noble-8-fold path is often represented by means of the dharma wheel (s. p. 398), whose eight spokes represent the eight elements of the path (s. p. 400).



Buddha Siddhartha Gautama

Siddhartha Guatama, the later Buddha, was born in Northern India at 563 BC and died at the age of 80.

Giant Buddha-Statue in Bodhgaya, India

399

The Noble Eightfold Path

1. «Right vision» or understanding: understanding that life always involves change and suffering. Realising that following the Noble Eightfold Path is the way to overcome suffering and be realy happy.
2. «Right emotion / right thinking»: Committing oneself to wholeheartedly following the path.
3. «Right speech»: Speaking in a positive and helpful way; speaking the truth.
4. «Right action»: Living an ethical life according to the precepts.
5. «Right livelihood»: Doing work that doesn't harm others and is helpful to them.
6. «Right effort»: Thinking in a kindly and positive way.
7. «Right mindfulness»: Beeing fully aware of oneself, other people, and the world around you.
8. «Right meditation» or concentration: training the mind to be calm and positive in order to develop Wisdom.

400

Breathing in Buddhism

The Buddhist Tradition of Breath Meditation

One who has gradually practized,
Developed and brought to perfection
Mindfulness of the in-and-out breath
As taught by the Enlightened One,
Illuminates the entire world
Like the moon when freed from clouds.

(Theragatha 548)

The basic text on Buddhistic Breath Meditation is the Anapanasati Sutra.

There is much more Buddhist material on Breath Meditation than that of other traditions. This is because Buddha quite openly and continually advocated Breath Meditation and it was never «lost» to Buddhism at any time. So we have over two thousand years of very clear tradition on the highly important subject of breathing.

Buddha: Breathing meditation

Breathing meditation in Buddhism

401

9.4.5 The Judaism

The Star of David is a hexagram . It is named after the King David of Israel (1040 BC to 970 BC). The Hexagram is a six-pointed geometric star figure consisting of two equilateral and interlocking equilateral triangles.

The original Menorah is a seven-branch candlestick. It is one of the most important religious symbols of Judaism. Six of the seven branches represent human wisdom, guided by the center branch of Divine light.

402

The Judaism - General

Judaism is a religion based on written scripture; it does not have a spiritual leader (as the Pope in the Catholic Church). Instead, the Rabbi, the superintendent of a community, has the responsibility to advise the Jewish community. The Rabbi is a very learned man who relies on the work and advises of the Torah, which is the central element of Jewish belief. The Torah is the Hebrew Bible, the «Old Testament» of Christianity. A second important sripture is the Talmud which contains explenations and interpretations for a better understanding of the Torah.

- The Jewish religion is a very old and original one, because it is at the basis of Christianity, 2000 years ago, as well as on the basis of the Islam, 1400 years ago.
- Jewish are still expecting the arrival of the Messiah which has been announced by the Hebrew Bible. In contrast to Christianity, they do not admitt the Messiah as Jesus of Nazareth.

Western Wall at the Temple Mount in Jerusalem. Many visitors place a prayer card in the crakes of the Wall, hence the name «Wailing Wall»

- According to Jewish faith, a Jew is a person having a Jewish mother. Based on this definition, it is, in principle not possible to convert from another religion to Judaism.
- Already since the Middle Age, Jews had to suffer from anti-Semitism. The culmination of anti-Semitism was reached during the progrom by the German National Socialism wher nearly six million of Jews have been killed (s. Chapter 5: Appendix, p. 5-A-3-2).
- Today, about 14 million Jews are living worldwide; about 5 million Jews are living in Israel.

403

Breath in Judaism

In the Hebrew Bible or Tanach, soul and body are considered as two aspects of one entity. The power vitalizing the body is known as «nefesh», «neshama» or «ruach» in Biblical Hebrew (p. 390). Originally, these notions stand for «Wind», «Odem» or «Breath».

Neshama is the «Breath of Life», and according to the Book of Genesis, God blew his breath into the nose of his creature Adam which he formed from soil and thereby created a living being called «nefesh». The concrete basic meaning of «nefesh» is «Breath» or «respiratory passage». As a stimulating breath, nefesh is the vital force which leaves the body after death. The Jewish Bible neither assigns nefesh an existence before the formation of his body nor a life after his death and nefesh does nowhere appear in a form removed from the body. Moreover, neither nefesh nor neshama nor ruach are specific human notions; all three expressions are also used for animals. The notion «ruach» interrelates the meanings of «Breath», «Wind» and «Spirit».

Parts of the modern Judaism believed, however, on a continued existence of humans after their death; for some Authors, this was related to a soul bound to the body, whereas for others, the soul was considered to be freed from the body.

Inhaling breath of life

404

Appendix: Chapter 9

9-A-0

Buddhist Prayer Flags

Significance of the prayer flags in the four cardinal directions:

blue: Sky
white: Clouds
red: Fire Element
green: Water Element
yellow: Earth Element

9-A-4-1

References: Chapter 9

R-9-0

9.1 Respiration in Psychology

R.9.1.0 p. 375: Respiration in Psychology (Title)

R.9.1.1 p. 376: Physiological and psychological aspects of breathing

a) Respiration (physiology) - https://en.wikipedia.org/wiki/Respiration_(physiology)
b) The Science of Breathing - http://www.unm.edu/~lkravitz/Article%20folder/Breathing.hrml
c) The Healing Power of Spiritual Breathing . http://www.btreathmastery.com/spiritual-breathing-2/
d) Definition der Psychologie – Atem - Was ist Psychologie ?
Dipl.-Psych. Sabine Eva McGregor – Psychologin FSP
http://www.diplompsychologin.ch/Was-ist.Psychologie.html
e) Atem-, und Herzrythmus - http://www.atemmassage.de/allgemeines-zum-atmen-und-herzrythmus
f) Es atmet uns … - http://www.duenengras.de/?p=1738
g) Quadratische Atmung - Aus Yogawiki (enthält Bild der atmenden Frau)
http://wiki/yoga-vidya.de/Quadratische_Atmung

R.9.1.2 p. 377: Animus, Anima and Breath

a) Carl Jung - http://en.wikipedia.org/wiki/Carl_Jung
b) Anima and animus - https://en.wikipedia.org/wiki/Anima_and_animus
c) Collective unconscious - https://en.wikipedia.org/wiki/Collective_unconscious
d) Jung's Archetypes - http://changinminds.org/expöanations/identity/jung_archetypes.htm
e) Carl Gustav Jung - http://de.wiipedia.org/wiki/Carl_Giutav_Jung
f) Animus und Anima - http://de.wikipedia.org/wiki/Animus_und_Anima
g) Kollektives Unbewusstes - http://de.wikipedia-org/wiki/Kollektives:Unbewusstes

R.9.1.3 p. 378: The Breath Soul

a) The secret of breathing - Part III: Mental Purification - by Nav Menu
Volume IV - Mental Purification and Healing
https://wahiduddin.net/mv2/IVIV_32.htm
b) Atemseele - http://de.wikipedia.org/wiki/Atemseele
c) Schmetterlinge – Ref. R.4.2.13, p. 133 b)
Mythologische Bedeutung des Schmetterlings: Seele und Tod
d) Bild von Schmetterling: http://www.fotocommunity.de/pc/display/12266530

R-9-1

9.2 Respiration in Philosophy

R.9.2.0 p. 379: Respiration in Philosophy - Title

R.9.2.1 p. 380: Respiration in Indian Philosophy

a) Philosophy - http://en.wikipedia.org/wiki/Philosophy
b) The importance of Exhaling in Yoga - by Andrea Cespedes. Demand Media
http://healthyliving.azcentral.com/importance-exhaling-yoga-6963.html
c) Yogic Breathing: The Physiology of Pranayama - by Angela Wilson; Ma; RYT
www.huffingtonpost.com/.../yoga-practice_h_4762...
d) Pranayama: Yoga Breathing - http://yogabasics.com/practice/pranayama/
e) Pranayama - https://en.wikipedia.org/wiki/Pranayama
f) Philosophie - Definition - http://www.wissen.de/lexikon/philosophie
g) Yoga - http://de.wikipedia.org/wiki/Yoga
h) Yoga: eine der sechs indischen Philosophien - praktischer Erlösungsweg
Pranayama (Zurückhalten der kosmischen Energie)
http://www.yoga-zeit,de./news486_1__101_Pranayama-(Zurückhalten-der-kosmischen-Energie).html
i) Ashtanga (Vinyasa) Yoga - In der Tradition von Sri T. Krishnamacharya
http://de.wlkipedia.org/wiki/Ashtanga_(Vinyasa)_Yoga
k) Yogakshemam - Schule für traditionellen Unterricht in indischer Philosophie
Text und Bild (links) von Sri T. Krishnamacharya (1888 – 1989)
http://www.yogakshemam.net/German/SriT.Krishnamacharya.html
l) Dirgha Pranayama – Volle yogische Atmung
Bild rechts: http://www.jaisiyaram.de/yoga-uebungen/dirgha-pranayama.html

R-9-2

9.3 Respiration in World Religions

R.9.3.0 p. 381: Respiration in World Religions (Title)

R.9.3.1 p. 382: World Population

a) Heroes Not Zombies becoming not being …..
The times they are a'changin' Part 1
http://heroesnotzombies.com/2014/02/19th-times-they-are-achangin-part-t/
(Contains the Graph for the Population of the Earth from the years 1700 to 2050)
b) World population clock 2015 - http://countrymeters.info/en/World
(Contains the World population clock, i.e. the actual populations in increments of seconds:
«Current total population» – «Current mail population» - «Current female population» - «Births this year» – «Deaths this year» – «Births today» – «Deaths today»)
c) Weltbevölkerung zum Jahreswechsel 2012 / 2013
Stiftung Weltbevölkerung: Weltbevölkerung zum Jahreswechsel 2012 / 2013
http://www.Weltbevoelkerung.de/index.php?id=71&tx_ttnews%5Btt_news%5D=789&cHash=d2939dd01a12921902e8…

R.9.3.2 p. 383: World Religions - 1

a) Major Religions of the World – Ranked by Number of Adherence
b) World Religions 2012: Percentages and numbers of different World Religions
(Found under Images in www.google.ch)

R.9.3.3 p. 384: World Religions – 2

a) Major religious groups - https://en.wilipedia.org/wiki/Major_religious_groups
b) Weltreligionen - http://de.wikipedia.org/wiki/Weltreligion - (Text translated from German to English)
c) Weltreligionen - http://code-knacker.de/weltreligionen.htm - (contains symbols of World Religions)

R.9.3.4 p. 385: The five World Religions: Table

Table found under: «Die fünf Weltrekigionen_Tabelle» → Bilder; s. also
http://www.docdatabase.net/more_tabelle_weltreligionen_loesungsvorschlag_1075716.htm
(Text translated from German to English by P. Brüesch)

R-9-3

9.4 Respiration in the five World Religions (p. 386)

R.9.4.0 Respiration in the five World Religions
aphilia - Theologie: Contains the Symbols of the 5 World Religions
http://www.aphilia.de/theologie-buddhismus-01-religion-philosophie.html

9.4.1 Der Atem im Christentum

R.9.4.1.0 p. 387: Christianity (Title with Cross- Symbol from: www,google.ch/search)

R.9.4.1.1 p. 388: Christianity – General

a) Jesus - https://en.wikipedia.org/wiki/Jesus
b) Brief Life Summary: Who was Jesus Christ ? - http://www.jesuscentral.com/historical-jesus/jesus-life.php
c) Brief Summary of Jesus' Life - http://covenantgrace.tripod.com/id1.html
d) Das Christentum /Faszination Glaube / de – ARTE
http://www.arte.tv/de/das-christentum/1172966,CmC=1172976.html
e) Das Kreuz: Bild an der Ostsee von Caspar David Friedrich
http://de.wikipedia.org/wiki/Caspar_David_Friedrich
http://commens.wikipedua.org/wiki/File:Caspar_David_Friedrich_024.jpg

R.9.4.1.2 p. 389: Breathing and the Holy Spirit– 1

a) What is the Holy Spirit? - http://www.cogwriter.com/what-is-the-holy-wpirit.htm
b) How is wind like the Holy Spirit ? - http://christiananswers.net/q-eden/windandholyspirit.html
c) The Breath of Life and The Holy Spirit - http://cafelogos.org/breathoflife.html
d) Question: Is the Holy Spirit the same as the breath of life that God breathed out ?
http://cafelogos.org/breathoflifequestion.html
e) What Did Jesus Mean When He Said: «Receive Ye the Spirit»?
https://www.christiancourier.com/articles/999-what.did-jesus.mean-when-he-said-receive-ye-the-spirit
f) Text: Beistand Gottes: Der Heilige Geist (P. Hermann Geissler) http://www.daswerk-fso.org/deutsch/?p=63
g) Bild links: Der Atem Gottes (Bild von Melchior Broederlam)
http://de.wikipedia.org/wiki/Melchior_Broederlam (1350? – 1409?)
h) Bild rechts: «Hilfe zur täglichen Besinnung & Gebetstexte - Der mich atmen lässt – Gebetstexte / Canisiuswerk
http://www.canisius.at/spiritualitaet/gebetstexte.php?show=494

R-9-4

R.9.4.1.3 p. 390: Breathing and the Holy Spirit – 2

a) The Breath of Life - God's Gift to All Creatures
by David Demik - http://answersingenesis.org/human-body/the-breath-of-life
b) Pentecost - https://en.wikipedia.org/wiki/Pentecost
c) Feast of Holy Pentecost - http://www.goarch.org/special/listen_learn_share/pentecost_html
d) Ruach - In the «Old Testament» the word «ruach» or «rûah» is translated as Spirit
The basic meaning of «rûha* ist «Wind» and «Breath» - http://www.de.wikipedia.org/wiki/Ruach
e) Pfingsten – «Religion des Geistes»
http://www.ekd.de/glauben/feste/pfingsten/religion_des_geistes.hrml
f) Geist und Verstand - http://www.sonntagsblatt-bayern.de/news/aktuell/2013_21_01_01.htm
g) Das Glaubensportal Lebendiger Christen
http://jesusliebtdich.blog.de/2012/01/10/bedeutet-eigentlich-taube-12424566/
h) Eugen Drewermann
- Atem des Lebens – Band 1: Das Gehirn - Die moderne Neurologie und die Frage nach Gott
Patmos Verlag, Düsseldorf
www.patmos.de/atem-des-lebens-band-1-das-gehirn-p-691.html
- Atem des Lebens . Band 2: Die Seele
Patmos Verlag, Düsseldorf
http://www.patmos.de/atem-des-lebens-band-2-die-seele-p-692.html

R.9.4.1.4 p. 391: Citations about Breath and Spirit in the Holy Bible

a) Bible Hub: John – Chapter 3, Verse 5 - http://biblehub,com/john/3-5.html
b) Bible Gateway : John – Chapter 3, Verse 8
https://www.biblegateway.com/passage/?search=John+3%3A8&version=NKJV
c) Bible Gateway: John - Chapter 20, Verses 19 – 22
https://www.biblegatewy.com/passage?search=John+20%3A19-22%2CYochanan+20%3A19-22%version=ESV.OJB
d) Bild – Image:
Ein Engel holt die Seele eines Sterbenden ab
An Angle comes for the soal of a dying and the soal is leaving the body
Holzschnitt aus dem 15. Jahrhundert - Woodcut from the fifteenth century
Autor unbekannt - Author not known
Seele aus einer Hand; aus:
http://de.academic.ru/dic.nsf/dewiki/1268981

R-9-5

9.4.2 Breath in Islam

R.9.4.2.0 p. 392: Islam (Title with Symbol: www.google.ch/dearch)

R.9.4.2.1 p. 393: Islam – General

a) Islam - From Wikipedia, the free encyclopedia - http://en/wikipedia,org/wiki/Islam
b) Allah - From Wikipedia, the free enxyclopedia - https://en.wikipedia.org/wiki/Allah
c) Prophet Muhammad . http://www.relgionfacts.com/people/prophet-nuhammad
d) Mohammed, The Prophet of Islam - A free download from http://manybooks.net
e) Islam - aus Wikipedia, der freien Enzyklopede - https://de.wikipedia.org/wiki/Isla,
f) Allah - aus Wikipedia, der freien Enzyklopedia - http://de.wikipedia.org/wiki/Allah
g) Mohammed - sein Leben und sein Wirken (570 – 632 n.Chr,)
http://www.efg-hohenstaufenstr.de/downloads/texte/is02:moh:leben.html
h) Symbol des Islams: unter: www.google.ch. – Bilder
i) Allah – Kalligraphie: unter: www.google.ch. - Bilder
k) The face of Muhammed: www.gppgle.ch. - Bilder
This realistic depiction of Muhammed can be found in a Spanish language educational web site

R.9.4.2.2 p. 394: Holy Spirit, Breath and Wind in Koran

a) Holy Spirit (Islam) - https://en.wkipsia/Holy_Spirit_/Islam)
b) Surat Sad (The Letter «Saad») - http://curan.co/38/72
c) Surat Fatir (Originator) - http://quran.com/35/9
d) Bild aus: Al-Qiyamah (The Resurrection) - http://www.al-qiyamah.org/
e) What is Islamic Spirituality ? - http://www..hamzatzortzis.com/q-alwhat-is-islamic-spirituality/
f) Islamic Concept of Spirituality - http://www.islamreligion.com/articles/10033/islamic-concept-of-spirituality/
g) Der Atem Allahs: Die islamische Welt und der Westen – Kampf der Kulturen ?
Bernard Levis (Autor) - Taschenbuch
http://www,amazon,de/Der-Atem-Allahs-islamische-Kulturen/dp/3423306408
h) Heiliger Geist im Islam
http://www.orientdienst.de/muslime/minikurs/heiligergeist/

R-9-6

9.4.3 Hinduism

R.9.4.3.0 p, 395: Hinduism (Title with symbol from: www.google.ch/search)

R.9.4.3.1 p. 396: Hinduism - General

a) Hinduism - from Wikipedia, the free encyclopedia - https://en.wikipedia.org/wiki/Hinduism
b) Hinduism - http://www.relgionfacts.com/hinduism
c) Hinduismus - http://de.wikipedia.org/wiki/Hinduismus
d) Symbol of Hinduism: found under Hinduismus: www.google.ch: Bilder des Hinduismus»
e) Der Hinduismus - Picture of the Holy Cow
http://www.arte.tv/de/der-Hinduismus/1172966,CmC=1172972.html
f) Heilige Kuh und ewiger Kreislauf - der Hinduismus
http://www.demokratiewebstatt.at/thema/thema-religion-und-glaube/die-fuenf-weltreligionen/heilige-kuehe-
…Kühe sind heilige Tiere. Ihre Verehrung verdankt die Kuh vor allem der Legende, dass der Gott Krishna - ein besonders wichtiger Gott – als Hirtenjunge mit einer Kuh -Herde heranwuchs. Die Kühe dürfen nicht geschlachtet werden, sie können sich überall frei bewegen und haben sogar im Strassenverkehr Vorrang.. Wer eine Kuh tötet, wird mit schlechtem Karma bestraft.

R.9.4.3.4 p. 397: Breath or Prana in the Upanishads

a) Upanishads - https://en.wikipedia.org/wiki/Upanishads
b) Breath or Prana in the Upanishds - by Jayaram V.
www.hinduwebsite.com/hinduism/essays/breath.asp
c) The Hindu Tradition of Breath Meditation
by Abbot George Burke (Swami Nirmalananda Giri) (http://www.ocoy.org/author/abbot-george)
http://www.ocoy.org/original-yoga/how-to-meditate/zhe-breath-of-life-the-practice-of-breath-medutation/the-hindu
(contains left-hand picture: Hindu breathing meditation)
d) Atman: http://wikipedia.org/wiki/Atman
e) Axel Michaels: Der Hinduismus – Geschichte und Gegenwart
books.google.ch//books?isbn=3406549748
f) (Right-hand picture: Breathing meditation from Indian Jainas; Google.ch – Images

R-9-7

9.4.4 Buddhism

R.9.4.4.0 p. 398: Buddhism (Title Symbol from : www.google.ch/search)

R.9.4.4.1 a) History of Buddhism - https://en.wikipedia.org/wiki/History_of_Buddhism
b) Die Geschichte Buddhas - http://www.buddhas.ch/die-geschichte-buddhas

R.9.4.4.2 a) Buddhism - https://en.wikipedia.org/wiki/Buddhism#Noble_Eightold_Path
b) Der Buddhismus - http://www.diedalailamas.ch/buddhismus.php

R.9.4.4.3 p. 399: Buddhism: General

a) Guatama Buddha - https://en.wikipedia.org/wiki/Guatama_Buddha
b) Buddha - http://de.wikipedia.org/wiki/Buddha
contains Text and left-hand picture of Buddha Siddhartha Gauatama
c) A Five Minute Introduction - BuddhaNet Basic Buddhisn Guide
http://www.buddhanet.net/e-net-learning/5minbud.htm
d) Right-hand picture: http://www.great-buddha-statue.com/

R.9.4.4.4 p. 400: The Noble Eightfold Path

a) Noble Eightfold Path - http://en.wikipedia.org/wiki/Noble_Eightfold_Path
b) Clear Vision Trust Audio-visual resources exploring Buddhism
The Noble Eightfold Path - http://www.clear-vision.org/schools/students/ages-12-14/noble-eightfold-path.aspx

R.9.4.4.5 p. 401: Breathing in Buddhism

a) The Buddhist Tradition of Breath Meditation
Chapter 4 of The Breath of Life - by Abbot George Burke (Swami Nirmalananda Giri)
Text and left-hand Figure - http://breathmeditation.org/the-buddhist-tradition-of-thr-meditation
b) : The Koran of Breathing -
http://www,beliefnet.com/Faiths/Buddhism/Articles/The-Koan-of-Breathing.aspx
c) Zur Bedeutung des «Kõan» siehe nachfolgende Literatur:
Kõan: http://de.wikipedia.org/wiki/K%C5%8Dan

R-9-8

9.4.5 The Judaism

R.9.4.5.0 p. 402: Judaism (Title with symbols)

a) Left-hand symbol: Star of David - https://en.wikipedia.org/wiki/Star_of_David
b) Hexagram - https://en.wikipedia.org/wiki/Hexagram
c) King David - https://en,wikipedia.org/wiki/David
d) Light Your Fire: What does the Menorah Symbolize? – www.unitedisrael.org/what-does-the-menorah-symbol...

R.9.4.5.1 p. 403: Judaism - General

a) Judaism - https://en.wikipedia.org/wiki/Judaism
b) Jews - https://en.wikipedia.org/wiki/Jews
c) What Do Jews Believe ? - http://www.religionfacts.com/Judaism/beliefs
d) Rabbi - https://en.wikipedia.org/wiki/Rabbi
e) Torah - https://en.wikipedia.org/wiki/Torah
f) Talmud - https://en.wikipedia.org/wiki/Talmut
g) Antisemitism - https://en.wikipedia.org/wiki/Antisemitism
h) Judentum - http://de.wikipedia.org/wiki/Judentum
i) Judentum - Klagemauer am Tempelberg in Jerusalem
http://www.spirii.de/de/Wissen/Spiritualitaet/Weltreligionen/Judentum.html
(with Picture of: «Wailing Wall» or «Western Wall» at the Temple Mount in Jerusalem – «Klagemauer»
k) Das Judentum - http://www,arte.tv/de/das-judentum/1172966.CmC=1172968.html
l) Juden - http://de.wikipedia.org/wiki/Iuden
(contains Figure of «Menorah» – Symbol of Jewish belief)
m) Die Klagemauer in Jerusalem
http://www.missions-palestine.org/die-klagemauer-in-jerusalem.html

R.9.4.5.2 p. 404: Breathing in Judaism

a) Tanach - http://www.thefreedictionary.com/Tanach
b) Nefesh - http://www.britanica.com/topic/nefesh-udaism
b) Neshama - http://en.wikipedia.org/wiki/Neshama
d) Holy Spirit (Judaism) - ruach = «holy spirit»
https://en.wikipedia.org/wiki/Holy_Spirit_(Judaism)

R-9-9

R.9.4.5.2 (cont.)

e) What is the meaning of the Hebrew Word ruach ?
http://www,gotquestions.org/meaning-ruach.html

f) The Soul - http://www.alsh.com/jl/sp/bas/48942091.html

g) Ruach & Being Prayed By The Whole Breath of Life: Judaism
http://livininthemonasterywithoutwallsdotcom.wordpress.com/2013/09/06/ruach-being-prayed-by-the-hole-...
(contains picture shown on this page)

h) The Jewish «Roots» of the Holy Spirit - by Lea Sestieri
www.vatican.val.../ju_mag_01021998-p-23-en.ht...

i) What does Judaism teach about the afterlife ?
http://www.religionfacts.com/judaism/beliefs/afterlife

k) Seele - http://de.wikipedia.org/wiki/Seele

l) Der Heilige Geist Gottes - http://www,dawnbible.com/de/2008/08031s,htm

m) «Alles, was Odem hat, lobe den Herrn»
Menschen und Tiere unter der gleichen Verheissung Jahwes
www.uni-due-de/~gev020/courses-stuff/lit-Gerlitz, Peter 1998.pdf

Appendix - Chapter 9

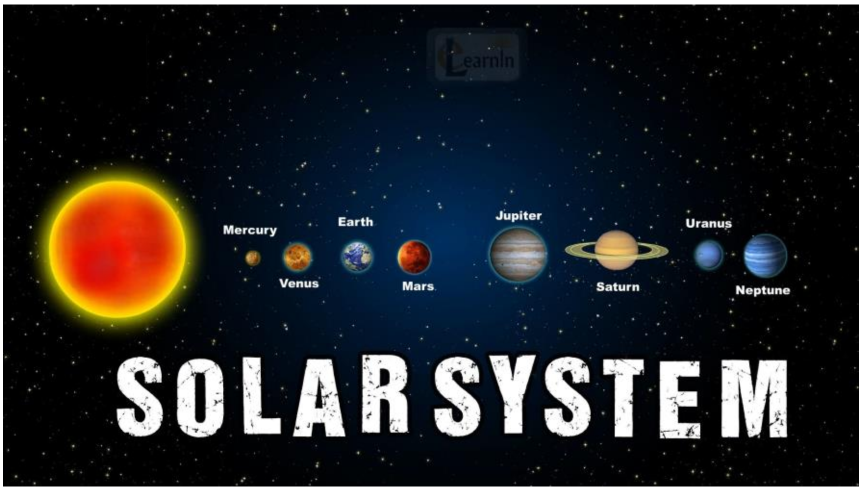
9-A-4-1 p. 9-A.4-1: Prayer flag of Buddhismus

https://en.wikipedia.org/wiki/Prayer_flag
[This page has been composed from Literatur data by P. Brüesch]

10. Atmospheres of Planets and of Exoplanets

405

10.1 The Planets of our Solar System: General Considerations



Atmospheres: Definition and Layers

The Atmosphere is defined as the gaseous layer surrounding celstial bodies such as Stars and Planets. It consists most often on a mixture of different gases which are attracted by the gravitational force of the celestial body. The Density of the Atmosphere is densest at the surface (s. pp 25, 30) and at sufficiently large altitudes it smoothly merges into the interlanatery space. It is possible to distinguish between the following Atmospheres:

- Atmospheres of Earth-like Planets (inner Planets)
- Giant Gas Planets (exzernal Planets)
- Extrasolar Planets (Exoplanets)
- Moons
- Stars.

With increasing altitude, It is usually possible to distinguish between the following layers of the Atmosphere (s. Chapter 2):

a) Troposphere (innermost layer)
b) Stratosphere
c) Mesosphere
d) Thermosphere
e) Exosphere (outermost layer)

This segmentation is only a rohgh classification; and not each of these layers is present in all the different Atmospheres.

Atmospheres of Inner Planets

- Mercury does not have an Atmosphere in the traditional sense, but rather an Exosphere which is comparable with the Exosphere of the Earth. The high concentrations of Hydrogen and Helium originate probably from the solar wind.
- The Atmosphere of Venus consists mainly on CO_2, but appart from that, it is similar to that of the Earth.
- The Earth's Atmosphere consists on a mixture of Oxygen (O_2) and Nitrogen (N_2) (see Chapter 2). Our Atmosphere is able to bear heavy elements as Argon (Ar); light elements such as hydrogen (H_2) and Helium (He) have been lost during its development.
- As Venus, the Planet Mars has a CO_2- Atmosphere. The largest part of its Atmosphere has probably been strippt off by the solar wind and disappeared into space (pp 353 – 356).

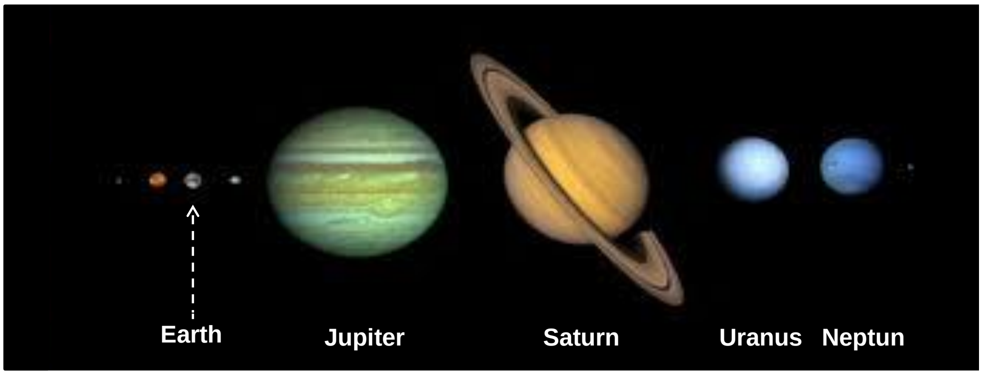
The inner Solar system

Atmospheres of Moons

- The Earth's Moon has no Atmosphere in the commom sense, but only an Exosphere. It consists to about equal parts on Helium, Neon, Hydrogen and Argon. The origine of this Exosphere is due to captured particles from the Solar wind (s. Ref. R.10.1.4).
- Saturn's Moon Titan has a dense Atmosphere, consisting to a large part of Nitrogen.
- The Jupiter Moons Europe and Ganymede possess a thin Oxygen- Atmosphere which is attracted by gravitational forces but they are not of biological origin.
- The Jupiter Moon Callisto has a thin Carbon dioxide (CO_2) Atmosphere.
- The Jupiter Moon Io has a thin Sulfur Dioxide (SO_2) - Atmosphere
- The Neptun Moon Triton (a single Planet – Moon system) has a thin Nitrogen-Methan-Atmosphere.
- The Saturne Moon Rhea consists of a thin Atmosphere of Carbon.
- The other satellites (Moons) of the Solar system as well as the Moon of the Earth and the Planet Mercury (s. p. 408) have only an Exosphere.

Atmospheres of the outer Solar systems: Gas Giants

- The compositions of the Gas Giants (outer Planets) such as Jupiter, Saturn, Uranus and Neptune are essentially based of Hydrogen and Helium. Their cores are, however, cold and similar to the Stars, there is no radiation pressure.
- The interiour of Jupiter und Saturn consist of liquid Hydrogen and Helium with a core of metallic Hydrogen.
- Uranus und Neptune have, however, a mantel and core of Water and Ice or of Ice, Ammonia, Methane and Rocks.



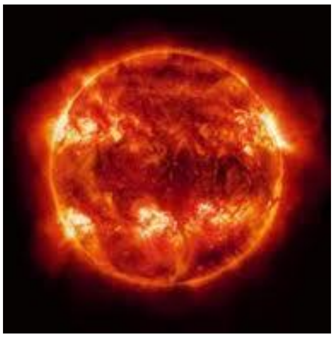
← The outer Solar System →

410

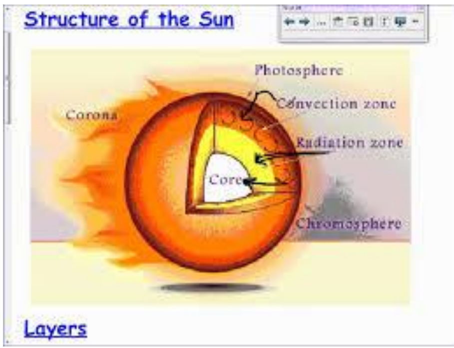
The Sun: Structure and Atmosphere

In the «Atmosphere» of the outmost shell of the Sunn, three different layers can be distinguished, namely the «Photosphere», the «Chromosphere» and the «Corona». In leaving the Sun, the Atmosphere becomes thin and thinner, until it merges the interplanetary space. The mass of the Sun is 1.988 x 10^{30} kg and its mean radius is 696'000 km.

- The Photosphere is the surface of the Sun which is visible to our eye. It consists of about 70% H_2 and 28% He. Thickness about 200 km, temperature about 6'000 ^{0}C.
- Above the Photosphere there is the Chromosphere. Thickness ≈ 10'000 km, Temperature up to 10'000 ^{0}C !!
- Outermost layer: «Corona»; temperature up to 2 Million ^{0}C !! After several millions of kilometers it approaches the interplanetary space.



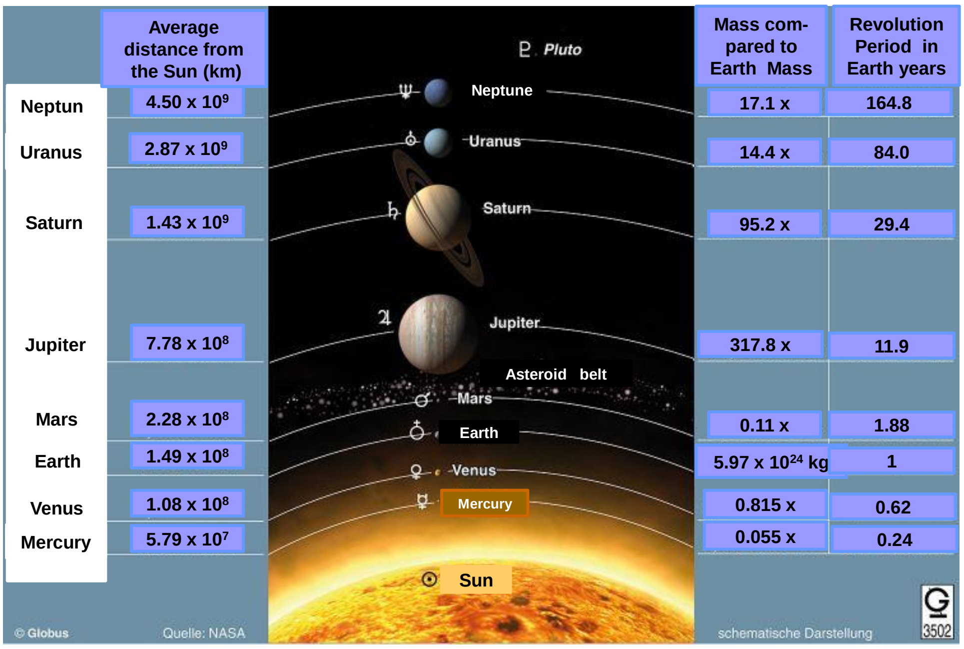
Solar Tornadoes at the Surface of



Structure of the Sun

411

The Solar System: Distances, Masses and Revolution Periods of Planets



412

Properties of Planets

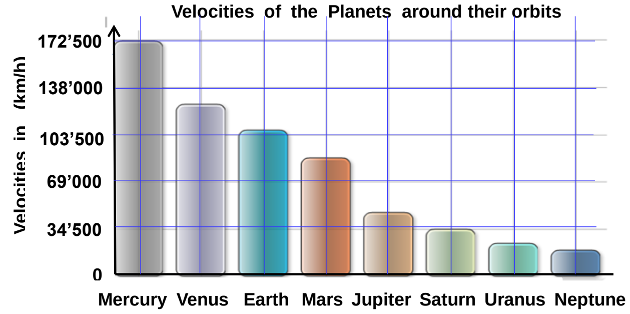
Planet	Diameter (km)	Mean velocity. (km/h)	Aggregation state	Density (g/cm^3)	Day-duration (in Earth days)	Min. Temp. (^{0}C)	Max. Temp. (^{0}C)	Neigung der Rotationsachse (deg)	Magnetic field (x Earth-field at) (Equator)
Mercury	4'879	172'332	s	5.427	58.65	- 173	427	~ 0	~ 0.01
Venus	12'103	126'072	s	5.243	243.02	+ 437	497	177.36	~ 0
Earth	12'734	107'208	s	5.515	1.00	- 89	58	23.45	1.0
Mars	6'772	86'868	s	3.933	1.026	- 133	27	25.19	~ 0.001
Jupiter	138'346	47'052	g / l / s	1.326	0.413	- 108	- 108	3.13	~ 13
Saturn	114'632	34'884	g / l / s	0.687	0.449	- 139	- 139	26.73	~ 1.3
Uranus	50'532	24'516	g / l / s	1.270	0.718	- 197	- 197	97.77	~ 0.74
Neptune	49'105	19'548	g / l / s	1.638	0.665	- 201	- 201	28.32	~ 0.42

g: gaseous / l: liquid / s: solid

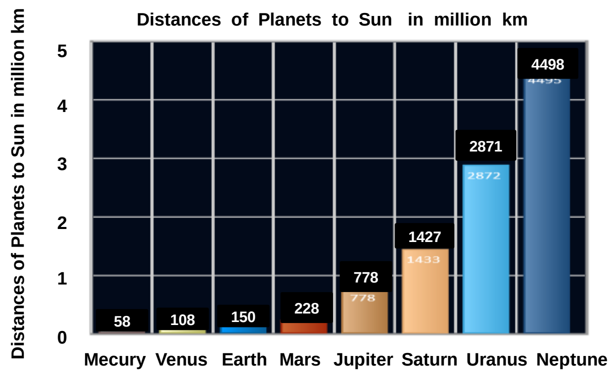
Earth's magnetic field: 31 μT = 0.31 Gauss at Equator, (1T = 1 Tesla = 10^4 Gauss; the quoted relative fields are very approximative)

413

Velocities and Distances of Planets around and to the Sun



The Graph shows the velocities of the Planets orbiting around the Sun. We have quotet average values because the Planets are not moving with constant velocicities: since they are moving on elliptical orbits, they are moving somewhat faster in Perihelion (closer to the Sun) and somewhat more slowly in Aphelion (farther from the Sun). The fundamental physical laws have been derived by J. Kepler (s. Referenzce R.10.1.2 b)).



Together with the below Figure, it is seen that the average velocities of the Planets are the slower, the further away they are orbiting around the Sun: The innermost Planet Mercury is the fastest one; it is moving with the gigantic speed of 172'000 km/h. On the other hand, the most distant Planet Neptune moves much more slowly: its velocicity is only about 20'000 km/h. It is, however still about 100 times faster than a car moving with 200 km/h !].

414

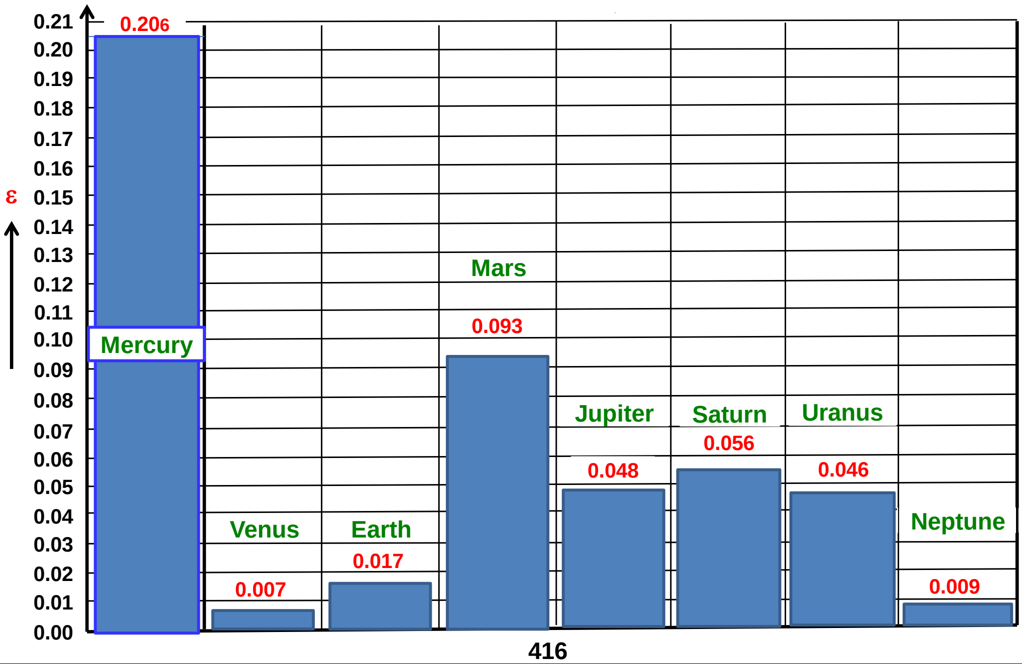
Most important Gases in the Atmospheres of our Planets

	Amount Component 1	Amount Component 2	Amount Component 3	Amount Compomemt 4
Mercury	42.00 % Oxygen	29.00 % Sodium	22.00 % Hydrogen	6.00 % Helium
Venus	96.50 % Carbon dioxide	3.50 % Nitrogen	0.02 % Sulfur dioxide	———
Earth	78.08 % Nitrogen	20.95 % Oxygen	0.93 % Argon	0.04 % Carbon dioxide
Mars	95.32 % Carbon dioxide	2.70 % Nitrogen	1.60 % Argon	0.13 % Oxygen
Jupiter	89.80 % Hydrogen	10.20 % Helium	0.30 % Methane	0.03 % Ammonia
Saturn	96.30 % Hydrogen	3.25 % Helium	0.45 % Methane	0.03 % Ammonia
Uranus	82.50 % Hydrogen	15.20 % Helium	2.30 % Methane	———
Neptune	80.00 % Hydrogen	18.00 % Helium	1.00 % Methane	———

415

Numerical excentricities of Orbits of Planets around the Sun

The numerical excentricity ε of the elliptic orbits of Planets with semi-axis a and b is defined by $\varepsilon = (1/a) * (a^2 - b^2)^{½}$; if a = b → circular orbit with $\varepsilon = 0$



10.2 Specific Properties and Atmospheres of the Planets of our Solar System

417

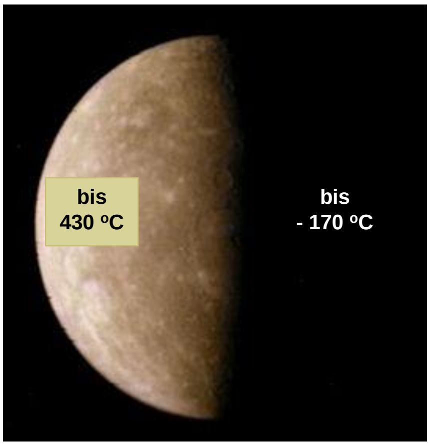
10.2.1 The Planet Mercury

Messanger of the Gods -
or God of Merchants,
of Travelers and of Poets,
Son of Zeus

418

Mercury: General Properties

With a Planet diameter being close to 4’880 km and with an averagege orbital diameter of 58 million km from the Sun, Mercury is the Planet closest to the Sun and for this reason, it is also the fastest moving of the Solar System. His maximum daily temperature is + 430 ^{0}C and the night temperature is as low as - 170 ^{0}C; it has the largest temperature fluctuations of all Planets (s. p 413 and pictue below). Due to ist size and chemical composition, it belongs to the Earth-like (or terrestrial) Planets. Due to its peihelion, it is difficult observable from the Earth. Equator diameter: 4’878 km; mass: 3.3×10^{23} kg; average density: 5.420 g/cm^3; acceleration due to gravitation: 3.70 m/s^2; rotation period: 87.96 d (0.241 y); atmospheric pressure at surface: ~ 0 bar; excentricity: 0.206.

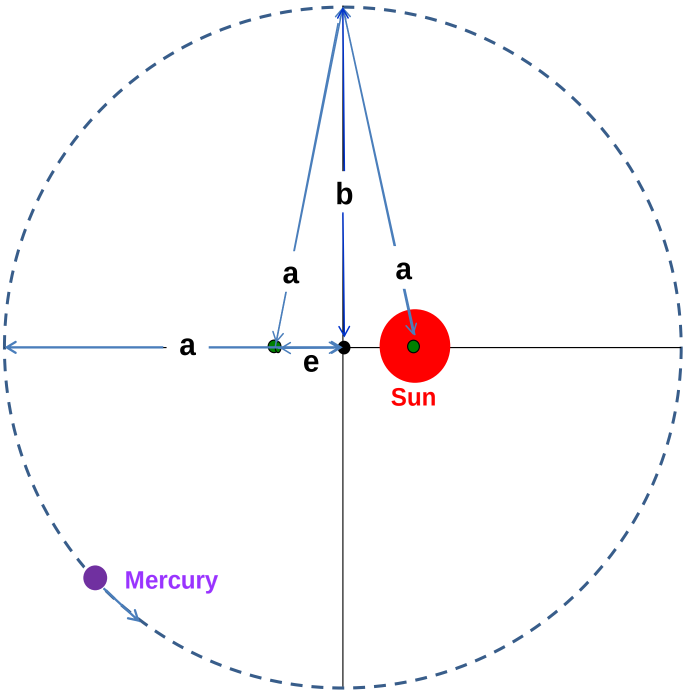


Mercury in natural colours

Because of the difficult elusiveness of the orbit at the Solar neighborhood and the associated danger due to the intense Solar wind, hitherto only two Spacecrafts, Mariner 10 (1970) and Messenger (2008), have visited and studied the Planet.
The lunar-like surface, the surface interspersed with craters consisting of rough and porous rocks reflects the Sun light only weakly. The average spherical Albedo is 0.06, i.e. the surface is scattering at the average only 6% of the insitense radiation.
The density of Mercury is only slightly smaller than that of the Earth. It is assumed that about 70% must be located in an iron core which amounts to about 75% of the radius; at the outer shell, there are about 30% silicates..
Because of the high temperature in the direction of the Sun and the small mass, Mercury essentially can not hold an Atmosphere. (s.p. 421).

419

Elliptic Orbit (to scale) ot Mercury around the Sun



Mercury describes an elliptic orbit around the Sun; the Sun is located at one of the foci of the ellipse having the semi-axis a and b and the excen-tricity e. ε is the numerical excentricity.

$a = 57.908 \times 10^6$ km
$b = 56.671 \times 10^6$ km
$e = (a^2 - b^2)^{1/2} = 11.9 \times 10^6$ km
$\varepsilon = e/a = 0.205624$

Smallest distance from the Sun $= a - e = 46.00 \times 10^6$ km

Largest distance from the Sun $= a + e = 69.82 \times 10^6$ km

Orbit time around Sun (siderial period):
0.241 Earth-ys = 87.969 days

Mean velocity:
172’332 km/h

420

The Atmosphere of Mercury - 1

So far it was a riddle: How is it possible that the low-mass intermost and hottest Planet can keep a permant Atmosphere, even though this Atmosphere is extremely thin? On the day side, the surface temperature of Mercury is over 400°C (s. p. 419). Due to the strong radiation of the Sun, the components of its Atmosphere would evaporate in a short time by photoevaporation, i.e. by ionization and acceleration of the particles with escape velocity into the free space. Since Mercury can, however, maintain his residual Atmosphere over long periods of time, there must exist a constant replenishment of particles (s. p. 422).

It must, however, be kept in mind that in the case of Mercury, it is strongly exagerated to speek from a real Atmosphere. At the surface, the atmospheric pressure is only one quadrillionth of 1 bar (p_{Merkur} = 10^{-15} bar = 10^{-10} Pa). Under terrestrial conditions , this would correspond to a high vacuum.

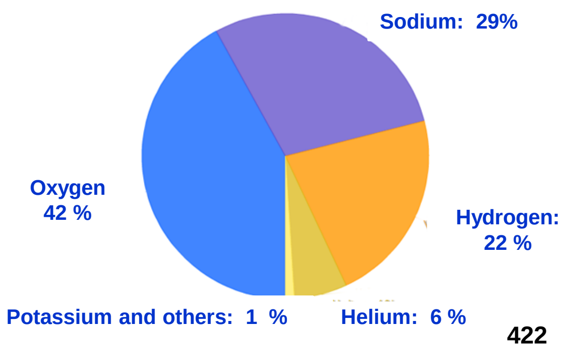
The absence of an Atmosphere is also responsible for the extreme temperature fluctuations of the Planet. On other Planets, the Atmosphere acts as a protection shield which acts as an efficient heat contribution. At Mercury, however, the extremely thin atmospheric layer does not shield the incoming Sun and does not stabalize the temperature. Since the distance between Mercury and the Sun is so small, the day side of the Planet is exposed to the Sun without protection, while the night side is extremely cold. The absence of an Atmosphere on Mercury does, however, not mean that Mercury is the hottest Planet of our solar system. This honor must rather be attributed to the Planet Venus because of its runaway global warming (s. Section 10.2.2.0).

The Atmosphere of Mercury - 2

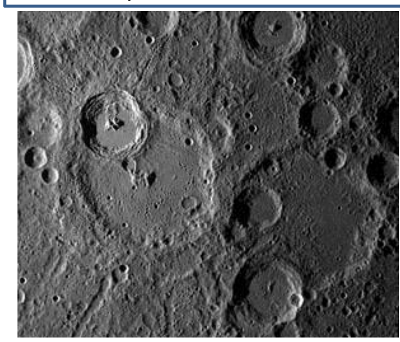
The extremely small atmospheric pressure of Mercury is partially due to the fact that its magnetic field is incomplete (patchy). Particles of the solar wind can than penetrate through these gaps and reach the surface of the Planet, thereby «refrashing» its surface. In addition, by degasing of the surface, an additional contribution to the Atmosphere is generated.

Nethertheless, the Planet Mercury does not have an Atmosphere in the traditional sense, because its gas pressure is smaller than a laboratory achievable vacuum; its atmosphere is similarar to that of our Moon. The «atmospheric» contributions are Hydrogen (H_2, 22% by volume), and Helium (He, 6 %) which most probably are due to the solar wind. On the other hand, oxygen (O_2, 42%), Sodium (Na, 29%) and Potassium (K, 0.5%) are probably released from the material of the surface of the Planet.

Main components of Mecury's Atmosphere



Surface, covered with craters



10.2.2 The Planet Venus

Goddhes of love and beauty

Planet Venus - General

With an average Sun distanc of 108 million km, Venus is the second innermost Planet and with a diameter of 12'100 km it is the the third-smallest Planet of the Solar system. It belongs to the four Earth-like Planets which are also referred to as terrestrial or rocky Planets.
On his orbit, Venus is the Planet whith approaches the Earth to a minimal distance of only 38 million km. Its size is essentially the same as that of the Earth (right-hand picture), but differs from the Earth mailnly by ist Geology and with regard to its Atmosphere.
After the Moon, it is the brightest natural object at he twilight sky or at the natural starry sky. Venus is therfore also referred to a «Morning Star of «Evening Star».

Properties of its Orbit:

Semi-major axis a = 108.209×10^6 km; numerical excentricity: $\varepsilon = e/a = 0.00679$;
→ Excentricity $e = \varepsilon a = 0.7347 \times 10^6$ km; Small semiaxis b = 108.206×10^6 km;
→ In a verry good approximation, the orbit around the Sun is a circle.
Orbit time around Sun = 224.701 days; average orbit velocity = 35.02 km/s.

Venus in natural colors

Comparision of Venus (left) with Earthh

Venus: More Data and Properties

Properties of the Planet:

- Mean radius : R_{Venus} = 6051.8 km = 0.949 Earth-radii;
- Mean Earth-Radius R_{Earth} = 6371 km;

- Mean Mass: $M_{Venus} = 4.869 \times 10^{24}$ kg;
- Mean Mass of the Earth: $M_{Earth} = 5.973 \times 10^{24}$ kg

---

- Mean Density: ρ_{Venus} = 5.243 g/cm^3;
- Mean Dansity of the Earth: ρ_{Earth} = 5.515 g/cm^3;

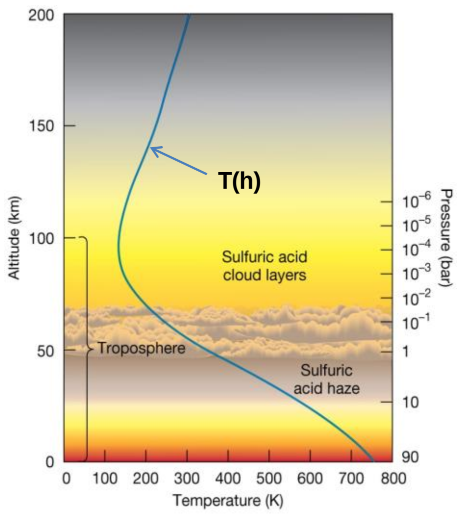
- Surface: $F_{Venus} = 4.60 \times 10^8$ km^2;
- Surface of the Earth: $F_{Earth} = 5.1995 \times 10^8$ km^2;

- Graviatiomal acceleration: 8.87 m/s^2 ;
- Gravitational acceleration of the Earth: 9.81 m/s^2;

425

Layers of the Atmosphere of Venus

The Atmosphere of Venus is much denser and hotter than that of the Earth . The Temperature at the surface is 467 ^{0}C, while there, the pressure is 93 bar! The Atmosphere of Venus contains opaque clouds of sulfuric acid (H_2SO_4); this Atmosphere makes observations from the Earth and from spaceships impossible. Information regarding the Topography could only be obtained by Radar Image Techniques. The blue curve in the picture below shows the temperature T(h) as a function of the altitude.



Temperature and pressure as a function of altitude

The most important atmospheric gases are Carbondioxide (CO_2) and Nitrogen (N_2).
For other trace gases see p. 427.
The Atmosphere is in a state of violent circulations and Super-Curls.
Similar to the Atmosphere of the Earth (s. pp 7 und 9, Chapter 1) it is possible to subdivide the Atmosphere of the Venus into several layers. The Troposphere starts at the surface of the Planet and extends up to 100 km. In the vicinity of the surface, the winds are weak, but at the upper end of the Troposphere, the temperatures and pressures are reaching values similar to that of the Earth and the velocities of the winds are up to 100 m/s! The pressure of CO_2 at the surface is so high, that there is no gas but rather a supercritical liquid.
About 99% of the mass of the Atmosphere of Venus is contained in the Troposphere; 90% of the Atmosphere is contained in a layer of 28 km above its surface..

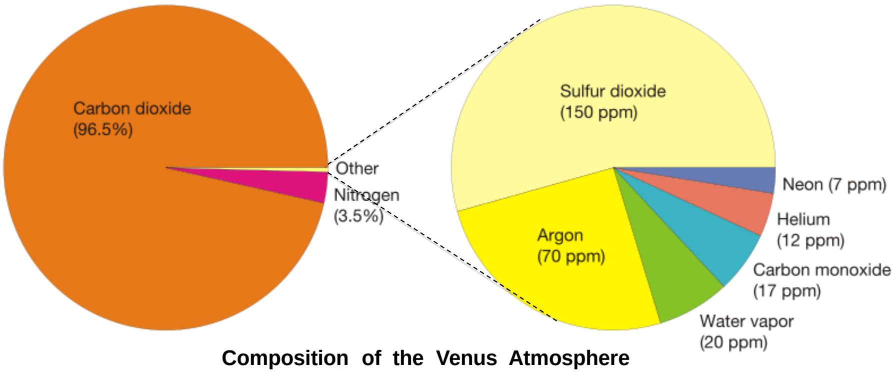
426

Composition of the Atmosphere of Venus

The Atmosphere of Venus consists manly on Carbondioxide, CO_2 (96,5%) and in addition it contains a much smaller amout of Nitrogen, N_2 (3.5%) (s. left-hand Figure). There exist also number of trace gases, namely Sulfurdioxide (H_2SO_4): 150 ppm), Argon (Ar: 70 ppm), Water (H_2O: 20 pp), Carbonmonoxide (CO: 17 ppm); Helium (He: 12 ppm), and Neon (Ne: 7 ppm) (s. right-hand Figure).

Because of the large total amount of mass, it contains about five times as much Nitroge as in the Earth's Atmosphere and as a consequence, its pressure is about 93 bar at the middle floor level. This corresponds to a pressure at a depth of 910 m sea level on Earth. At the surface, the density is about 50 times larger than at the Earth.

Viewed from outside, the Atmosphere of Venus is compleately opaque. This is due to a permantly closet cloud cover. The underside of this cloud cover is located at an altitude of about 50 km and its thickness is about 20 km. Its main constituent consists of about 75% droplets of sulfuric acide. In addition, there are also chlorine- and phosphourus aerosols.



Composition of the Venus Atmosphere

427

10.2.3 The Planete Earth

Gaia: Goddes of the Earth - personalized Earth in Greek mythology

428

The Earth - General

The Earth is the densest, the fith-largest and the third closest Planet to the Sun. Its age is about 4.6 billion years. The Earth is the home of all living creatures in our Solar system. Because of its prevailing chemical composition, the Earth is also referred to as a terrestrial Planet; this notion is also used for the Planets Mercury, Venus and Mars.

The Earth observed from Apollo 17 at Decenber 7, 1972.

Main Orbital Properties :

- Semi-major axis: 149.6 Mio. km
- Numerical excentricity ε : 0.0167
- Orbital speed: 29.78 km/s

Physical Properties of Planet:

- Equatorial diameter: 12’756 km
- Polar diameter: 12’713 km
- Mass: 5.972×10^{24} kg
- Average density: 5.515 g/cm^3
- Gravitational acceleration: 9.80665 m/s^2
- Escape velocity: 11.186 km/s
- Rotational period: 23 h 56 min 4.1 s
- Inclination of rotational axis: 23.44^0
- Geometrical Albedo 0.367

Properties of the Atmosphere:

- Pressure (at Sea level): 1.014 bar
- Minimum Temperature: - 89 ^{0}C
- Average Temperature: 15 ^{0}C
- Maximum Temperature: 58 ^{0}C

Composition of Air (in % by volume):

- Nitrogen (N_2): 78.084%; Oxygen (O_2): 20.946%;
- Argon (Ar): 0.934%; CO_2: ≈ 0.04 %;

429

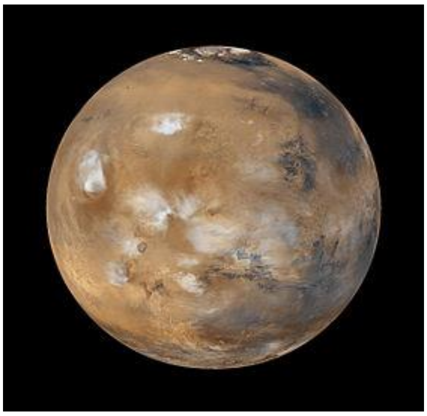
10.2.4 The Planet Mars

God of War

430

Mars: General Data and Properties

Viewed from the Sun, Mars is the fourth Planet in our Solar system and it is the outer neighbour of the Earth (s. p. 408). It belongs to the four terrestrial Panets of our Solar system.



Mars in natural colours; the Data for the picture have been obtained on 1999 from the «Mars Global Surveyer».

Orbital Properties:

- Semi-major axis: 228 Mio. km
- Excentricity: 0.0935
- Average orbita velocity. 24.13 km/s

Physical Properties:

- Average diameter: 6’772 km
- Mass : 6.419×10^{23} k
- Average density: $3.933\ g/cm^3$
- Gravitational accelerarion: $3.69\ m/s^2$

Properties of the Atmosphere:

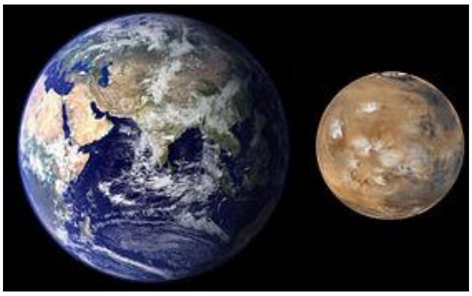
- Pressure: 6×10^{-3} bar
- Minimal temperature: - 133 ^0C
  Average temperature: - 55 ^0C
  maximum temperature: + 27 ^0C

Gases of the Atmosphere:

- Carbon dioide (CO_2): 95.97 %
- Nitrogen (N_2): 1.89 %
- Argon (Ar) 1.93 %
- Oxygen (O_2): 0.146 %
- Carbon monoxide (CO): 0.0557 %

431

Comparision: Earth - Mars



	Mars	Earth
Diameter (km)	6'772	12'7345
Mass (kg)	6.419 x 10^{23}	59.74 x 10^{23}
Atmospheric pressure at surface (bar)	6 x 10^{-3}	1.014

Surfaces of South- and Northern Hemispheres of Mars

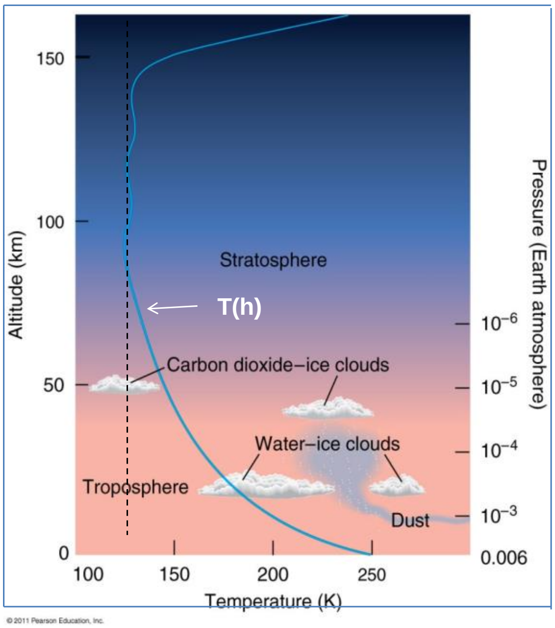
The reddish colour of the Planet is due to iron oxide dust which has spread over the surface and into the Atmosphere.

The two Hemispheres of Mars are strongly different:

- The Southern Hemisphere is a vast upland which is on the average 2 – 3 km over the global level and contains extended shield volcanoes. The large number of impact craters originate from the very high age of about 4 billion years.
- This is in contrast to the Northern hemisphere representing a lowland plane lying about 3 – 5 km below zero level. It has lost its original structure by a yet unkown geological process (eventually by collisions?).

432

Temperature and Pressure of the Atmosphere as a function of altitude



Temperature and pressure of the Atmosphere of Mars as a function of altitude (Temperature in K, altidude in km and pressure in atm).

As Venus, the Atmosphere of Mars consists mainly on CO_2 (pp 426, 427, 434).

The Atmosphere of Mars is very thin, about 100 times less dense as that of the Earth. There do not eixst clouds of Water vapour but only a few clouds consisting of Water-ice.

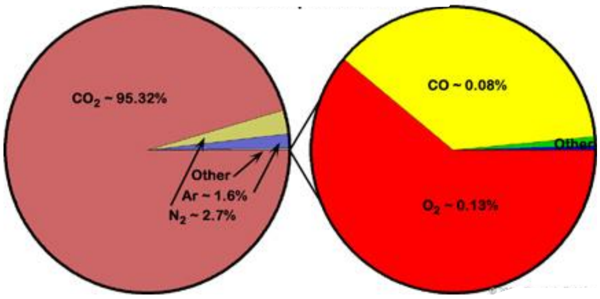
Clouds which are observed in an altitude of 50 km consist primarily on CO_2 – Ice and dust..

Both, temperature and pressure at the surface of Mars are low. At the immediate surface , the temperature is about 250 K (– 23 ^{0}C) and in altitudes between 80 and 120 km it is about. 123 K (- 150 ^{0}C).

The average atmospheric pressure at the surface of Mars is only about 6.36 hPa = 6.36 mbar. In comparision to the average pressure of 1013 hPa = 1.013 bar = 1 atm this amounts only to 0.63% of the average pressure at sea level on the Earth and corresponds to the air pressure at an altitude of 35 km. Most probably, the Atmosphere of Mars has been gradually removed by the Solar wind and entraned into space.

433

Chemical composition of the Mars Atmosphere



Composition of the Atmosphere on Mars

Gas	Formula	Distribution (Percent)
Carbon Dioxide	CO_2	95.4
Nitrogen	N_2	2.7
Argon (40)	Ar-40	1.6
Oxygen	O_2	0.13
Carbon Monoxide	CO	0.07
Water	H_2O	0.03*
Argon (36)	Ar-36	0.0005
Neon	Ne	0.0003
Krypton	Kr	0.00003
Ozone	O_3	0.00001*
Xenon	Xe	0.000008

*Abundance varies with season and location

434

10.2.5 The Planet Jupiter

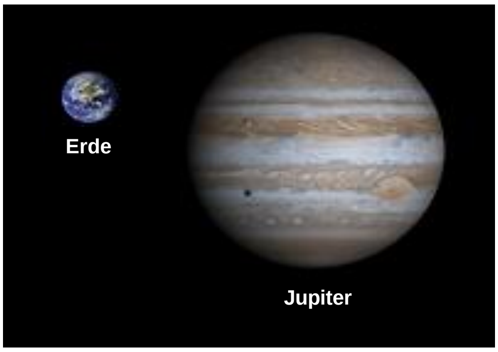
King of the Gods - Master of the Olympus

435

Jupiter: General Data and Properties

With its equatorial diameter of about 143'000 km, Jupiter is the largest Planet of our Solar system. Its distance from the Sun is about 778 million km and it is the fifth Planet of our Solar system. Because of its chemical composition it belongs to the so-called Gas panets («Gas giants») and therefore it has no visible outer surface..

The other Gas giants are therefore also called Jovian Planets or Jupiter-similar Planets. In our Solar system, they belong to the group of the four «Outer Planets».



Comparision of Jupiter with the Earth

Properties of the Orbit:

- Semi-major axis: 778.5 million km
- Excentricity: 0.0484
- Average orbital velocity: 13.07 km/s
- Orbital period: 11.86 years

Physical properties:

- Equatorial diameter: 142'984 km
- Polar diameterr: 133'708 km
- Mass: 1.899×10^{27} kg
- Average density: 1.326 g/cm^3

Main components:

(Composition of the outer layers)

- Hydrogen (H_2): 89.8 %
- Helium (He): 10.2 %
- Methane (CH_4): 0.3 %
- Ammonia (NH_3) 0.026 %

Further Properties:

- Gravitational acceleration: 24.79 m/s^2
- Rotational period: 9 h 55 Min 30 s
- Albedo: 0.52
- Temperature: 105 K (- 108 ^{0}C)

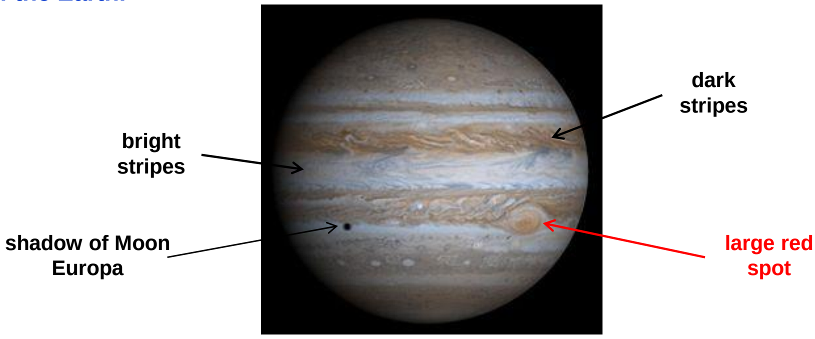
Rings of Jupiter:

s. Ref. R.10.2.5.1

436

The Atmosphere of Jupiter - 1

Jupiter has the largest planetary Atmosphere in our Solar system; its altitude is about 5'000 km. Since Jupiter has no solid surface, the base of the Atmosphere is defined at the point where its atmospheric pressure is 10 bar, i.e. at the altitude where the pressure is 10 times larger than the atmospheric pressure at the surface of the Earth.



A composite image of Jupiter obtained from the Cassini spacecraft

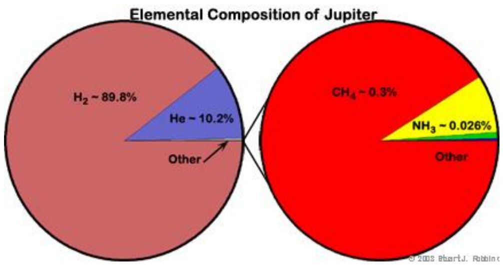
The dark point at the left is the shadow of the Moon Europe. The large red spot something at the bottom right is a permanently sustained storm. At the surface, Jupiter is covered by huge cloud structures which form briht and dark regions parallel to the Equator. The bright regions are areas which are causd by gases rising from the interior of the Planet; the dark regions are marking sinking matter.

437

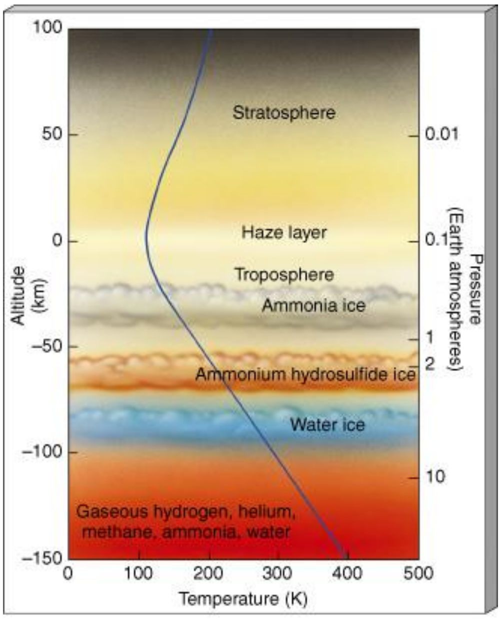
Atmosphere of Jupiter - 2

The Atmosphere of Jupiter is very dense and cold and therefore the lower atmospheric layers are liquid rather than gaseous. In the region in which atmospheric behaviour is observed, the pressure is 5 to 10 times larger than the atmospheric pressure at the surface of the Earth (1 bar).

The Atmosphere of Jupiter consists of 89.8% molecular hydrogen (H_2) and 10.2% Helium (He). In addition, there exist some other compounds: crystallites and clouds of ammonia (NH_3), of water (H_2O), and of ammonium hydrosulfide (NH_4SH) (see left-hand Figure).



Chemical composition of Jupiter



The layers of the Jupiter – Atmosphere (Pressure in bar)

438

10.2.6 The Planet Saturn

One of the Titans - God of agriculture

439

The Planet Saturn - General

Saturn is the sixth Planet of the Solar system (s. p. 412) and with its Equarorial diameter of 120'500 km (9.5 times the diameter of the Earth) it is the second largest Planet after Jupiter. Its mass is 95 times larger than the Eath mass, but its mass is only 30% of that of Jupiter.

The investigated upper layers consist of 96% of hydrogen. With its small density of only about 0.69 g/cm^3, it has the smallest density of all Planets of the Solar system.

From the other Planets, Saturn differs by its distinct rings which consist to a large extent of rocks.

Color enhanced image of Saturn

Properties of the orbit

- Semi-major axis: 1'433.5 Mio. km
- Excentricity: 0.05648
- Average orbital velocity: 9.69 km/s

Physical properties

- Equatorial diameter : 120'536 km
- Polar diameter: 108'728 km
- Mass: 5.685 x 10^{26} kg
- Average density: 0.687 g/cm^3

Main components

(Composition of the upper layer)

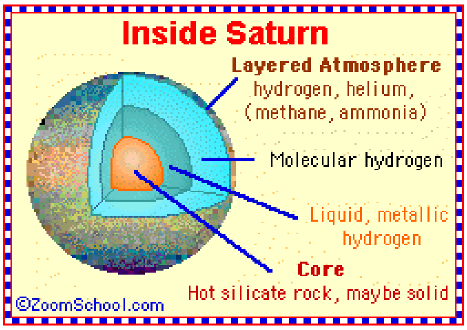
- Hydrogen (H_2): 96.30 %
- Helium (He): 3.25 %
- Methane (CH_4): 0.45 %
- Ammonia (NH_3): 0.026 %

Further properties

- Gravitational acceleration: 10.44 m/s^2
- Inclination of rotational axis : 26.73^0
- Rotational period: 10 h 47 min
- Geometric Albedo: 0.47
- Surface temperature : - 139 ^{0}C

440

Structure and chemical composition of Saturn

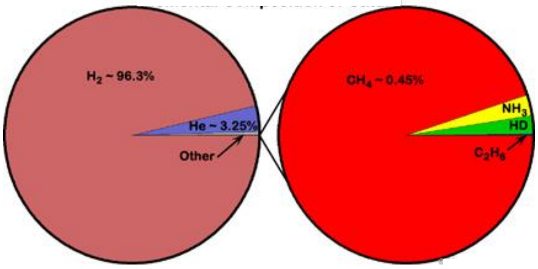


Structure inside of Saturn

Structure:

Saturn is a gas Planet with a rocky core from, silicates followed by a liquid Hydrogen layer and a subsequent layer of molecular Hydrogen.

The Atmosphere has a layer structure consisting of Hydrogen (H_2), Helium (He), Methane (CH_4), and Ammonia (NH_3).



Chemical composition of Saturn

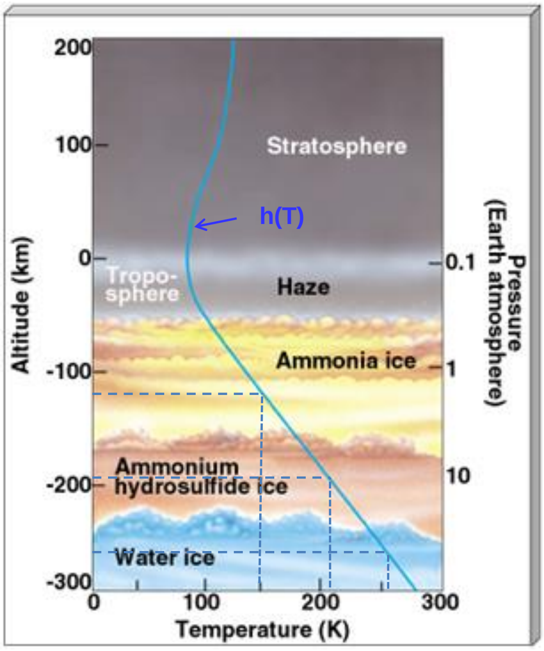
Chemical composition:

According to current knowledge, Saturn essentially consists of a single large «Atmosphere» with the following composition:

- Hydrogen (H_2): 96.30 %
- Helium (He): 3.25 %
- Methane (CH_4): 0.45 %
- Ammonia (NH_3): 0.0125 %
- Hydrogen Deuterium (HD) 0.011 %
- Ethane (C_2H_6): 0.0007 %

441

Atmosphere of Saturn

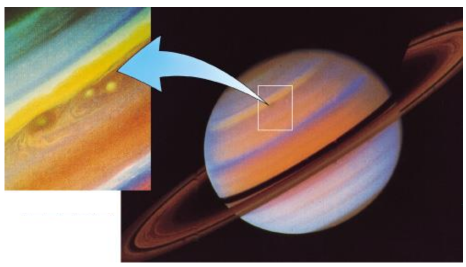


Vertical structure of Saturn – Atmosphere.
The blue curve shows h(T), the altitude h as a function of temperature T.

The composition of the Atmosphere of Saturn is similar to that of Jupiter (s. p. 438). Its average temperature is, however, somewhat smaller. This is due to its larger distance from the Sun. In addition, its total thickness (~ 200 km) is larger than that of Jupiter (~ 80 km).

The Troposphere contains three distinct cloud layers indicated by the three pairs of horizontal and vertical dashed lines: The mean (h,T)- values are: at about (- 270 km; 260 K (-13^{0}C)) it consists of Water-ice (H_2O), at about (-190 atm; 210 K (-63^{0}C)) the main composition is Ammoniumhydrosulfide-ice, ($(NH_4)SH$, and at about (-115 atm; 150 K (-123^{0}C)), Ammonia-ice (NH_3) is present.

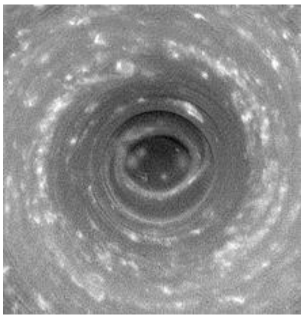
Above the clouds, there is a Haze. At still higher altitudes the Stratosphere is present.



The cloud structure of Saturn

442

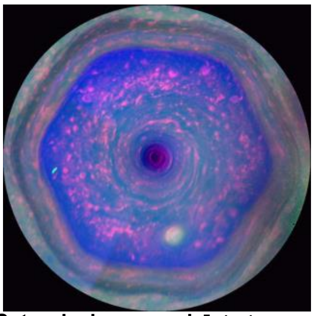
Saturn : South Pol Storm and hexagonal Jet stream at the North Pol



Saturn's South Pol

The spacecraft Cassini has made a discovery on Saturn which has never been observed on the other Planets: a Hurrican-like storm at the South Pol of the Ringplanet with a clearly marked eye which is surrounded by towering clouds. The storm system has a diameter of about 8'000 km, i.e. of two third of the diameter of the Earth.

The storm rotates clockwise with a speed of 550 km per hour around the South Pol of Saturn. Cassini also discovered the shadow of towering clouds which are rotating around the eye of Saturn.
In contrast to the Hurrican moving on Earth which are formed over the Oceans, the discovered whirlwind does not move away from the Pole of Saturn.



Saturn's hexagonal Jet stream, «the Hexagon» at the North Pol

The North Pole region of Saturn shows one of the strangest phenomena which has been discoverd up to now – a stable, hexagonal cloud pattern.

The formation of this pattern is still unclear. Recen laboratory experiments could help to solve the riddle.

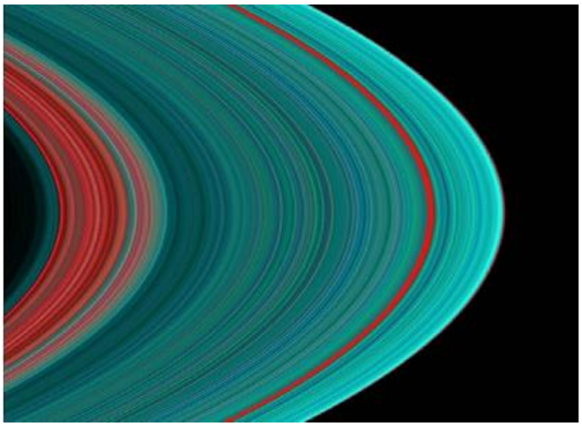
The Hexagon at the North Pole has already been discovered by Voyager and the spacecraft Cassini confirmed it at 2006: The observation showed in fact a rotating Hexagon with a side length of 13'800 km having a circular period of 10 h and 40 seconds.

Scientists from the University of Oxford have conducted experiments and were able to simulate the phenomenon (s. Ref. R.10.1.6.5).

443

The Rings of Saturn

The rings of Saturn are forming a ring system which is surrounding the Planet. These rings are the most prominent feature of the Planet and can be observed already using a telescope with a magnification of 40. The rings consist essentially of Water-Ice but they contain also rocks which are orbiting Saturn. The sizes of the particles varies between dust and several meters. The rings of the system are separated by many larger and smaller gaps. Its maximum diameter is nearly one million kilometers but the thicknesses of the individual rings are only a few 100 meters (according to NASA between 200 and 3'000 meters), and viewed relatively, they are extremely thin.



The large number of rings of Saturn
(Color enhanced (ultraviolet photo) recording of NASA)

[The best view of Saturn's rings indicate there is more Ice towards the outer part of the rings, than in the inner part].

Today it is well known, that more than 100'000 individual rings with different compositions and shades exist which are separated from each other by sharply definde gaps. The innermost ring begins alread 7'000 km above Saturn's surface (radius of Saturn: ~ 60'00 km) and the ring diameter is about 2 times 67'00 km = 134'000 km; the outermost ring is about 420'000 km above the surface and its diameter is as large as 960'000 km.

Concerning the mechanism of the formation of the rings, there is still no consensus. Some features suggest a relatively recent origin. On the other hand, theoretical models suggest, that the rings developed already shortly after the formation of the Solar system..

444

10.2.7 The Planet Uranus

Primordial God of heavan - Father of Cronus
begotten with his mother Gaia,
the prmordial mother.

445

The Planet Uranus - General

The aveage distance of Uranus from the Sun is 2.9 billion km; it is the seventh Planet in the Solar system and has been discovered at 1781 by Wilhelm Herschel.

The diameter of this Planet is more than 51'000 km and is about four times as large as that of the Earth (s. picture below). Its volume is about 65 times larger than the volume of the Earth.

Physically, Uranus is comparable with Neptun and its mass is around 14 times larger than the mass of the Earth. In the solar system, Uranus is the Planet with the fourth largest mass. With regards to its diameter, it is only slightly larger than Neptun: it is the third largest Planet. Uranus is an Ice-giant, because in the inside, methane in the form of Ice is present.

Uranus – Comparision with Earth

Properties of the Orbit

- Large semi-major axis: 2'872.4 million km
- Excentricity: 0.0472
- Average orbital speed: 6.81 km/s

Physical Properties

- Equatorial diameter: 51'118 km
- Polar diameter: 49'946 km
- Mass: 8.683×10^{25} kg
- Average density: 1.27 g/cm^3

Main components

Composition at the upper ice cloud layer:

- Hydrogen: 82.5 %
- Helium: 15.2 %
- Methane (CH_4): 2.3 %

Composition in the interiour:

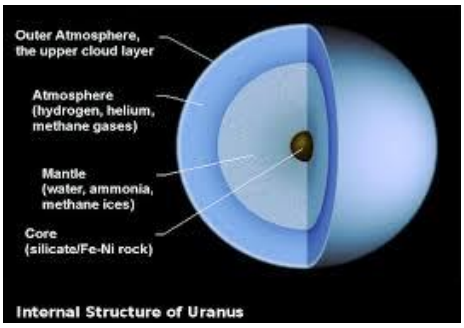
- Water, Ammonia, Methane Ice

Further Properties

- Gravitational acceleration: 8.86 m/s^2
- Inclination of rotational axis: 97.77^0 (!)
- Rotational period: 7 h 14 min 24 s
- Geometrical Albedo: 0.51
- Surface temperature at 1 bar: - 197 ^{0}C

446

Structure and chemical composition of Uranus

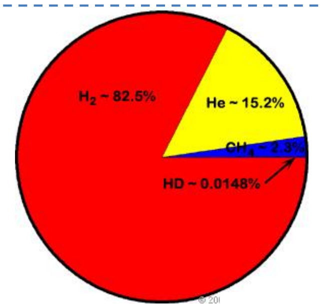


Internal structure of Uranus

Internal Structure

In the «Standard Model» of the structure of Uranus, three layers are distinguished: 1) A rocky core (Silicate-Iron-Nickel) in the center, 2) an «icy» coat in the middle, 3) An outer gaseous envelope of Hydrogen and Helium.

- Core: relatively small with 0.55 Earth masses and a radius of less than 20% of the Uranus-radius. Density about 9 g/cm^3 and a pressure of about 8 million bar or 800 GPa; the tempe-rature is about 5'000 K.
- Mantel: Bulk-mass with about 13.4 Earth-masses.
- Inner and outer Atmosphere



Chemical composition of Uranus

Chemical composition

According to current knowledge, Uranus consists essentially on a single large «Atmosphere» if the central core is ignored.

This Atmosphere has the following compo-sition:

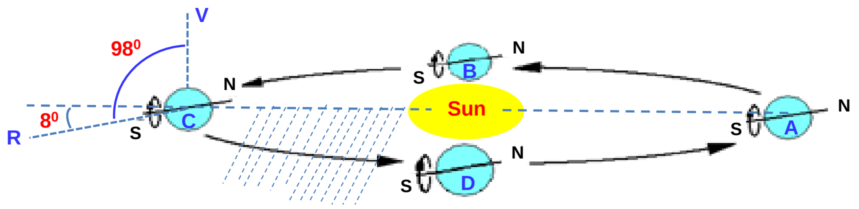
• Hydrogen (H_2):	82.5 %
• Helium He):	15.2 %
• Methane (CH_4):	2.3 %
• Hydrogen-Deuterium (HD):	0.00148 %

447

Axis of rotation and orbit – Extreme seasons

With the exeption of Uranus, the axis of rotation of the Planets are almost perpendicular to their orbital planes (s. Table, p. 413). This is not the case for the Planet Uranus for which the axis of rotation R is very inclined, even overtilted (s. Figure below and Appendix 10-A-3-5): The axis of rotation forms <u>an angle of about 98^0 to the vertical V.</u> With respect to the orbital plane (marked by the oblique dashed blue lines) it forms an angle of 8^0. Uranus is therefore «rolling» around the Sun.

In position A of Uranus, the largest part of the Southern Hemisphere S is in the sunlight, while the Northern Hemisphere lies in the shade. In position C, however, the situation is just reversed: the largest part of the Southern Hemisphere lies in the shade while the Northern Hemisphere is exposed to the Sun. The orbital period from A → B → C → D → A is 84 Earth years and the rotation period around the axis N – S has been determined by the spacecraft Voyager 2: it amounts to 17.2 hours. In the intermediate positions B and D, there are relatively «normal day and night conditions with a day-night time of 17.2 hours.



Orbit, direction of axis of rotation and day-night times of Planet Uranus.

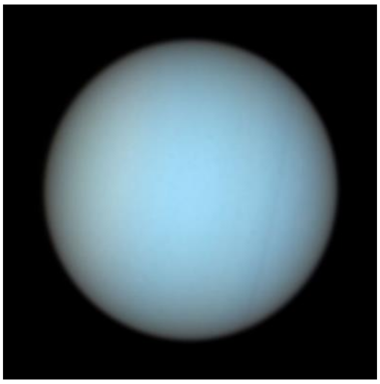
[With its small excentricity of ε = 0.0472 the orbit is nearly a circle. The elongated ellipse shown above arises through the rotation of a circle around the axis A-C toward a plane which is almost perpendicular to the drawing plane].

448

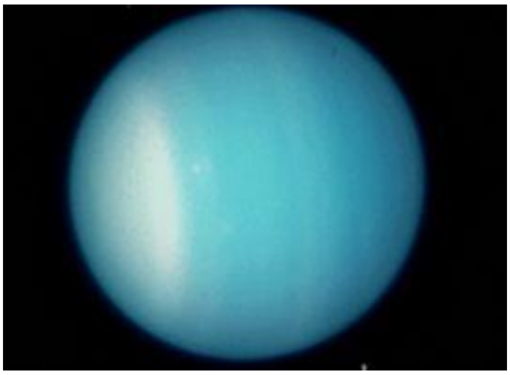
The Atmosphere of Uranus - 1

In the structural model, Uranus is considered as a liquid Planet with a gaseous upper layer or Atmosphere which is not clearly bounded. Since with increasing depth the pressure increases above the critical point, the gas shell transforms from the gaseous state to the liquid state without phase transition. The «surface» is defined as the region, at which the pressure is 1 bar.

The sunlight is partially reflected by the upper cloud level. These cloud layers are located below a layer of Methane gas (CH_4). If the light transverses this CH_4-layer, the reddish part of light is strongly absorbed by the CH_4–gas, whereas the blue part is scattered and reflected. Therefore, Uranus appears in a blue-green color.



Uranus in natural colors;
Photograph from Voyager 2, 1986



Uranus with a southern, dense and bright cloud band.
Courtesy of NASA / ESA / M. Showalter (SET)

449

The Atmosphere of Uranus - 2

The Atmosphere of Uranus can be devided into three layers. The Troposphere is located in a height scale between – 300 and 50 km and the pressures is between 100 to 0.1 bar (the zero point of the height scale, i.e. of the «surface», is fixed at a pressure of 1 bar). The Stratosphere extends from 50 to 4'000 km and the pressures are between 0.1 and 10^{-10} bar. The Thermosphere/Corona extends from 4'000 km to 50'000 km above the surface.

The Troposphere

The Troposphere is the lowermost and densest part of the Atmosphere. Its temperature decreases with increasing altitude. At the lowest part of the Troposphere, , which is located at about 300 km below the 1 bar level, the temperature is about 320 K (~ 47 ^{0}C). Up to the top of the Troposphere, at an altitude of about 50 km, the temperature drops to about 53 K (- 220 ^{0}C). The Troposphere contains almost the whole mass of the Atmosphere and is also responsible for the planetary thermal radiation (radiation in the Infrared region of the spectrum).

The clouds consits probably of frozen particles of methane (CH_4), which went up from deep levels as hot gases and condensed in the upper layers. It is assumed that the lower clouds consist of water, while the upper clouds consist of methane. The wind velocities are up to 200 m/s or about 700 km/h (!). At 1 bar, the temperature is about 76 K (- 197 ^{0}C), at 0.1 bar it is about 53 K (- 220 ^{0}C).

The Stratosphere

In the Stratosphere, the middle layer of the Atmosphere of Uranus, the temperature generally increases with increasing altitude. At the lower limit at about 50 km (at the Troposphere) the temperature is still 53 K, while at an altitude of 4'000 km (at the limit of the Thermosphere) the temperature is as high as 800 to 850 K (527 – 577 ^{0}C). The reason for the heating of the Stratosphere is due to the absorption of UV- and IR-radiation by methane and by other hydrocarbons; in these altitudes, the gases are generated by the production of methane protolysis (processes by which methane molecules are broken into smaller units through the absorption of light). In addition, the heat transport from the hot Thermosphere could also contribute to the heating of the Stratosphere.

450

The Atmosphere of Uranus – 3; The Ring - system

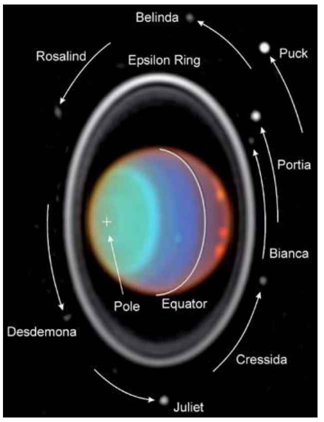
Thermosphere and Corona

The outermost layer of the Uranus- Atmosphere is the Thermosphere and Corona. It has a uniform temperature of 800 to 850 K (527 – 577 ^{0}C). This latter temperature is considerably higher than the 420 K (157^{0}C) of the Thermosphere of Saturn. The necessary heat sources are not known. Neither solar UV-light nor polar light activities are able to provide the necessary heat. Reduced heat radiation due to the lack of hydrocarbons could contribute to the maintenance of the high temperatures. In addition to molecular hydrogen (H_2), the Thermosphere and the Corona contain a large amount of free hydrogen atoms (H). The small masses of both, H_2 and H, together with the high temperatures, could explain the extremely large extention of the Corona (up to 50'000 km, a distance coresponding to two radii of the Uranus- Planet).

This extended Corona is a unique feature of Uranus. The small particles orbiting the Uranus are decelerated by the Corona. As a consequence, the rings of Uranus have a very low dust concentration.

Rings and Moons of Uranus

As all gas planets of the Solar system, Uranus is surrounded by a large concentration of very small bodies and particles which are orbiting around the Planet in the direction of its rotation. Their densily populated different orbits are forming a system of concentric rings. Most of these rings are orbiting in the equatorial plane of the Planet.



Rings and inner Moons of Uranus

10.2.8 The Planet Neptune

God of flowing Waters and Oceans

452

Planet Neptune – General

With reference to the Sun, Neptune is the eighth and outermost Planet of our Solar system; its mean distance from the Sun is about 4.5 billion km.

Its diameter is almost 50'000 km which is nearly five times the diameter of the Earth while its volume is about 57.57 times the volume of the Earth. It is the fourth largest Planet of the Solar system (remember that Uranus is the third largest Planet).

Together with Uranus, Neptun belongs to the subgroup of the so-called Ice Giants. Neptune is dominating the outer zone of the planetary system. At present, 14 Moons of Neptune are known! By far the largest Moon is Triton having a diameter of 27'000 km.

Neptune - compared with the Earth

Properties of the Orbit

- Semi-major axis: 4'495 million km
- Excentricity: 0.0113
- Siderical period: 164.79 years
- Average orbital speed. 5.43 km/s

Physical properties

- Equatorial diameterr: 49'528 km
- Polar diameter: 48'682 km
- Mass: 1.0243×10^{26} kg
- Average density: 1.638 g/cm^3

Main components

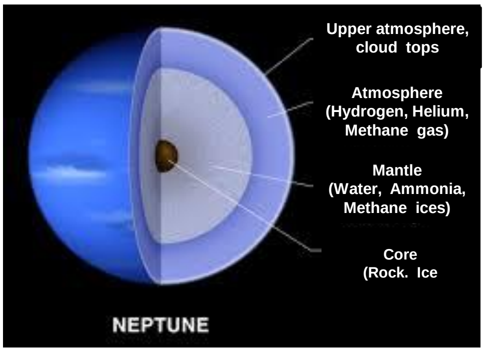
- Hydrogen (H_2): 80.0%
- Helium (He): 19.0%
- Methane (CH_4): 1.5%
- Hydrogen deuterium (HD): ~ 0.019%
- Ethane (C_2H_6): ~ 0.00015%
- Different Ices (NH_3, H_2O, CH_4, …)

Further Properties

- Gravitational acceleration: 11.15 m/s^2
- Inclination of axis of rotation 28.32^o
- Rotation period: 15 h 57 min 59 s
- Geometric albedo: 0.41
- Temperature: - 201 ^{0}C

453

Neptune's Interior and chemichal composition

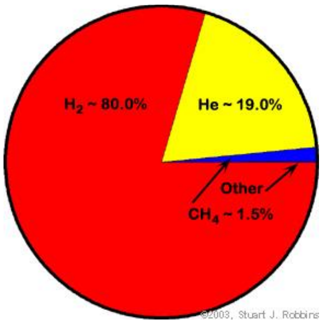


Neptune's Interior

a) Neptune's Interior

Similar to the structure of Uranus, three layers can be distinguished: 1) a rocky core of about 1 to 1.5 Earth masses made of rock in the center , 2) a mantel of 10 to 15 Earth masses of a mixture of rock, water (H_2O), Ammonia (NH_3) and Methane CH_4), and 3) an upper layer of about 1 to 2 Earth masses of H_2O, He and CH_4.

- **Core: The pressure is several million bar, about twice as large as that in the center of the Earth;**
- **The temperature in the center is up to 7'000 ^{0}C.**
- **Mantel: A liquid with high electrical conductivity**
- **Inner and outer gaseous Atmosphere**



Chemical composition of Neptune

b) Chemical composition

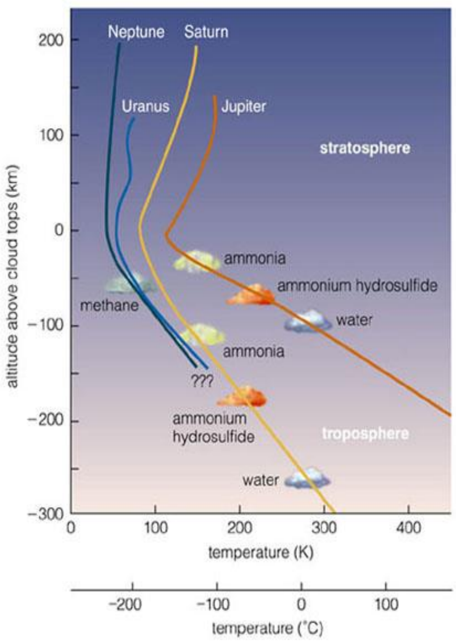
Apart from the core, Neptun consists essentially of a single large «Attmosphere». The Atmosphere has the following composition:

- **Hydrogen (H_2): 80.0 %**
- **Helium (He): 19.0 %**
- **Methane (CH_4): 1.5 %**
- **Hydrogen - Deuterium (HD): 0.0142 %**
- **Benzene (C_6H_6): 0.00015 %**

[The temperature at 1 bar is about 72 K (≈ – 200 ^{0}C) and at 0.1 bar it is about 55 K (≈ - 218 ^{0}C].

454

The Atmosphere of Neptune - 1



Temperature T as a function of altitude h. T(h) are shown for Jupiter, Saturn, Uranus and Neptune. Note especially T(h) of Neptune.

Similar to the Atmosphere of Uranus, the Atmosphere of Neptune can be subdivided into three layers:

The Troposphere starts immediately above the surface In the Troposphere, the temperature decreases with increasing altitude.

In the next layer, the Stratosphere, the temperature increases slightly with increasing altitude. The reason for this increase is not well understood. It is, however, believed that this increase is related to the motion inside the Planet's core which heats Neptune more than the rays from the distant Sun.

The next layer is the Thermosphere (not shown in the Figure), where pressures are lower.

The very outer edge of the Atmosphere is known as the Exosphere.

The minimum temperature is about – 225 ^{0}C. (about 48 K).

In comparision to Uranus with an axis of rotation at an angle of 98^0 (s. p. 448), Neptune has a normal rotation behavior since the inclination of its axis of rotation is only 28.32^0 (s. p. 453).

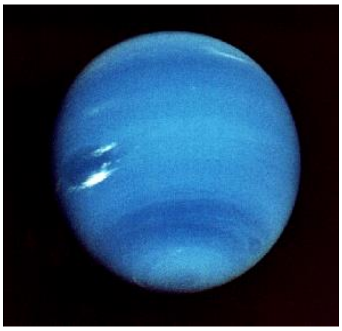
455

The Atmosphere of Neptune - 2

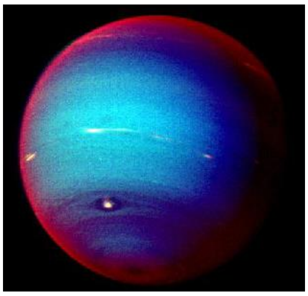
The Atmosphere of Neptune is similar to that of the other Ice-giants of the Solar system: It consists mainly of (H_2) and Helium (He); in addition, traces of Methane (CH_4), Ammonia (NH_3) and other Ices. But in contrast to the other Planets of the Solar system, Neptune has a great part of Ices in the form of Ice particles of Methane in its outer Atmosphere → deep blue color.

The upper cloud layers appear where the pressure is sufficiently small such that Methane can condense out. Astronomers have photographed these high-altitude clouds; these clouds form shadows on the underlying clouds. (see left-hand picture).

In the highest altitudes, in which the Atmosphere passes into space, it consists of 80% hydrogen and 19% Helium. As already mentioned, the Atmosphere contains in addition traces of Methane. The light we are observing is the Sunlight reflected and scattered by Neptune. From the total spectrum of the Sunlight, the traces of Methane absorb the red light component (see the Fals-color image of the red margin in the right-hand picture) while the blue light is backscattered and reflected.



Contrast-enhanced color image of Neptune observed from 14.8 million km (NASA)



Haze and light absorption by Methane (red margin) in the Atmosphere of Neptune. Fals-color image – (NASA)

456

10.3 Exoplanets: History – Methods of Observations and Examples

457

10.3.1 Observations od Stars and Search of Exoplanets

458

L' Univère populaire : Camille Flammarion, Wood engraving, Paris 1888 (*)

(*) A composition ("Montage") of C. Flammerion for his art work

" L' Astronomie populaire ", created 1880 .

459

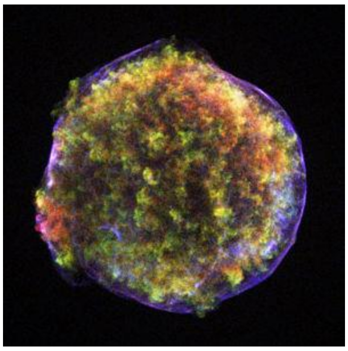
Giordano Bruno / Supernova von 1572

Giordano Bruno (1548 – 1600) coined the phrase:

«There are countless Stars and countless Earths which are orbiting in the same way as our seven Planets around our Solar Systemn […]. The countless worlds in the Universe are not less and worser habitated than our Earth.»

Giordano Bruno was sentenced to death by the Inquisition. On this judgement, Bruno responded with the famous phrase:
«Perhaps you pronounce this sentence against me with greater fear than I receive it». At February 17 of the year 1600 he was burned at the stake at the Campo di Fiori in Rome.

Supernova (SN) – Remnant of the Starburst from 1572



At the beginning of November 1572, the bright lightning of a Star was observed in the constellation of Cassiopeia in our Milky Way Galaxy. The most prominent observer was the astronomer Tycho Brahe. Such a bright lightning arises from a huge explotion at the end of the lifetime of a Star. The luminosity due to this explotion increases by a million to billions of time; for a short time it is so bright as a large Galaxy.

The picture shows the Supernova remnant of SN-1572 as it was observed from its emitted X–ray emission by the Chandra X-ray Observatory –Satellit.

<u>This observation showed that also the fixed Stars are not invariable, i.e. they have a finite lifetime.</u>

460

Astronomy in the 17th and 18th Century

The invention of the telescope (1608): No other invention revlolutionized Astronomy more than the invention of the telescope. In 1608, the Dutchman Lippenhey (1560 – 1619) had constructed the first telescope that allowed a three-to four fold magnification.

Galileo Galilei constructed a telescope having a 9 times and later even a 30 times magnification and aligned them toward the sky. With these telescopes he discovered that our Milky Way Galaxy was a huge collection of Stars. The Inquisition sentenced him to a life-long house arrest. Galileo recognized that the Earth was not the center of the Universe but rather orbited around the Sun. From Galilei comes the sentence: «And yet it moves !» - «E pur si muove !»

Johannes Kepler (1571 – 1630): Through careful observations and conclusions, Kepler established his three famous laws (s. Appendix 10-A-1-2). At 1618 he published his work «Harmonice mundi» which contains the third law of Kepler. Combined with Newton's gravitational constant it still plays an important role for the determination of the parameters of Exoplanets (s. pp 462 – 470).

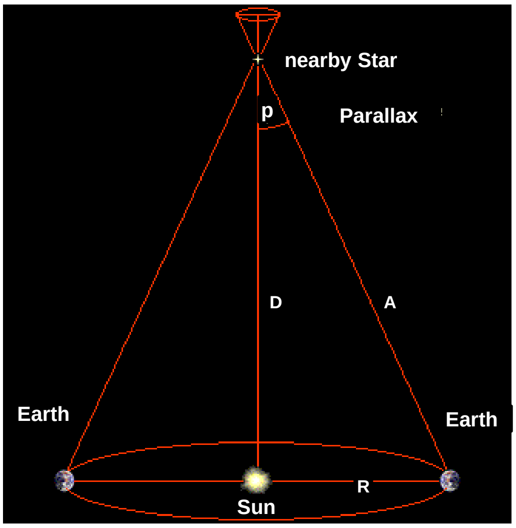
Isaac Newton (1643 – 1727): He was undoubtedly one of the greatest scientists of all times. In his «Principia», he established the three laws of Newton; among others, it contains also the gravitational constant designated so by himself. This constant allows the evaluation of the force of gravity or the determination of the orbital period of a Planet.

Christian Huygens (1629 – 1695): He was concerned with the existence of life on other Planets and postulated that the basic requirement for life was the existence of liquid water. In addition he postulated that aliens too have a human-like appearence. His most interesting theory is, however, that live has to adapt to the Planet.

Friedrich Wilhelm Herschel (1738 – 1822) constructed telescopes with diameters of up to 122 cm. With the powere of these telescopes he dicovered the Planet Uranus, some Moons and Nebula and he created a statistic of the Milky Way.

461

Importance of Parallax in Astronomy



Parallax: apparent angular displacement of nearby Stars

Parallax

The Mathematician and Astronomer Friedrich Wilhelm Bessel (1784–1846). made a significant discovery, namely the Parallax, an apparent angular displacement of nearby Stars due to the mouvement of the Earth around the Sun. For Astronomy, the Parallax p is of central importance because it allows the evaluation of the distanc between a Star and the Sun.

Let R = AU = Astronomical Unit (distance between Earth and Sun: R = 1 AU = 149.6 Mio. km), D = distance between Sun and Star, and p the angle of Parallax. Then it follows: $D = R / tg(p)$ or $A = R / sin(p)$.

Example: For the Star Alpha Centauri C, the distance D ≈ 4.243 lightyears (lj) = $40.14 \cdot 10^{12}$ km [1 lj = $9.4605284 \cdot 10^{12}$ km] one obtains:

$tg(p) = R/D \approx 3.726 \cdot 10^{-6}$ or

$p = 3.726 \cdot 10^{-6}$ radians ≈ $2.135 \cdot 10^{-4}$ degrees = 0.768 arcseconds = 0.768 "

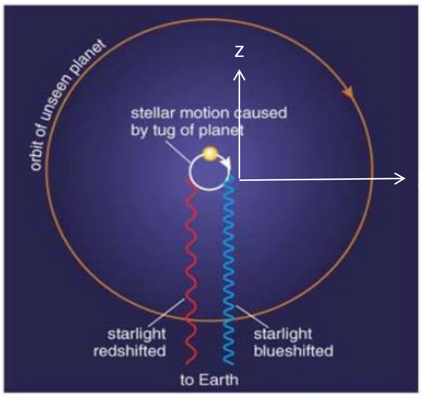
[1 degree = 3'600 "].

462

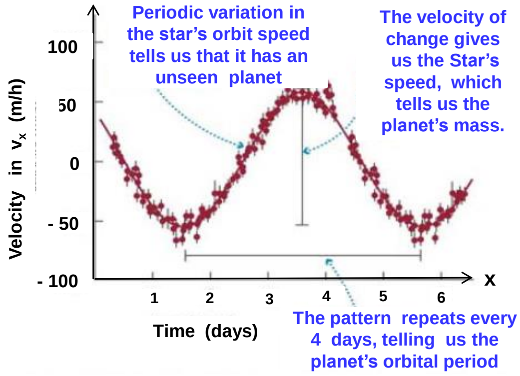
Discovery of Exoplanets with the help of the Doppler-Effect

Christian Doppler (1803 – 1853) calculated the frequency changes of the light waves depending on whether the source and the observer are moving towards or away from each other: The light is shifted to the reddish end of the spectrum if the object (in the present case a Star) is moving away from us and a shift to the blue end if it is moving toward us.

The Doppler technique is a good method for discovering Exoplanets. With the help of the Doppler effect, the movements and properties of the Stars and the Planets can be analized. Both, the Star and the Planet are moving around a fixed common point, the center of mass of Star and Planet. A more detailed description of the Figure below is found in Appendices 10-A-3-1 and 10-A-3-2.



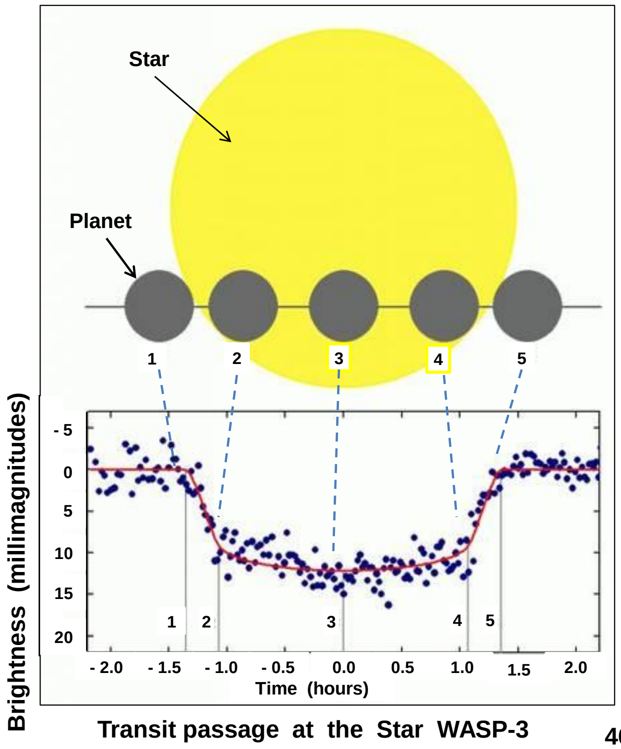
a) The Doppler shifts allow us to detect the slight motion of a Star caused by an orbiting Planet.



b) A periodic Doppler shift in the spectrum of the Star 51 Pegasi shows the presence of a large Planet with an orbital period of about 4 days. Dots are actual data points; bars through dots represent measurement uncertainty.

463

Transit – Methode for the observation of Exoplanets



Transit passage at the Star WASP-3

Transit-methode of Planet WASP-3b at his Central Star WASP - 3

For the transmit- method one is interes-ted in Planets, which are transiting over a central Star if viewed from the Earth. During such a transit, the brigjtness of the Star is reduced. This small reduction of brightness can be observed. For a Planet of the size of Jupiter which is orbiting around a Sun-like Star, a reduc-tion of brightness of ~ 1 % is observed.

But a single transit is not sufficient to discover a Planet with certainty. After all, there are other phenomena which can reduce the brightness of a Star. Examples of such phenomena are Star spots or pulsations of a Star. In fact, it is nessessary to observe three periodically occurring minima of brightess.

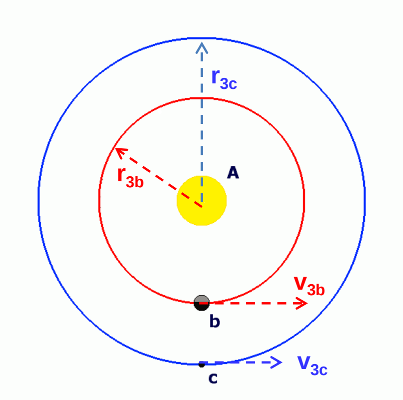
The Figure shows a plot of brightness of the Star versus observing time. Here, it is common practice to measure the brightness in units of millimagnitudes = 10^{-3} magnitudes. [A magnitude is a logarithm measure of brightness; see Ref. R.10.3.1.5].

464

Resonance of two Planets orbiting around a Star

In the observation of Planet WASP-3b (p. 464) and a more precise analysis around the Star WASP-3 by a team of astronomers from Germany, Bulgaria and Poland, a small variation of the expected orbit time of WASP-3b has been detected. It could be shown that this so-called transit time variation was due to another Planet, the so-called Planet WASP-3c (see Figure).

By combination of more exact observations and Computer simulations of the data, the existance of the Planet could be confirmed. Its orbit is farther out than that of the gas giant WASP-3b and is related by the former with a so-called **2:1 Resonance**. This means that the time needed for two orbits of the gas giant WASP-3b is just the same as for one orbit of the newly discovered Planet WASP-3c. If T_{3b} and T_{3c} are the corresponding orbit times, we than have: $T_{3c} = 2\ T_{3b}$; $T_{3b} = 1.847$ d → $T_{3c} = 3.694$ d (1d = 1 day.



2 : 1 Orbital resonance of the Planets WASP-3b and WASP-3c around the Star WASP-3

The orbit of Planet 3b is almost circular. We assume that this is also the case for the Planet 3c. If r_{3b} and r_{3c} are the radii of the circular orbits, Kepler's third law (p. 10-A-1-2) gives: $(T_{3b}/T_{3c})^2 = (r_{3b}/r_{3c})^3$ and with $T_{3c}/T_{3b} = 2$ it follows: $r_{3c} = (4)^{1/3}\ r_{3b} = 1.587\ r_{3b}$. This is in good agreement with the dimensions of the adjacent Figure. With $r_{3b} = 4.74225\ 10^6$ km one obtains $r_{3c} = 7.528\ 10^6$ km.

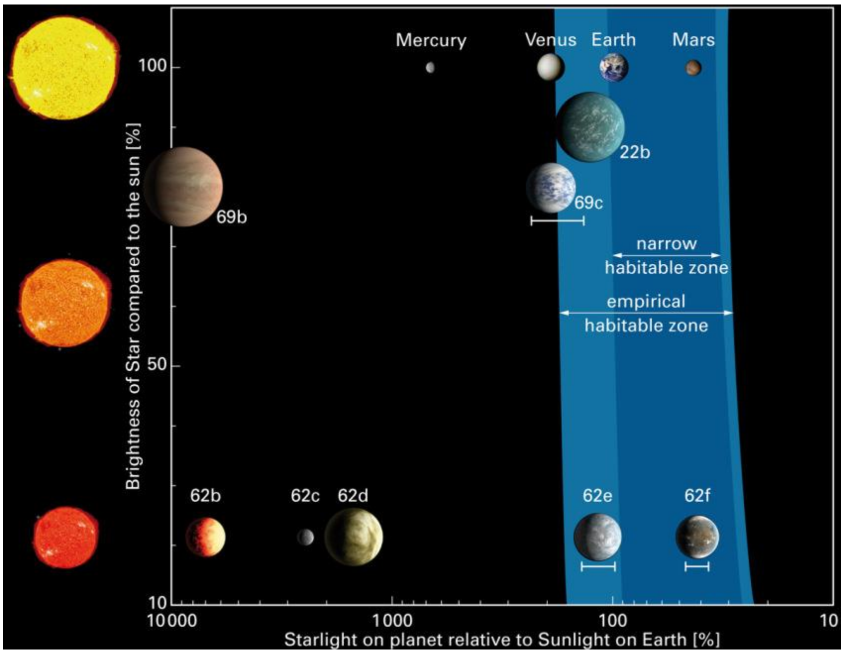
The mass of WASP-3b is $M_{3b} = 3.912\ 10^{27}$ kg and that of the Planet WASP-3c is $M_{3c} \approx 15\ M_E$ where $M_E = 5.972\ 10^{24}$ kg is the mass of the Earth (s. p. 429). → $M_{3c} \approx 8.958\ 10^{25}$ kg, i.e. $M_{3b}/M_{3c} \approx 43.7$. Hence, the mass of the Planet 3c is about 44 times smaller than the mass of the Planet 3b or $M_{3c} \approx 0.023\ M_{3b}$, ($M_{3c} \approx 2.3$ % of M_{3b}).

The orbit velocities around the Star WASP-3 are $v_{3b} = 2\pi\ r_{3b}/T_{3b}$ and $v_{3c} = 2\pi\ r_{3c}/T_{3c}$. It then follows: $v_{3b} = 188.6$ km/s and $v_{3c} = 148.1$ km/s.

10.3.2 Discovery and Systematics of Selected Exoplanets

466

Exoplanets in habitable Zone



Explanation to Figure: s. p. 468

467

Comments of Exoplanets in the habitable Zone

In the Figure of p. 467, the habitable zone of some Stars are shown. In the habitable zone (blue marked area), liquid Water can exist at the surface of the Planet.

The inner Planets of our Solar System are shown at the top of the Figure. Here, the Earth and Mars are in the habitable zone.

The Star Kepler-62 is at a distance of about 1200 light years (ly) from the Earth. It is considerably colder than the Sun and it is orbited by at least five Planets. Here, the two Planets Kepler-62e and Kepler-62f are in the habitable zone.

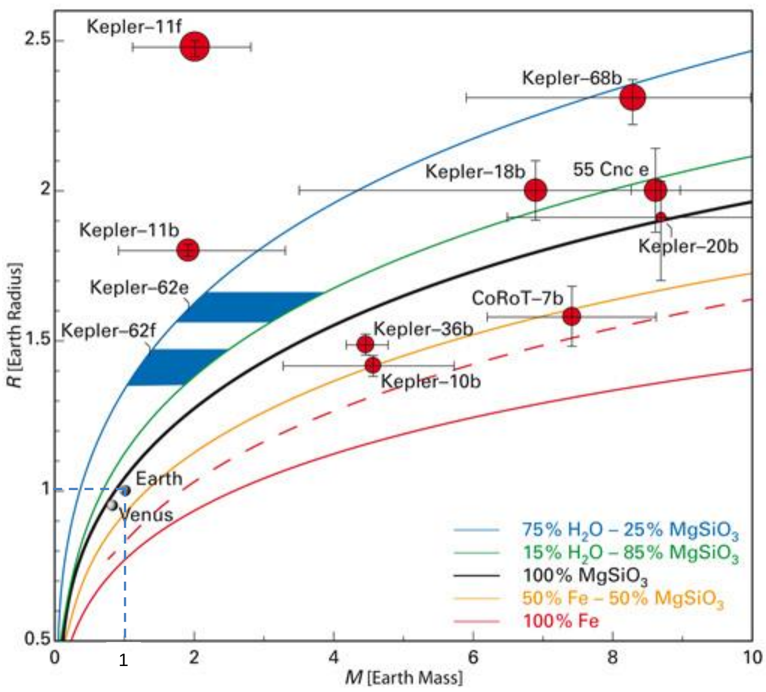
The Star Kepler-69 is a Sun-like Star, which has a distance of 2'700 ly from the Earth. It is orbited by at least two Exoplanets. In April 2013, NASA has discovered a new Planet, the Planet Kepler-69c. It is assumed that Kepler-69c is possibly also a habitable Planet.

The Star Kepler-22 is a Star at a distance of about 600 ly from the Earth. In its planetary system the Planet Kepler-22b is located. It is one of the smallest Planets found so far and it is possibly a mini-Neptune (pp 452, 453), i.e. it is a very small gas Planet.

The designation «empirical habitable zone» means that Water is present at the surface of the Planet and in addition that it has a sufficient layer of clouds. On the other hand, the designation «conservative habitable zone» means, that liquid Water can exist at the surface but without a layer of clouds.

468

Radius als Funktion der Masse für ausgewählte Exoplaneten



M in Einheiten der Erdmasse M_E :
M_E = 5.972 x 10^{24} kg

R in Einheiten des mittleren Erdradius R_E:
R_E = 6'371 km

Erläuterungen zur Graphik: s. p. 471

469

Masses and sizes of selected Planets: Explications of the Graph at p. 469

The curves in the Figure of p. 469 show the radii R as a function of masses M [average densities ρ = M/V; Volumes V = $(4\pi/3)$ R^3] for different types of Planets.

- The blue line indicates the locii of Planets made mostly (75%) of Water.
- The black line indicates Planets similar to the Earth which consist almost exclusively of rock (represented here by the mineral Entstatite, $(Mg_2(SiO_3)_2$, a member of the pyroxite silicate minerale series that makes up most of the Earth's mantel).
- The measured radii of Kepler-62e and Kepler-62f plus an estimate of their masses places them in a region (blue areas) where it is highly probable for them to be Earth-like Planets, that is: Planets with a solid mantel surface (possibly covered with Water).
- The Planet Kepler-11f, on the other hand, is a Mini-Neptune, showing clearly that a comparatively low mass does not necessarily make for a solid Planet (Image: L. Kaltenbrunner (MPIA)..
- The Star Kepler-62 in the constellation Lyra is about 1'200 light-years from the Earth. It is somewhat colder than the Sun and is orbited by at least 5 Planets.
- The radius of Planet Kepler-62e is 1.61 times the Earth's size and circles the Star in 122.4 (Earth days). Its core consists probably on silicates and iron and is covered by a considerable quantity of Water.
- The radius of the Planet Kepler-62f is 1.4 times the size of Earth, and orbits its Star Kepler-62 in 267.3 days. It is located in the habitable zone of his Star and is probably completely covered with Water. Previously, the smallest Planet with known radius inside a habitable zone was Kepler-22b, with a radius of 2.4 times that of the Earth.

10.3.3 Our Milky Way Galaxy

Our Milky Way Galaxy - 1

Diameter :

~ 10^5 light-years
($9.5 * 10^{17}$ km)

Thickness :

~ 10^3 light-years
($9.5 * 10^{15}$ km)

Age :

~ 13.6 billion years
($13.6 * 10^9$ years)

Number of Stars:

~ 300 billion
($300 * 10^9$ Stars)

The observable Universe contains about 100 – 400 billions (100 - $400 * 10^9$) Galaxies of similar sizes as our Milky Way Galaxy. 1 light-year (ly) is $9.46 * 10^{12}$ km ! The oldest known Star in our Milky Way Galaxy is about 13.2 billion years ($13.2 * 10^9$ years) .

The layered Milky – Way Galaxy - 2

Classification of Galaxies

Edwin Hubble studied and classified the types of Galaxies: He distinguished between elliptical, lenticular and spiral Galaxies. The spiral Galaxies are disc - shaped with spiral arms (s. Figure p. 472 of the Milky-Way System).

An elliptic Galaxy is a Galaxy having an approximately elliptic shape with a smooth and nearly uniform brightness profile. Depending on the Galaxy, they range from almost spherical to strongly flattened shapes. Lenticular (linsenförmige) Galaxies have shapes and properties ranging between elliptical and spiral Galaxies.

473

The Milky – Way Galaxy : Facts and Explenations

The Milky Way , or simply the Galaxy , is the Galaxy in which our Solar System is located . It is a barred spiral Galaxy that is part of the Local Group of Galaxies . It is one of billions of Galaxies in the observed Universe .

The stellar disk of the Milky Way (s . pp 472 , 473) is approximately 100‘000 light-years (ly) (9.5 * 10^{17} km) in diameter , and is considered to be , on average , about 1‘000 (ly) (9.5 * 10^{15} km) thick . It is estimated to contain at least 200 billion stars and possibly up to 400 billion stars; the exact figure depends on the number of very low-mass stars, the number of which is highly uncertain .

As a guide to the relative physical scale of the Milky Way, if it were reduced to 10 m in diameter, our Solar System, including the Oort cloud (spherical cloud of Comets), would be no more than 0.1 mm in width ! This is a factor of 100‘000 (!) .

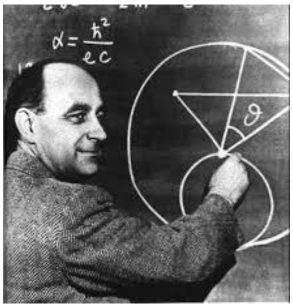
By including the estimated age of the stars in the globular cluster (about 13.4 billion years) , the age of the oldest stars in the Milky System has been estimated to about 13.6 billion years . Based upon this newest scientific result, the Galactic thin disk is estimated to have been formed between 6.5 and 10.1 billion years ago .

The galactic disk, which bulges outward at the galactic center, has a diameter between 70‘000 and 100‘000 ly . The distance from our Sun to the galactic center is now estimated at 26‘000 ± 1400 ly .

The galactic center harbors a compact object of very large mass as concluded by the motion of material around the center. The intense radio source named Sagittarius A*, thought to mark the center of the Milky Way, is newly confirmed to be a «Supermassive Black Hole» . Most Galaxies are believed to have a supermassive black hole at their center .

474

The Fermi – Hart Paradoxon



Enrico Fermi (1901 – 1954)

Michael H. Hart (1932 ---)

The Fermi-Paradoxon is a contradiction which has been formulated by the physicist Enrico Fermi in 1950. The Paradoxon questions the probability for extraterrestrial intelligent life. Its aime is to try to answer a fundamental question: «Are humans of the Earth the only technically advanced civilization?»

In our Galaxy there are about 100 billion of Stars. If only a ver small fraction of these Stars are orbited by Planets in which a technological civilization has been developed, a very large number of such civilizations must exist . If only a few of these cultures have developed civilizations which have been spread out with a small fraction of the velocity of light c (0.01 c to 0.1 c), Planets of next Stars could be populated; this population could then have spread out over the whole Galaxy. For this reason, our whole Galaxy would be populated within some millions of years. Since the age of the Galaxy is billions of years, our Earth should have been visited and colonized a very long time ago.

A detailed scientific investigation of this problem has been started in the early 1970'th by studies of Michael H, Hart (born 1932), and therefore the term Fermi - Hart Paradoxon is used. According to Michael H. Hart, the conclusion is the folowing:

«We observe that no intelligent beings from outer space are now present on Earth. It is suggested that this fact can best be explained by the hypothesis that there are no other advanced civilizations in our Galaxy. Reasons are given for rejecting all alternative explanations of the absence of extraterrestrials from Earth».

475

Drake– and Seager Equations

In contrast to the hypothesis of M.H. Hart (p. 475), according to which no highly developed civilizations exists in our Galaxy, the Astronomer Frank Drake tried to estimate in 1961 the number N of Planets having technical and intelligent civilazations in our Milky Way Galaxy. One variant of the equation for N is: $N = N^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot f_L$. In this equation, the significance of the factors for N is:

- N^* = Number of Stars in Milky Way Galaxy;
- f_p = fraction of Stars having «habitable» Planets» ;
  (existance of liquid Water and life- friendly Atmospheres]
- n_e = number of habitable Planets per Star;
- f_l = fraction of Planets in n_e, in which life is really developing:
- f_i = fraction of f_l, in which intelligent live (civilizations) is developed;
- f_c = fraction of f_i which is communicating.
- f_L = fraction of the duration of Planets, during which the communicating civilizations exists

The Drake equation lists the factors for the evaluation of N. For the actual evaluation of N, however, it is not really useful. The equation assumes, that all factors are of equal importance (probability «as well as» for independent events). In addition, the last 4 factors, f_l, f_i, f_c and f_L, can hardly been estimated.

Frank Drake (2002)

In the following, we give an example:

$N^* = 100 \times 10^9$; $f_p = 2\% = 0.02$; $n_e = 1$; $f_l = 10\% = 0.10$; $f_i = 10\% = 0.10$;

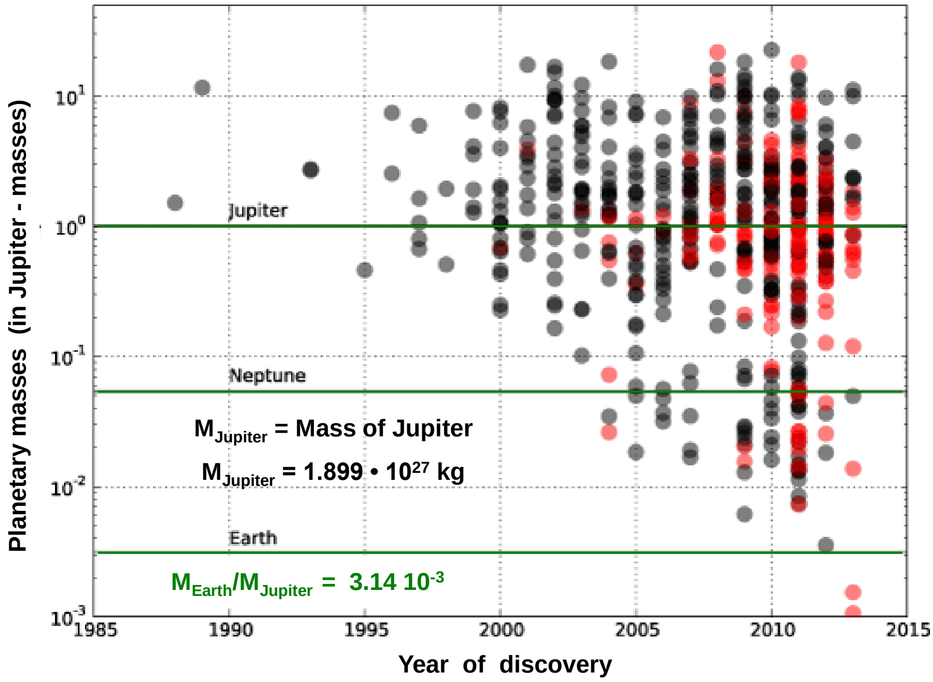
$f_c = 10\% = 0.10$; $f_L = 50\% = 0.50$; → $N = 1 \times 10^6$ in Milky Way Galaxy

→ The estimation is extremely inaccurate !

A new equation for the estimation of N is based on the 30'000 discovered Planets and has been put forward by Sarah Sieger in 2013 [s. Ref, R.10.3.2.9 – f)]. This evaluation is based on the large number of data which have been gained in the meantime about the Atmosphere of the Planet (s. pp 484, 485; 489).

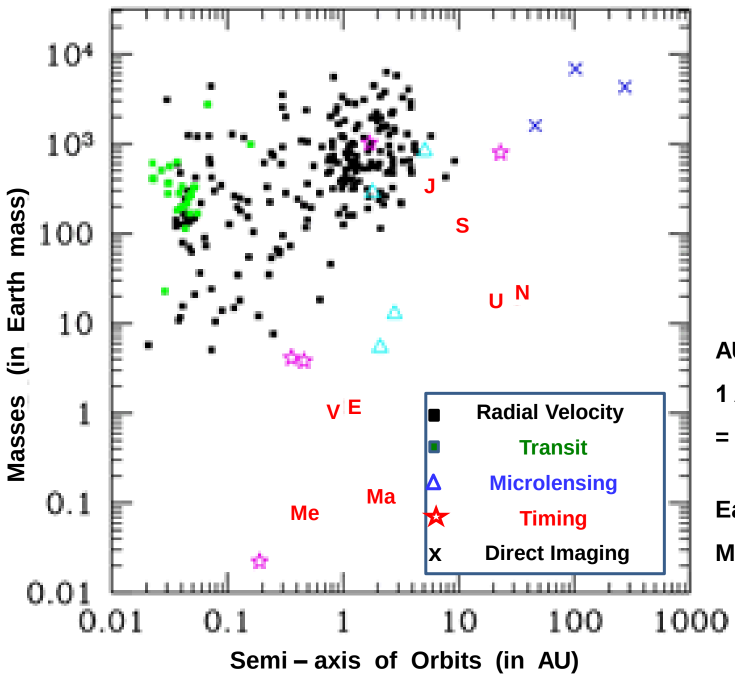
476

Planetary Masses versus Year of Discovery



477

Exoplanets of nearby Stars: Masses vs Semi – axis of Orbits



AU = Astronomic Unit

1 AU = 149’597’870.7 km

= mean distance between Earth and Sun

Earth Mass $M_\oplus$

$M_\oplus = 5.97219 \cdot 10^{24}$ kg

478

Comments to pp 477 and 478

Planetary Masses versus Year of Discovery:

p. 477: The Graph shows the mass-spectrum as a function of years between 1988 to 2013; note the logarithmic mass- and semi-axis scales. The masses are normalized with respect to the Jupiter mass. Unconfirmed data and pulsars have been excluded.

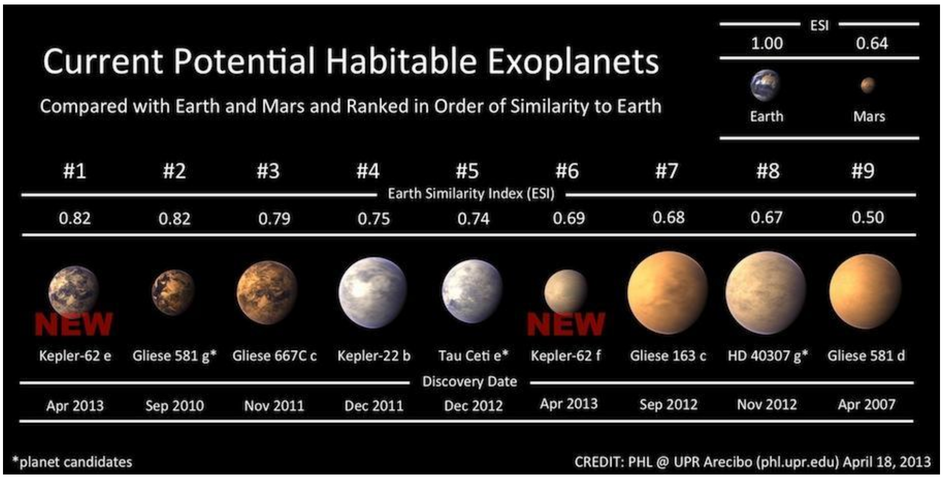
Planets which have been dicovered by using the Doppler- method are shown in gray circles, those which have been observed by using the Transit- method are shown in red circles. The Figure also indicates the mass- positions of the Earth, of Neptune and of Jupiter: the latter is the reference Planet with mass 1.

Exoplanets of nearby Stars: Masses vs Semi-axis of Orbit

p. 478: More than 400 Planets are known to orbit nearby, Sun-like Stars. As regard to the Exoplanets discovered recently, the Figure of p. 10-A-3-4 should also be considered. The Figure of p. 478 belongs to Prof. Seager's favorite diagrams. It shows the masses of Exoplanets as a function of the semi-axis of the orbits. The diagram (updated every month) shows that Exoplanets have all masses and semi-major axes possible, showcasing the random nature of Planet formation and migration. The differen Planet detection techniques are shown in the diagram. Parts of the diagram with no Planets are where technology can not yet reach Exoplanets. The red letters indicate Planets of our Solar System: Me: Mercury; Ma: Mars; V: Venus; E: Earth (Earth: normalized semi-axis = 1, normalized mass = 1); U: Uranus; Ne: Neptune; S: Saturn; J: Jupiter.

479

Some important Earth- like Exoplanets

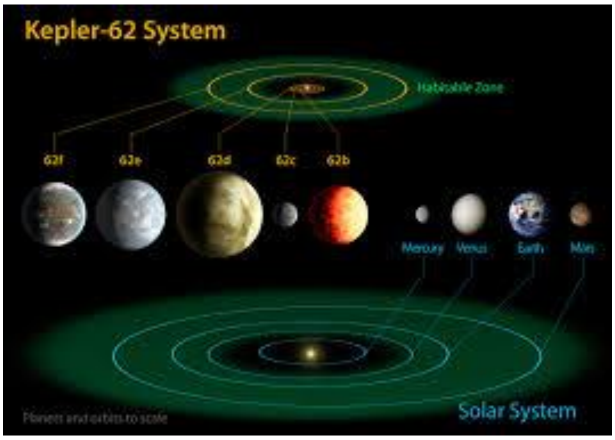


Recently, scientists have discovered two new Exoplanets, Kepler-62e and Kepler-62f, which are orbiting in a distance of 1'200 light-years (ly) from the Earth around their Star Kepler-62. At the top right of the Figure, the Planets Earth and Mars are shown. The Planets Kepler-62e and Kepler-62f are the smallest Planets which have been discovered by the Kepler - Mission.
The numbers added to to the Planets (for example 0.82 for Kepler-62e) are the so-called ESI- values (Earth Similarity Index), which are a measure fot the similarity of the Planets with respect to the Earth [ESI (Erde) = 1, ESI (Kepler-62e) = 0.82]. The ESI value depends on the radius, on the the mean density, on the escape velocity and on the surface temperature of the Planet.

480

The Kepler 62 Planetary System – Comparison with the Solar System

An international team of scientists, to which also Lisa Kaltenegger from Max-Planck Institute for Astronomy (MPIA) is a member, have announced in May 2013 two potentially Earth-like Planets, namely Kepler-62e and Kepler-62f. This discovery was made with NASA's Space Telescope Kepler. [The distance between the Earth and Kepler 62 is about 1'200 light-years (!); Kepler 62 is somewhat colder than the Sun. Judging by their relatively small radii [the radius of Kepler-62e is only 1.62 times and the radius of Kepler-62f is 1.41 times larger than the radius of the Earth], these Planets are expected to be rocky Planets. If this is the case, they would be the best candidates for life-friendly Planets. The investigations of Dr. Kaltenegger show, that both Planets are located in the habitable zone [liquid Water and Earth-like Atmosphere].



The illustration shows a comparison of the planetary system Kepler-62 with our own Solar System. The Planet's orbits (shown above and below) are relativ to each other at the right scale; the same applies for the sizes of the Planets. The habitable zones are shown in green. As mentioned above, they have solid surfaces and are located in the habitable zone. At this point it should, however, be mentioned that the list of References, [Ref. R.10.3.2.13 c) and d)] contains other candidates for habitable Planets.

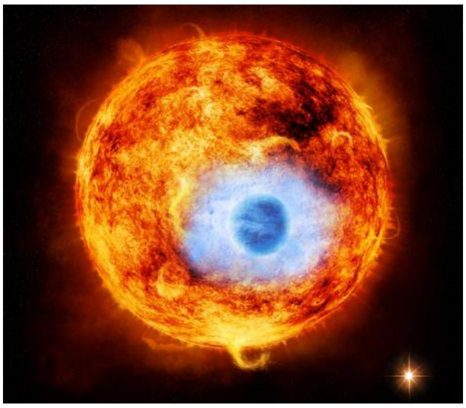
481

10.4 The Atmospheres of Exoplanets

482

Atmospheres of Exoplanets - General

American Astonomers have developed a new method for the measurment of the mass of an Exoplanet. This method is based on the investigation of various parameters of the Atmosphere of the celestial body. The new technique could it make possible to gain important insight in remote Earth-like objects and in addition, it could contribute scientists to provide a basis for the existance of life. Although this method has been tested up to date only for large Jupiter-like gas Planets, scientists believe that with the help of more powerfull Telescopes- generations which are under development (s. p. 488), it is also possible to investigate small Earth-like Planets.



Artistic representation of the Planet «hot Jupiter» HD 189733b during his transit between the Earth and his Star HD 189733. Note the Planet's Atmosphere.

Until January 2014 more than 900 Planets have been discovered which are orbiting around their Stars; in addition, 2'300 further celestial bodies have been discovered, which look like Exoplanets. Most of these Planets are similar to the gas Planet Jupiter (pp 435 – 438) because it is much simpler to observe these gigantic gas Planets with the help of the presently existing Telescopes (for example Hubble, Herschel, Spitzer). Nevertheless, several Earth-like rocky Planets have also been found. The Astronomers expect that with the help of next-generation Telescopes (for example with the James Webb Space Telescope (s. p. 488)), much more small rocky Planets will be detected.

[The Atmosphere of our Planet Jupiter is in the range, which is accessible to direct observation; it lies in the pressure range between a few 10 bar and a few hundreths bar. For a Planet, the «surface» is defined at a gas pressure of 1 bar.]

483

Masses of Exoplanets - Wobbling motion of Stars

It is expected that the chemical composition of an Exoplanet contains important information of whether a Planet can sustain life. Information about the inner composition of an Exoplanet is obtained from its density ρ; the density is the ratio of mass M and volume $V = 4\pi r^3$ (r = radius of the Exoplanet): $\rho = M/V$. The mass M of an Exoplanet can be obtained from the fact that its orbit generates a small wobbling motion of the Star: The Star moves very slightly toward the Earth and this displacement is then followed by a slight displacement away from the Earth. This wobbling motion of the Star is due to its rotation around the center of garavity of the Star and the Planet. It generates a Doppler–effect of the starlight (Red- and Blue shift, s. p. 463 and Appendix 10-A-3-1 and 10-A-3-2). If this information is compared with an independent estimate of the mass of the Star, an upper limit of the Planet's mass can be estimated.

Sara Seager - MIT

Julien de Wit - MIT

This method gives good results for Jupiter-like Planets as well as for Earth-like Planets which are orbiting very close around a bright Star. But the method fails for rocky Planets orbiting in large distances around the Star as is the case for our Earth orbiting around the Sun. But life is expected to exist just on these latter Planets.

Now, Sara Seager and Julien de Wit from the Massachusetts Institute of Technology (MIT) have developed a new method for measuring the masses of Planets which are periodically orbiting around their Star. This so-called Transit-method has been described at pp 464 and 465. There we have explained that «Transit Planets» are blocking part of the Star-light observed from the Earth. By measuring the resulting partial extinction of the Star-light, both, the orbital period as well as the diameter of the Planet relativ to the Star can be determined.

484

Absorption of Starlight by the Atmosphere of Exoplanets - 1

With the help of Transit – measurements, important additional information can be obtained: If the Planet transits its Star, a small fraction of the Starlight traverses the Atmosphere of the Planet before it reaches the Earth. From this light, a small part is absorbed by the Planet's Atmosphere before reaching the Earth and an other part will be scattered. From these observations, the Astronomers were able to gain important information concerning the chemical composition, the density and the temperature of the Atmosphere.

In their new scientific research, De Wit und Seager have extended their investigations to the atmospheric pressure. In particular they were interested to study the dependence of the atmospheric pressure as a function of the altitude above the surface of the Exoplanet. Their studies have shown that the pressure gradient (decrease of atmospheric pressure with increasing altitude), the density and the temperature of the Atmosphere are related to the mass of the Planet by relative simple equations. In addition, they have demonstrated that all properties mentioned above can be measured independently from the Transit – spectrum, allowing an independent determination of the mass.

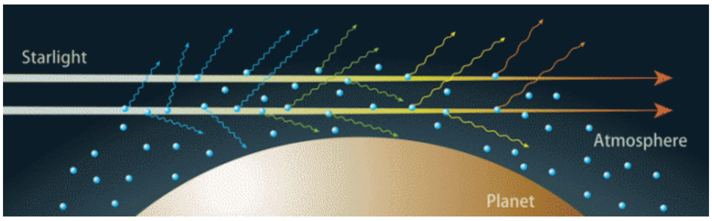
Seager and De Wit have tested their method by evaluating the mass of a newly discovered Exoplanet, the distance of which is about 63 light-years from the Earth. It is the Exoplanet HD 189733 b; this «hot Jupiter» is orbiting around its Mother-Star in a very short circulation period of only 2.2 days . Since for the presently available Telescopes, this Planet is an ideal candidate, its mass could be well determined. Within about 5%, its mass is about 1.16 times larger than the mas of our Jupiter.

Unfortunately, the presently existing Telescopes such as Hubble, allow only the study of gas-giants, but small Earth-like Planets can not be investigated. However, scientists are confident that with the successor of the Hubble – Telescope, the so-called gigantic «James Webb Space Telsecope» (JWST), which will be put into operation in 2018 (s. p. 488), small Earth-like Planets can be investigated. The reason for this assumption lies in the fact, that the Telescope is installed on bord of the Space craft and for this reason, it will be far superior to the Telescopes of today.

485

Absorption of Starlight by the Atmospheres of Exoplanets - 2

Under certain conditions it is possible today, to study the Atmosphere of Exoplanets. For the identification of the Atmosphere of Exoplanets, it is advantageous to observe Planets orbiting around a large and bright Star; it is then possible to analyze a strong intensity of photons. In addition, the Planet should be as large as possible and its Atmosphere should be as cloud-free as possible. In addition, the Planet should have the shortest possible period of revolution; this increases the number of transit observations and improves the statistics. The following Figure illustrates schematically the Planet's Atmosphere which is irradiated by the light of the Star.



The light from the Star is partially scattered and partially absorbed by the atoms and molecules of the Atmosphere. By observing the spectra of the light before entry into the Atmosphere and after leaving the Atmosphere and by subtraction of the two spectra, it is possible to obtain the absorption spectrum of the Atmosphere..

The WASP- Project (WASP = Wide-Angle Search for Planets) is well suited for such studies, because it is specially designed for the investigation of large Jupiter–like Planets which are orbiting close to its Star. NASA has investigated three WASP- Planets, WASP-12b, WASP-17b and WASP-19b. Thereby, a broad absorption band at a wavelength of 1.4 micrometers (µm) in the Near-Infrared region of the spectrum has been observed which is caused by the absorption of Water in the gaseous state.

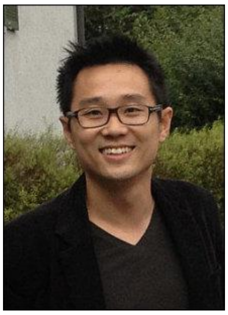
486

Two young Astronomers explore the Atmospheres of Exoplanets

Lisa Kaltenegger - MPIA

Lisa Kaltenegger from the Heidelberger Max-Planck-Institute for Astronomy (MPIA) studies the Atmospheres of Exoplanets. By Computer- supported research she is exploring spectral fingerprints of the Atmospheres of extrasolar terrestrial Planets which provide decisive evidence of potential traces of life. The aim of these studies is to find indications of Water (H_2O), Oxygen (O_2) and other gases such as Carbon dioxide (CO_2) and Methane (CH_4). The combination of O_2 with a reducing gas such as CH_4 is considered as a proof for the existance of biological activity on a Planet.

For her important contributions , Lisa Kaltenegger has obtained the «Heinz Maier - Leibnitz – Price».



Kevin Heng – University of Bern and ETH - Zürich

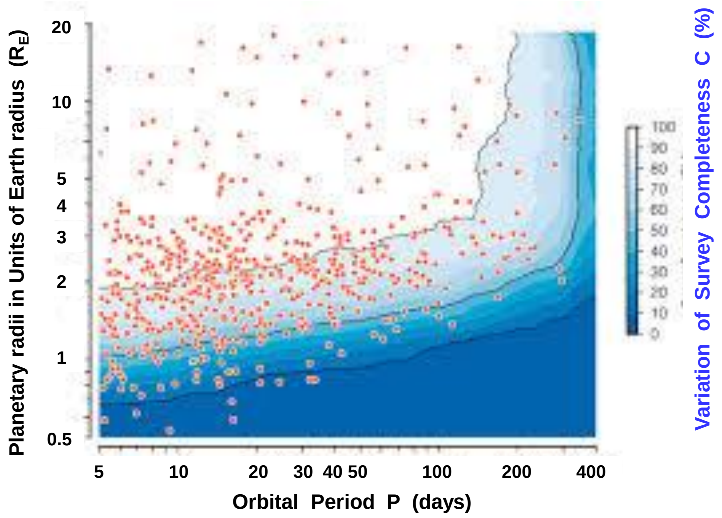
The working group of Kevin Heng at the «Center for Space and Habitability (CSH)» at the University of Bern is not devoted to the discovery of new Exoplanets but is rather searching Exoplanets which have an Atmosphere. The Atmospheres of Exoplanets are of interest for three reasons:

- Exoplanetory Atmospheres can harber a complex climate system → Information about chemical and physical relationships.
- Exoplanetory Atmospheres can be observed already today from afar.
- Analysis of exoplanetory Atmospheres may possibly show signs of life.

Kevin Heng is an ETH Zwicky Prize Fellow in Astrophysics

487

Planetary radii versus Orbital Periods



Transit-experiments of 603 Exoplanets orbiting around their Stars. The Graph contains the results of the planetary-radii as obtained with the Keppler-Telescope, as a function of the orbital periods. The colour scale (0 – 100%) on the right side of the Graph shows the Survey Completeness. It should be mentioned that at an orbital period of about 300 days, two Earth-like Planets have been discovered, the radii of which are about twice the Earth-radius.

488

Planets with «Biomarker Gases»: Astrobiology – Sara Seager

In Exoplanet - Science, «Biomarker Gases» are defined as gases, which are produced by life. [On the Earth, the most important biomarker gas is Oxygen (O_2), which is produced by plants, algae and some bacterial groups (see Chapter 6, p. 251)]. Such gases can accumulate in the Atmosphere of Planets in sufficiently high concentrations so that they can be observed with the help of distant Telescopes. It is assumed, that the living beings absorb and store energy by chemical processes and that the chemical processes nessasary for life then produce vital gaseous products.

In contrast to the Drake-equation (p. 476), which tries to estimate the Planets having technical and intelligent civilizations in our Galaxy, Sara Seager from MIT (pp 484, 485) is more modest: she is not considering intelligent live but she is rather searching for life itself. The Sara Seager equation can be written in the form: $N = N^{*} \bullet F_Q \bullet F_{HZ} \bullet F_O \bullet F_L \bullet F_S$, where

- N = Number of Planets with observable signs of life
- N* = Number of observable Stars
- F_Q = Fraction of «Quite Stars», i.e. of Stars which are not changing in their brightness
- F_{HZ} = Fraction of Stars with rocky-like Planets in the «Habitable Zone»
- F_O = Fraction of those Planets which can be observed
- F_L = Fraction of Planets harboring life
- F_S = Fraction of Planets which leave an observable signature in the Atmosphere.

Examples:

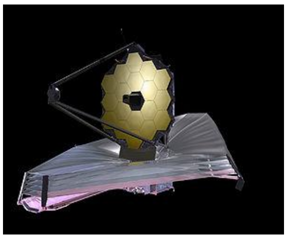
a) Sara Seager: N* = 30'000; F_Q = (0.2); F_{HZ} = 0.15; F_O = 0.001; F_L= 1 (optimistic); F_S = 0.5;
→ N = 0.45; Seager rather quotes a value of N ≈ 2; but thîs latter value follows for F_Q = 1:
→ N = 2.25 ≈ 2; → The value for F_Q seems to be quite uncertain !

b) With the «James Webb Space Telescope» (p. 490 b)), which will be taken into operation in 2018, the following values will bee predicted by Seager's equation:
→ N* = 500'000; F_Q= (0,2); F_{HZ} = 0.15; F_O = 0.001; F_L = 1; F_S = 0.5; → N ≈ 7.5

c) Milky Way: N* ≈ 100 x 10^9; F_Q = (0,2); F_{HZ} = 0.15; F_O = 0.001; F_L = 1; F_S = 0.5: → N ≈ 1.5 x 10^6

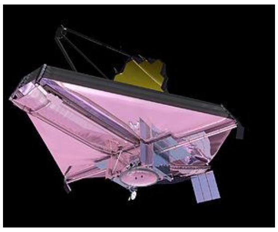
489

The James Webb Space Telescope (JWST)

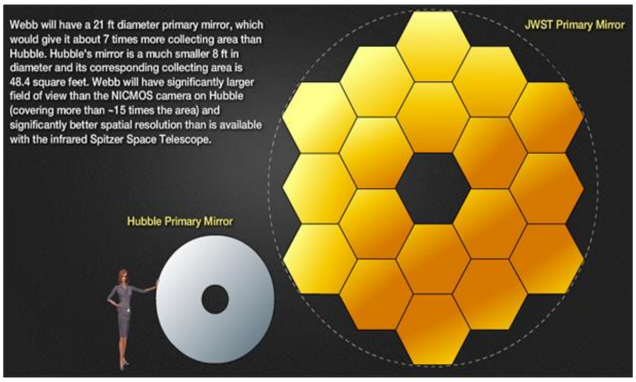


Topside of James Webb Space Telescope

Estimated
Start - Up:
at about 2018



Underside of James Webb Space Telescope



James Webb – Space Telescope (JWST)

The diameter of the JWST will be 6.4 meters → Receiving surface is about 7 times larger than that of the Hubble – Telescope.

- Consists of 18 hexagonal mirror segments
- Mirror segments will be unfolded only in Space
- JWST is an Infrared Telescope
- Weight: 6.2 tons
- Costs: about 8.7 billion US-Dollar

The Hubble – Telescope which is in operation since 1990 has delivered already extremely important information (s. p. 10-A-4-1).

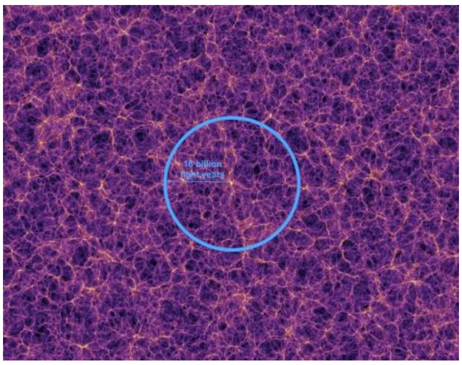
490

10.5 Galaxies and the Universe

The observable Universe

An estimation suggests that in the observable (*) Universe, there are about $7*10^{22}$ or ≈ 10^{23} Stars. The question arises as to the average number of Planets per Star. This is a hard question to answer: Scientists can only be sure that there is on the average at least one Planet per Star, but don't know much more than that. For the time beeing we asuume that there are 1 to 2 Planets per Star and arrive at a total number of Planets of about 10^{23} to $2*10^{23}$ Planets in the observable Universe.

(*) Note; The observable Universe consists of the Galaxies and other matter that can, in principle, be observed from the Earth at the present time, because light and other signals from these objects has had time to reach the Earth since the beginning of the cosmological expansion. Assuming the Universe is isotropic, the distance to the edge of the Universe is roughly the same in every direction. That is, the observable Universe is a spherical volume, a ball, indicated by the blue circle in the present Figure. This ball is centered on the observer and its diameter is estimated to be D = 8.8 * 1026 m = 28.5 Gpc = 93 Gly. [1Gpc = 1 Gigaparsec = $3.0857 * 10^{25}$ m; 1 Gly = 1 Gigalightyear = $9.461 * 10^{24}$ m and hence 1 Gpc = 3.26 Gly.



In other words: some parts of the Universe are too far away for the light emitted since the Big Bang to have had enough time to reach Earth, so these portions of the Universe lie outside the observable Universe (indicated by the blue circle in the Figure).

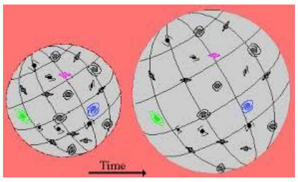
Origin and Expansion of the Universe

The generally accepted theory of scientists which describes the origin and development of the Universe is the theory of the Big Bang. According to this theory, the Universe originates from an extremely dense and hot initial state that existed about 13.8 years ago.

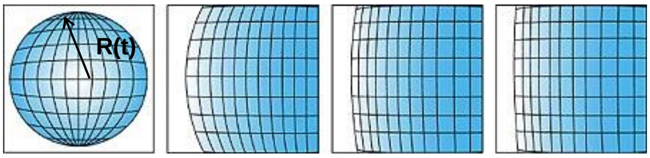
The law of Edwin Hubble (s. pp 472, 473, 494 - 496) (Hubble law) states: The Galaxis are moving away from us, and their escape velocities are the faster, the faster away they are from us.

If a Galaxy is observed at a double distance, than its escape velocity v is dobled. In the meantime one knows that not the Galaxies are moving but rather the space between the Galaxies is increasing. Despite of these fact one still speaks about the escape velocities of the Galaxies. It should not be forgotten, however, that we are dealing here with a problem in 4- dimensional space with 3 space coordinates x, y, z and the time coordinate t. Because of the very large expansion velocities, the problem must been treated with the Theory of General Relativity (Alexander Friedmann (1924) and George Lemaitre (1927)) .

In order to simplify, we discuss in the following a 3- dimensional model with two space coordinates x, y, and the time coordinate t. We consider an expanding sphere with radius R(t), and we assume that the Galaxies are located at the surface of this sphere. The location of a Galaxy on the surface of the sphere is given by two coordianates x and y. This model is called the balloon model. In this model, the Galaxies are two - dimensional and we can imagine that they are pinned on the surface of the inflating spheical balloon.



Balloon model of space



493

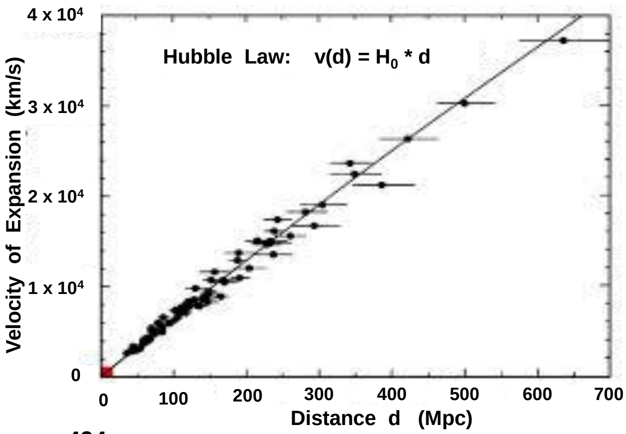
Flattening of the space in the balloon model.
The radius R increases over time: R = R(t)

The Hubble Law: $v = H_0\, d$

$H_0 = H(t_0)$ = present value of the Hubble parameter H(t)

- v = Espansion velocitiy; d = Distance between observer O and Galaxy G (s. Figure below).
- H_0 = 74.3 km / (s • Mpc) ≈ 2.4 • 10^{-18} s^{-1}; [1 Mpc = 1 Megaparsec = 3.08567758 • 10^{19} km];
- Because of the distance of the Galaxy G from the observer O with velocity v, O observes a redshift $\Delta\lambda = \lambda - \lambda_0$ of the light. For v << c we have: $z = \Delta\lambda / \lambda_0 \approx v / c \approx (H_0 / c) \cdot d$. For larger velocities v, the problem must be treated by the Theory of General Relativity (s. Appendix 10-A-5-1).
- It is assumed, that the present universe is nearly flat as represented by means of the balloon model (s. p. 493, right-hand Figure).

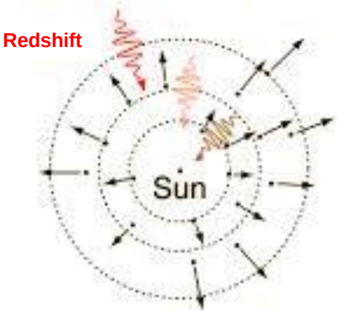
Edwin Hubble



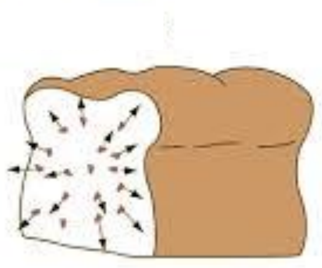
494

The Expanding Space - The Raisains Bread Model

The fact that all Galaxies are moving away from us does not mean that we are at the center of the Universe. One rather would observe from all Galaxies that the other Galaxies are moving away from us. An expanding raisin bread in the oven is a good model. If one is sitting at an arbitrary raisain in the oven, one can observe how all the other raisains are moving away. The individual raisains are not growing.



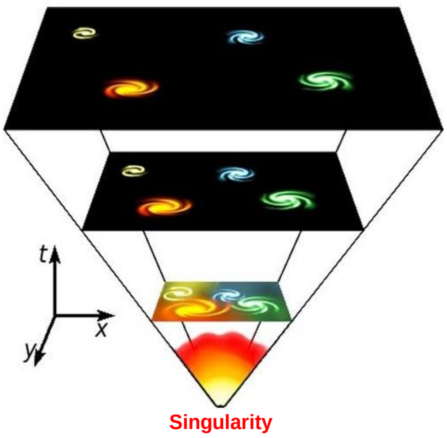
H_0 = 74.3 km / (s • Mpc)
(1 Mpc = 1 Megaparsec ≈ 3.08568 • 10^{19} km)
Viewed from the Sun (or from the Earth), all observable Galaxies are moving away.



Analogy of a raisin bread:
In the rising breath, each raisain observes that the other raisins are moving away.

495

More about the Big Bang and the Expansion of the Universe



Artistic illustration of the origin of the Universe starting from the Big Bang

The Big Bang does not refer to an explotion in space but rather to the common creation of matter, space and time from an original singularity (≈ pecularity, anomaly, abnormality).

The Big Bang is the starting point for the creation of matter and space-time. Based on cosmological theories, such a starting point is obtained by astronomers from the observed expansion of the Universe and by counting back until a time at which all matter and radiation was concentrated in a narrow space area. The real Big Bang is prior to that time and designates the formal point of time at which the energy density was infinitely large. Since the established physical theories such as Quantum Field Theory and General Theory of Relativity presupposes the existence of space, time and matter, the real Big Bang cannot be described on the basis of these concepts.

Predictions from the Big Bang model: The Big Bang models with the above characteristics are the generally accepted explenations of the present state of the Universe. The reason for this is that they are able to predict some central facts which agree well with the observed state of the Universe. The most important predictions are: The Expansion of the Universe, the Cosmic Background Radiation as well as the Distribution of the Elements, in particular the proportion of Helium (He) to the total mass of the atoms. In addition, the most important properties of the temperature fluctuations of the cosmic background radiation can be explained in the context of the Big Bang models on the basis of cosmological perturbation theory.

496

Interstellar Gas: An extremely diluted «Atmosphere» - 1

About 99% of the interstellar medium exists in the gaseous state, from which 90% consists of hydrogen. Thereby, about half of this gas is bound to interstellar gas clouds. Depending on temperature, these gases have different properties:

Horsehead Nebula: Orion – Nebula, containing dust and H_2 in the core.

In the coldest and densest regions of the interstellar medium, one finds clouds, whose cores contain mainly, molecular hydrogen (H_2). Molecular H_2 can only be found under these conditions, since it takes only a very small energy to break up the molecules. This happens if the light of Stars can penetrate deep enough into the clouds and can be absorbed by the molecules. The temperature of these molecular clouds is about 10 K (- 263 ^{0}C). Furthermore, the clouds contain a high concentration of dust. In the core of the cloud, this dust protects the molecular H_2-gas from dissociation by photons. In addition, compounds have been discovered, for example CH_3^+- ions, suggesting that these ions are functioning as a kind of cosmic Oil- Refinery.

If for the surviving of the H_2- molecules, the gas cloud is not sufficiently cold and dense, then a cloud of neutral hydrogen atoms (H) is formed. The temperature of this cloud is about 100 K (- 163 ^{0}C) and these clouds are referred to as HI- clouds.

Occasionally, one finds gas clouds in the vicinity of hot Stars, which heats up the gas to a temperature of 10’000 K. In this case, the radiation from the Star heats up the H-atoms such that they are ionized, i.e. they are loosing their electrons. By the recapture of an electron, red light with a wavelength of 656.3 nm is emitted (1 nm = 10^{-9} m). The resulting gas clouds are referred to as emission nebulas which consist of ionized H^+. Astronomers are referring them as HII – clouds.

497

Gases of the interstellar Medium - Table

Remarks: The enormously large collision times and mean free paths implies that the temperatures are not due to collisions between the molecules. The concentrations of the gases are enormously small implying a ballistic movement of the particles. The partially very high temperatures are rather generated by thermal radiation of neighbouring stars (in analogy with the Thermosphere, pp 49-53, Chapter 2).

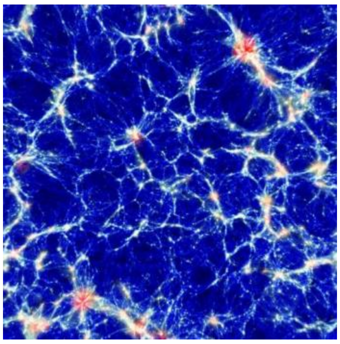
Properties / Media	Hydrogen	Temperature T(K)	Particles per cm³	Collision-times (s)	Mean free paths (m)
Coronal Gas	H^+	1’000’000	0.01	10^{11}	10^{14}
Diffuse Nebulae	H^+	10’000	100 – 1’000	10^{7}	10^{9}
Between the Nebulae	H	10’000	0.1	10^{11}	10^{13}
Diffuse clouds	H, H_2	50 - 100	10 - 100	10^{9}	10^{10}
Dark clouds	H_2	10 - 50	10^3 - 10^7	10^{4}	10^{5}
Giant molecular clouds	H_2	10	500	10^{9}	10^{10}
Earth’s surface	Air	300	~ 10^{19}	~ 10^{-8}	~ 10^{-7}

498

Intergalactic Gas: An extremely diluted «Atmosphere» - 2

An Inter-Galactic-Medium (IGM), also referred to as an intergalactic gas, is hydrogen gas , which is not bound to individual galaxies, but rather exists in the vast space between the galaxies. It consists mainly on ionized hydrogen gas H^+, the so-called Plasma HII (pp 497, 498). The concentration of neutral hydrogen H (also called HI) is only about one millionth of the total medium. IGM should not be confused with the interstelar medium consisting of H_2 and H (pp 497, 498) which is located between the Stars of the galaxies. The boundary between the intergalactic and interstellar region is, however, a smooth transition.

Cosmologists have suspected for a long time that the large-scale structure of the Universe resembles a spider web. Formidable filaments of hydrogen gas are traversing the dark expanses of the Universe. They constitute a branched network with nodes in which matter accumulates and galaxies such as our Milky Way are formed. Since the diffuse gas of cosmic filaments does not, however, emit light, cosmologists were forced to study the intergalactic network only by means of Computer simulations.

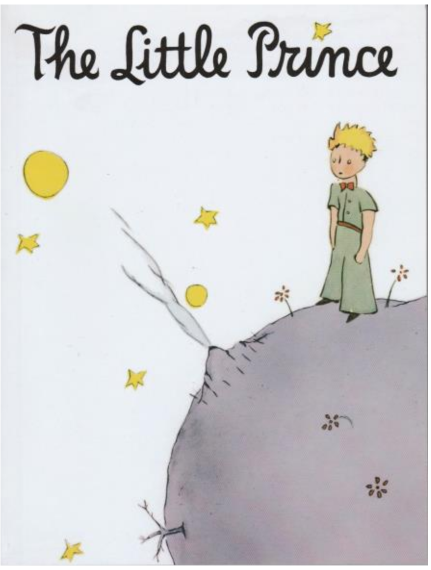


Network distribution of matter in the large-scale space of the Universe

Thanks to a pure coincidenc, the astromomer Sebastiano Castalupo from the University of California in Santa Cruz and his collegues were now able for the first time to observe a part of the mysterious network. At the W.M. Keck Observatory in Haway they were just studying the quasar UM287 as they discovered something very unusual: On their telescope recording they discovered suddenly a vast filament of hydrogen which extended over a distance of almost two million light-years into the intergalactic space. It was the enormous radiation of a quasar that caused the intergalactic gas to glow.

In the present picture (a simulation), the galaxies are only tiny dots in the nodes of the network!

The Little Prince on the Asteroid B 612



«What is important cannot be seen...»
«It is the same as with the flower.
If you love a flower
that lives on a star,
it is sweet to look up at the night sky.
All the stars are in bloom.»

«At night, when you look up at the sky,
since I shall be living on a star,
and since I shall be laughing on a star,
for you it will be as if
all the stars are laughing»

Antoine de Saint-Exupéry

Appendix: Chapter 10

10-A-0-0

Vincent van Gogh: «The Starry Night» (1889)

10-A-0-1

Johann Wolfgang Goethe
(1749 - 1832)

Faust: Prologue in Heaven

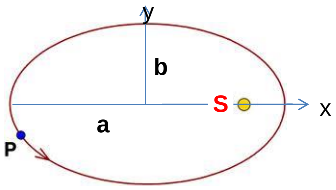
RAPHAEL

The sun-orb sings, in emulation,
Mid brother-spheres, his ancient round:
His path predestined through Creation
He ends with step of thunder-sound.
The angels from his visage spendid,
Draw power, whose measure none can say;
The lofty works, uncomprehended,
Are bright as on the earliest day.

(Bayard Tayler)

10-A-1-1

Kepler's Law of Orbit (1571 – 1630)



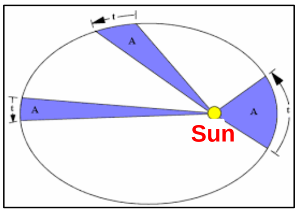
Ellipse with semi-axis a and b:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

1. First Law:

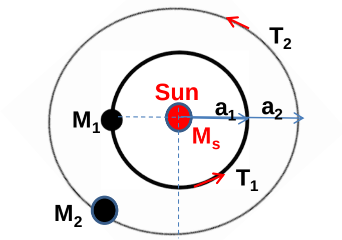
The orbit of a Planet P is an ellipse with the Sun S in one of the foci.

S: Sun - P: Planet



Second Law:

A line segment joining a Planet and the Sun sweeps out equal areas during equal time inter-valls: If t is this interval, then $A_1 = A_2 = A_3 = A$.



Third Law:

Let M_s be the mass of the Sun which is orbited by two Planets 1 and 2 having masses M_1 and M_2 and semi-major axis a_1 and a_2, respective and let G be the gravitational constant. Furtheremore, let T_1 and T_2 be the orbit times of Planets 1 and 2. The exact formula for orbit time 1 is then:

$$T_1^2 = \{4\,\pi^2 / [G\,(M_S + M_1)]\}\, a_1^3$$

and a similar formula applies for T_2. Since $M_1 << M_s$, $M_2 << M_s$, it follos immediately for the two Planets 1 and 2:

$$(T_1 / T_2)^2 = (a_1 / a_2)^3 .$$

10-A-1-2

Simplification: Circular orbits of Planets around the Sun - 1

According to pp 416 and 10-A-1-2, the orbits of Planets around the Sun are ellipses with the Sun in one of the focii. Since according to p. 416, the numerical excentricities ε are small for most Planets, we approximate the orbit of a Planet by a circle with Radius R_P. Let M_s = mass of the Sun, M_P = mass of a Planet and v is the constant magnitude of its orbit velocity. Then, the net <u>centrifugal foce</u> F_{cf} acting upon a Planet at each point of the circle is given by

$$F_{cf} = M_P v^2 / R_P , \qquad (1)$$

The net centrifugal force is balanced by the <u>gravitational force</u> F_G which is given b

$$F_G = G (M_P M_S) / R_P^2 , \qquad (2)$$

where G = 6.673 * 10^{-11} N m^2 / kg^2 is the gravitational constant. In equilibrium, $F_G = F_{Cf}$ and one obtains from eqs. (1) and (2).

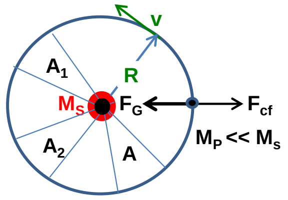
$$v^2 = G M_S / R_P = (2 \pi R_P / T)^2 \qquad (3)$$

where T is the time period of the Planet around the Sun. Substituting (3) into (1) one obtains;

$$F_{cf} = M_P (4 \pi^2 R_P) / T^2 \qquad (4)$$

From $F_{cf} = F_G$ one obtains from eqs. (2) and (4) the result:

$$T^2 = (4 \pi^2 / G M_S) R_P^3 . \qquad (5)$$

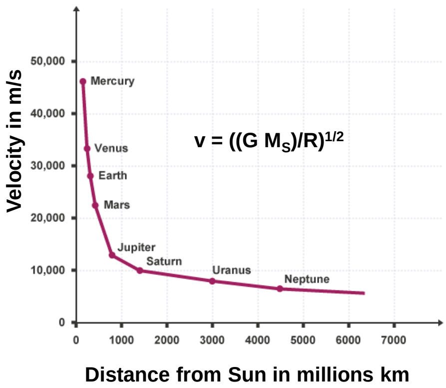


and

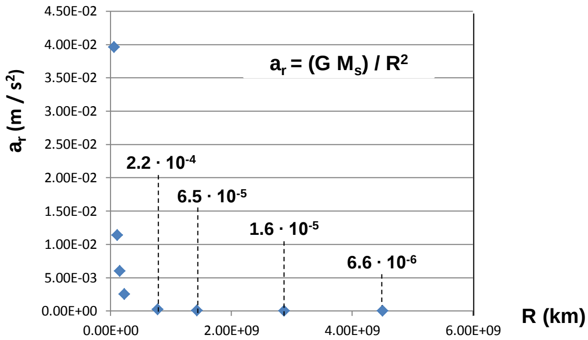
This is Kepler's third law for a Planet with a circular orbit (s. p. 10-A-1-2). The constant magnitude of the velocity v of the Planet orbiting around the Sun implies Kepler's second law: $A_1 = A_2 = A$.
[Note that for the vectors $\vec{F}_G = \vec{F}_{cp}$ = centripetal force where $\vec{F}_{cp} = - \vec{F}_{cf}$].

10-A-1-3

Simplification: Circular orbits of Planets around the Sun - 2



Acceleration as as a function of R:
$a_r = (G M_S) / R^2$



In the following we consider the acceleration forces asociated with the orbital motion around the Sun. Since the magnitude of v is constant, their is no tangential force a_t; there is, however, a radial acceleration force $a_r \neq 0$. This latter acceleration can be defined from

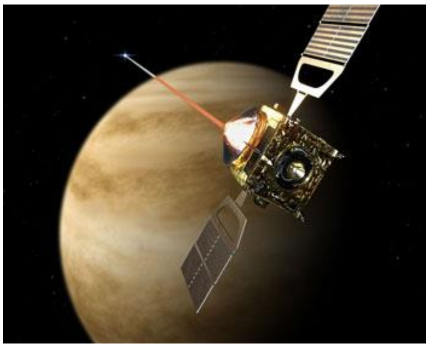
$$F_{cf} = F_G = M_p v^2 / R_P = G (M_P M_S) / R_p^2 = M_P a_r \rightarrow a_r = (G M_S) / R_P^2 \qquad (6)$$

<u>Terrestrial example</u>: The International Space Station is a LEO (Low Earth Orbit at a distance $R = R_E + h$, where R_E = Radius of the Earth, h = altitute above surface of the Earth). The acceleration is given by $a_E(R) = g(R) = (G M_E) / R^2$). Let $R_1 = R_E + h_1$ and $R_2 = R_E + h_2$. With R_E = 6'371 km, h_1 = 100 km, h_2 = 400 km, M_E = 5.98*10^{24} kg one obtains: $a_E(R_1) = g(R_1)$ = 9.53 m/s² and $a_E(R_2) = g(R_2)$ = 8.71 m/s². For h = 0 we have $a_E(R_E) = g = (G M_E) / R_E^2$ = 9.81 m / s² = graviational acceleration at Sea level.

10-A-1-4

Much Water in the Atmosphere of the jung Venus

To some extent, the Earth and Venus are twins. Scienctist assume that the today so different Planets – similar to the Planet Mars – have been formed about 4.5 billions of years ago from the same matter constituents (Prof. Bochsler from the Departement of Space Exploration and Planetology of the University of Bern (Switzerland)). This involves a hypothesis, according to which there existed a large water volume on the extremely dry Venus of today. Today, this assumption from the Bernise scientists is supported by about 40 scientists from Europe and the US. Data from the ESA Spacecraft «Venus Express» which is collecting information for several years strongly suggest that in the Venus-Atmosphere, water vapor was actually present (Prof. Peter Wurz; Univeristy of Bern).



The Spacecraft Venus circles around the Venus and explores its Atmosphere

…The researchers were able to prove, that - besides of a small amount of Helium – the observed ratio of hydrogen to oxygen was present in in the same ratio of 2 : 1 as for water of our Earth. As commented by Prof. Wurz; «This result has not been unambiguously expected». The existence of a former water resource had been expected, but it is still a larg surprise that the molecular composition was exactly the same as for our terrestrial water. The H_2O-molecules once present have then been carried away into space.

10-A-2-1

Earth's Moon

Moon photographed from the Earth (2006)

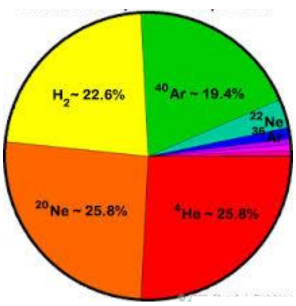
The Moon is Earth's only natural Satellite. Since the discovery of other Trabants of other Planets of the Solar System which in a transferred sense are also called Moons, our Moon is also called Earth's Moon. Owing to its relative proximity, it is the only foreign celestial body who has been visited by humans.

Properties of the Orbit:

Semi-major axis: 384'400 km; Excentricity: 0.0549;
Period: 27.3217 days; Average orbital speed: 1.023 km/s;

Physical properties:

Mean diameter: 3474.8 km; Mass: 7.349 x 10^{22} kg;
Average density: 3.341 g/cm^3; Gravitational acceleration: 1.62 m/s^2;



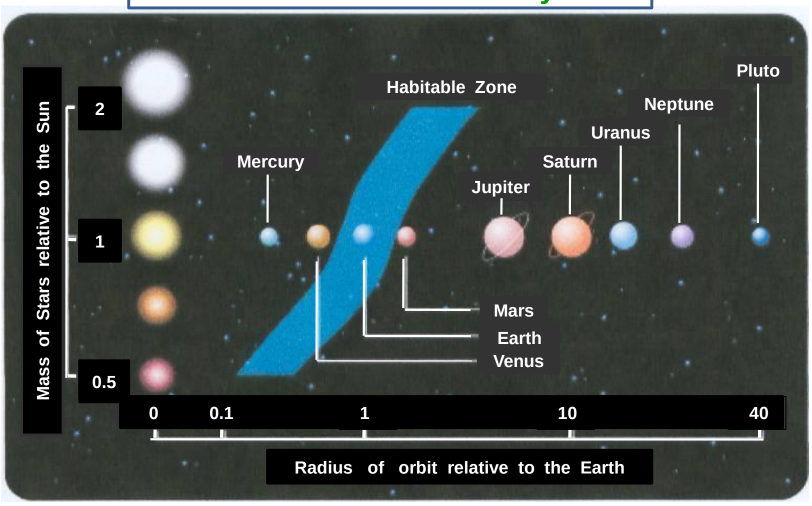
Composition of Moon's Exosphere

The Atmosphere of the Moon:

The Moon has no Atmosphere in the propre meaning of the word; it has only an Exosphere (a thin atmosphere-like sheath which surrounds the Moon). It consists of approximately equal parts of Helium (He), Neon (Ne), Hydrogen (H_2) and Argon (Ar). The presence of an Exosphere is due to trapped particles from the Solar wind. A very small part arises also through degasing from the lunar interior. Of special importance is ^{40}Ar, which is produced by the decomposition of ^{40}K inside the Moon.

10-A-2-2

Habitable Zone in Solar System

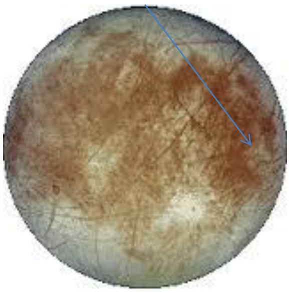


The Planets of the Solar System are shown on the central horizontal line; the blue region shows the habitable zone in the Solar System as a function of the size of five Stars. Star 1 is our Sun.

The Earth is located in the habitable zone. If the Earth would be shifted by 5% or by about 8 million km closer towards or farther away from the Sun, the simultaneous conditions for the three forms of Water (liquid, solid and gaseous) would not be fullfilled !

10-A-2-3

Jupiter's Moon Europa



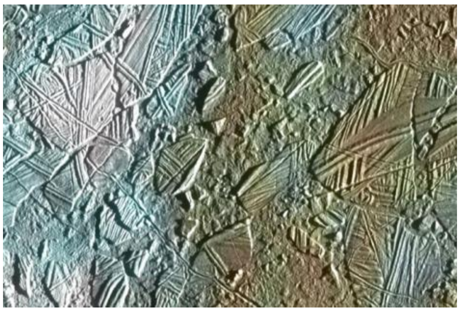
Jupiter's Moon Europa

With a diameter of 3121 km, Jupiter is the second innermost and smallest of the four large Moons of Jupiter.

Although the temperature at the surface of Europa reaches - 150 ^{0}C, it is suspected that below a crust of water ice an Ocean of water with a depth of up to 100 km could be present.

Images of the Hubble – Space Telescope provided evidence to the presence of a very thin Atmosphere of oxygen with an extremely small pressure of 10^{-11} bar. It is assumed that oxygen is formed by the radiation of sunlight onto the ice crust and that water ice is decomposed into oxygen and hydrogen. The light-weight hydrogen escapes while the heavy oxygen is hold in place by gravity.

Size comparision between the Moon Europa (bottom left), Earthmoon (top left) and Earth (to scale).



Enlarged view of «Conamara Chaos» with Ice floes as large as to 10 km.

10-A-2-4

Remarks: Oblique axis of rotation of Uranus

At p. 448 we have discussed the oblique axis of rotation and the corresponding consequences for the seasons. Uranus is the only Planet of the Solar system, the axis of rotation of which form an angle of 98^0 with respect of the orbital plane. All the other 7 Planets have relatively small angles with respect to the vertical direction of the orbital plane; for the Earth, this angle is only 23.44^0 (s. p. 429).

What is the reason for the unusually large inclination of the axis of rotation of Uranus? For the time beeing, there is no clear answer to this question. Two hypothesis have, however, put forward:

1) Uranus has been hit by an unusually large plaenetoid, thereby changing the rotation axis from its original normal direction to the present inclined direction. A similar collision occured probably in the history of our Earth, thereby generating the Moon. The difference in the results was probably due to the different geometry, i.e. a head-on collision for the Earth but a grazing collision for Uranus.

2) An alternative theory explains the exceptional direction of the axis of rotation of Uranus as a result of gravitational interaction: When the young and much more compact solar system was spread out, it was possible that temporary, Saturn and Jupiter were in a 2 : 1 orbital resonance relationship (*). Some models suggest that such a resonance was responsible for the change of the rotational axis.

(*) In celeestial mechanics, an orbital resonance occurs if two planets orbiting around the Sun (in this case Jupiter and Saturn) exert a gravitational fore on each other if the two orbital periods have a ratio of two small integers, for example 2 : 1.

10-A-2-5

Escape velocities v_{esc} from Planets of Solar System

The escape velocity v_{esc} of a mass m from a Planet P of Mass M_P and radius R_p can be calculated from the kinetic energy $E_{kin} = (1/2)\, m\, v^2$ and from the gravitational binding energy E_g. The gravitational force is $F_g = GM_P / R_P^2$, where G is the gravitational constant ($G = 6.674 \times 10\text{-}11\ m^3\ kg\text{-}1\ s^{-2}$) and R_P is the distance between the masses m and M_P. The gravitational binding energy is given by the integral of F_g:

$$E_g = \int_{R_1}^{R_2} F_G(R)\, dR = GM_P \int_{R_1}^{R_2} R^{-2}\, dR = -\, GM_P\, [(1/R_2) - (1/R_1)]$$

If the mass m is launched from the surface of the Planet with the escape speed v_{esc}, then $R_1 = R_P$ and $R_2 = \infty$. It then follows: $(1/2)\, m\, v^2_{esc} = GM_P/R_P$ and for the escape speed one obtains:

$$v_{esc} = \sqrt{2\, G\, M_P / R_P}\ .$$

Note that v_{esc} is independent on the escaping mass m.

The Table contains the escape speeds (minimum speeds) from the celestial bodies, including the Moon and the Sun.

The evaluation of v_{esc} has been performed without taking into account the retarding forces due to an eventually existing Atmosphere.

Celestial body	v_{esc} at equator in km/s
Merkcury	4.3
Venus	10.2
Earth	11.2
Moon	2.3
Mars	5.0
Jupiter	59.6
Saturn	35.5
Uranus	21.3
Neptune	22.3
Pluto	1.1
Sun	617.3

10-A-2-6

Thermal velocities and Escape speeds of atmospheric molecules

The root mean square velocity, v_{rms}, is given by

$$v_{rms} = \mathrm{sqrt}(3\,k\,T / m) \qquad (1)$$

Where k is Boltzmann's constant (k = 1.3806 10^{-23} kg m^2 s^{-2} K^{-1}), T the absolute temperature and m the mass of the atom or molecule. In the following we consider the velocities of oxygen (O_2)- and nitrogen (N_2)- molecules in the Atmosphere and compare these velocities with the escape speeds, i.e. with the speeds which are necessary to leave the atmosphere of the Earth. The escape speed v_{esc} is independent on the mass of the molecule and is given by

$$v_{esc} = \mathrm{sqrt}(2\,G\,M / R) \qquad (2)$$

In eq. (2), G is gravitational constant (G = 6.674 10-11 m^3 kg^{-1} s^{-2}), M is the mass of the Planet (the Earth) and R = R_E + H is the distance between the molecule and the center of the Earth (R_E = 6371 km = radius of the Earth). The molecule with mass m can escape the atmosphere of the Earth if $v_{rms} \geq v_{esc}$. We first consider the escape speeds for different altitudes H. For H = 0 (at the surface of the Earth) one finds v_{esc} = 11.19 km/s, for H = 100 km or R = 6471 km (in the Thermosphere (s. Chapter 2, Section 10.2) we find v_{esc} = 11.1 km/s and for H = 600 km (in the Exosphere) we have R = 6971 km and v_{esc} = 10.7 km/s. We see that the associated escape speeds vary only slightly in this range of altitude.

We now calculate the root mean square velocities v_{rms} of the molecules for T = 300 K and find with m(O_2) = 5.356 10^{-26} kg, m(N_2) = 4.65 10^{-26} kg and m(H_2) = 3.35 10^{-27} kg:

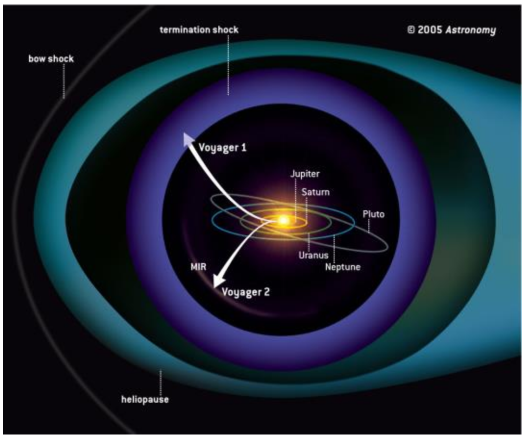
$v_{rms}(O_2)$ = 477 m/s $v_{rms}(N_2)$ = 510 m/s, $v_{rms}(CO_2)$ = 407 m/s and $v_{rms}(H_2)$ = 1'908 m/s .

These results show that $v_{rms} \ll v_{esc}$ and for this reason there will be very little change that the molecules will escape the Atmosphere of the Earth. There is, of course, a Boltzmann-type velocity distribution with velocities v > v_{rms}, but this does not change the above conclusion. [For H_2 the escape propability is considerably larger than for the other molecules which may be one of the reasons why the concentration of H_2 is vanishingly small in the Atmosphere of the Earth)].

10-A-2-7

The Heliosphere of our Solar System

The Heliosphere is a spacious, interplanetary area around the Sun, in which the solar wind (pp 353 – 358, Chapter 8) with its entrained magnetic field is effective. In this range of the solar system, the particle current of the Sun displaces the interstellar matter as far as to the Heliopause (the theoretical limit where the solar wind is limited by the interstellar medium). For electrically neutral atoms contained in the interstellar medium, it is possible that they can penetrate deeply into the Heliosphere. Besides the few particles which accomplish this goal, nearly the whole quantity of particles in the Heliosphere originates from the Sun.
While the regions near the Sun are marked by the solar wind itself as well as by the heliospheric current sheet, other phenomena become important after a distance of about 100 AU (1 AU = 1 Astronomical Unit ≈ 150 million km); this is due to the interactions with the interstellar gas: since the solar winds are moving away from the Sun with a velocity of several 100 km/s, there must exist limits after which the solar wind is decelerated and penetrates with a smaller velocity into the interstellar medium. Finally. deceleration occurs down to the «velocity of sound», v_s, in the interstellar medium ($v_s \approx$ 100 km/s). The last limit after which the solar wind does not produce any material effects is the Heliopause at a distance of 110 to 150 AU.



Because of the very large distances, the investigation of the effects proofs to be difficult (for a distance of 100 AU the travel time of a spacecraft is about 30 years !). Only the two spacecrafts Voyager 1 and 2 have reached the Heliosphere in the years 2004 and 2007; Voyager 1 at a distance of 94 AU and Voyager 2 at a distance of 84 AU.

The Heliosphere of our solar system 10-A-2-8

Doppler Technique for the Observation of Exoplanets

Explanation to the Figure of p. 463:

The Doppler technique is a good method for the discovery of new Exoplanets. It is based on the Doppler effect for the analysis of the movement and properties of the central Star and the Planet. The Star and the Planet are rotating around the commen center of mass. (s. pp 463 and 10-A-3-2).

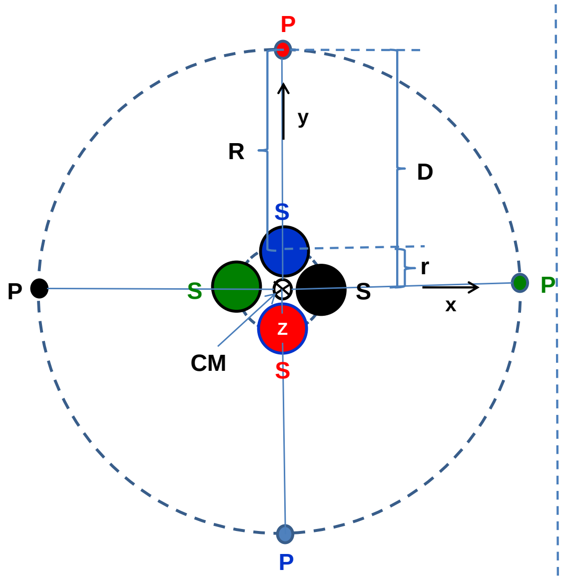
In our Solar System, all Planets and also the Sun rotate around the commen center of mass. Since the mass of the Sun is very much larger than the masses of the Planets, the center of mass is located inside the Sun! Therefore, the Sun is wobbling back and forth, causing a corresponding modulation of the spectrum of the sunlight. Now, we are not primarily interested in our Solar System but rather for the spectral displacement of other Stars in order to find out of whether these Stars are orbited by one or several Planets. If the Star moves toward us, its radiated light has a shorter wavelength, resulting in a blueshift (see blueshifted starlight in left Figure of p. 463). If, on the other hand, the Star moves away from us, its light has a longer wavelength, resulting in a redshift (see redshifted starlight in left Figure of p. 463).

The Doppler effect is often used for the investigation of extrasolar Planets. It must, however, be emphasisized that it can best be used for very massive Planets which in addition are orbiting closely around their Stars. The reason for this restriction is due to the fact, that the central Star is wobbling more strongly if it is orbited by a massive and nearby Planet, producing a larger and more easily detectable spectral shift. In fact, most of the Exoplanets which have been detected by this method have indeed a very large mass and are orbiting very closely around their Star.

In Appendix 10-A-3-2 we show the different phases of a Planet and Star, which are orbiting around its center of gravity.

10-A-3-1

Orbit of a Star S and a Planet P around Center of Mass CM



The Figure shows 4 phases of the rotation of a Planet P around its Center of Mass CM. The 4 phases are shown with 4 different colors. S and P orbit around its common center of mass ⊗ located in the origin of the coordinate system (x,y).

10-A-3-2

Let CM (⊗) be the center of mass of a Star S with mass M and let m be the mass of the orbiting Planet P, where m << M. [In reality, CM is excentric within the Star (p. 10-A-3-1); for demonstration purposes, we have located CM outside the Star S].

Let R and r be the distances between S and P and S and CM, respectively and the distance between CM and P is D = R + r.

The cener of mass is given by

$$r / R = m / M \quad (1)$$

with $R = D - r$ (2)

$$\rightarrow \quad r = (m / M)\, R = (m / M)\,(D - r) \quad (3)$$

From equation (3) it follows:

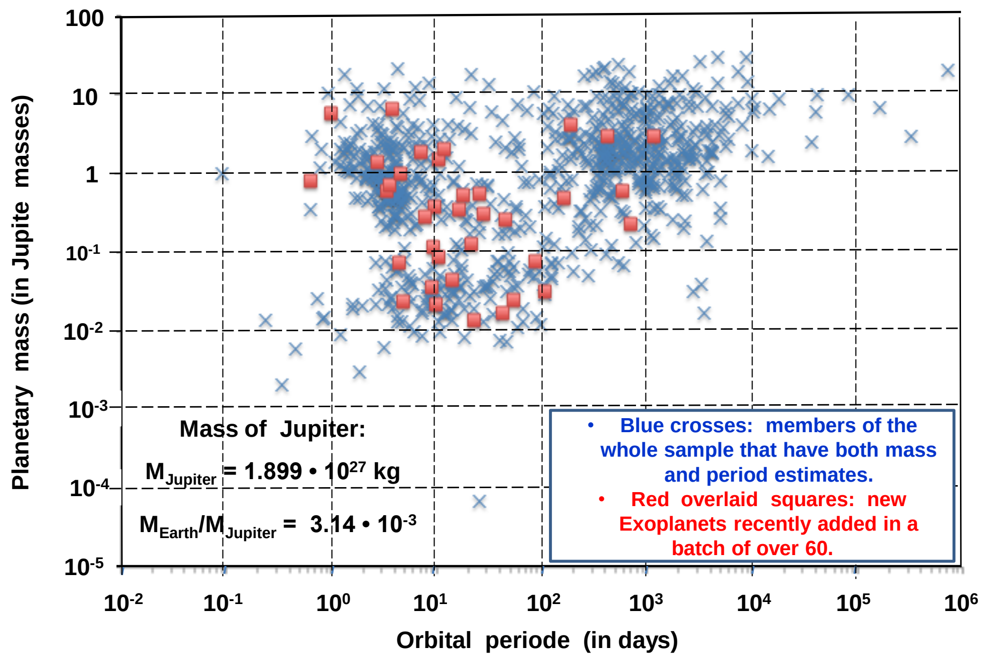
$$r = [m / (M + m)]\, D = [1 / (1 + M / m)]\, D \quad (4)$$

Since M /m >> 1 one obtains approximatively:

$$r \approx (m / M)\, D \quad (5)$$

Since m << M and r << R it follows R ≈ D, i.e. that most of the center of mass CM are located inside the Star S and are even close to the center of the Star.

Exoplanets: Planetary masses versus Orbital period

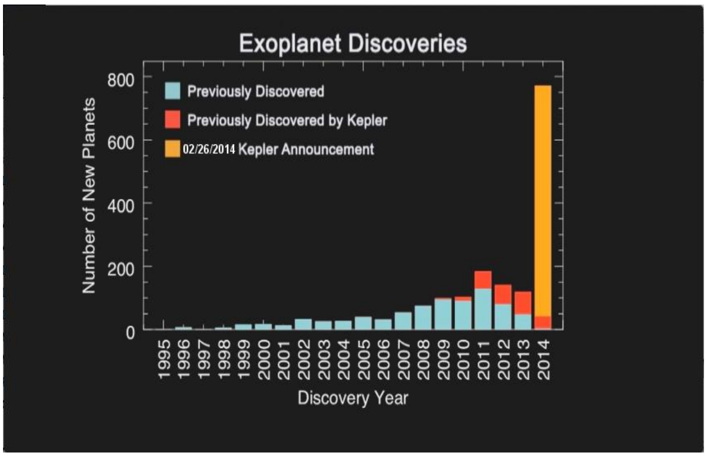


10-A-3-3

New Planets: «Verification by Multiplicity»

The discovery of new Exoplanets became possible in 2014 by a new method, called the «Verification by Multiplicity». This technique is based on the following baisis: If one images a Star with a bunch of Stars around him, the mutual gravities of each object would throw their relative orbits into a chaos. A Star with a bunch of Planets around it would, however, have a much more stable configuration. So if scientists see multiple transits of objects across a Star's face, its assumption is that it would be several Planets.

«This physical difference, the fact that you can't have multiple Star-systems that look like planetary systems, is the basis of the validation by multiplicity,» said Jack Lissauer, a planetary scientist at the «NASA Ames Research Center» who was involved in the research.



Histogram of Exoplanet Discoveries

The 715 Exoplanets shown by the yellow bar at right are orbiting 305 Stars (from NASA 26. 2. 2014). They have been observed by Kepler's Space Telescope.

These 715 Exoplanets have been found by the method of «Verification by Multiplicity».

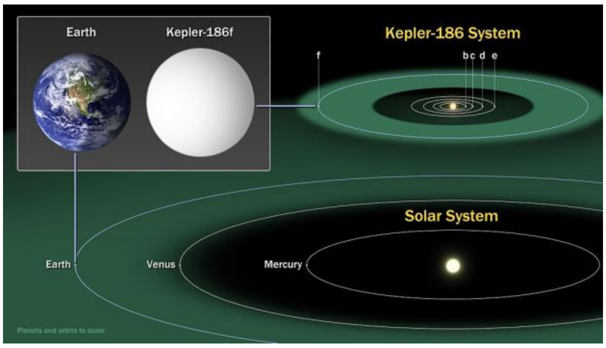
From the new Exoplanets discovered by this method, 95% are smaller than the Planet Neptune, and four of these Planets are smaller than 2.5 times the size of the Earth.

10-A-3-4

New Earth-like Exoplanet Kepler 186f - Comparision with Earth

In Section 3 (pp 467, 468; 476, 480, 481) and in Section 4 (pp 484, 489), some habitable Exoplanets have been discussed and we have made rough estimates for the number of technically intelligent civilisations (p. 476) or with observable signs of life (p. 489).

Estimates suggest that in the observable Universe about 10^{24} Planets exist (a number with a 1 and 24 zeros !). Among this giant number of Planets it would be almost a miracle if our Earth would be the only Planet with living creatures. It should, however, be realized, that all large Gas – Planets are excludet and that for the existence of Earth-like life, only the rocky Planets having a life friendly Atmosphere and liquid Water at the surface are good candidates.
A promising top candidate for an Earth-like Planet has recently be discovered by NASA. The Planet of interest is the Exoplanet Kepler 186f. Its distance from the Earth is more than 500 light-years and its diameter is only 10% larger than the diameter of the Earth. Its mass and its chemical composition are not yet known.

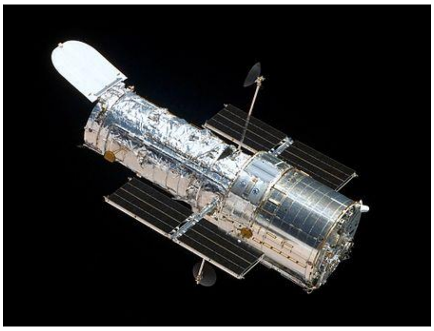


Planet Earth and Planet Kepler 186f with their orbits around the Sun and the Star Kepler 186, respectively.

The Planet Kepler 186f is quite close to its Star 186, about three times closer than the distance of the Earth from the Sun. Therefore, its orbit period is only 130 days. On the other hand, the temperature of its central Star is only about 3'500 ^{0}C, considerably lower than the temperature of our Sun. For this reason, Kepler 186f may well be located in the habitable zone of its Star. Therefore, the probability exists that the Planet has an Earth-like Atmosphere and liquid Water at its surface.

10-A-3-5

The Hubble Space Telescope



Operator:	NASA
Launch mass:	11'110 kg
Dimensions:	13.2 m x 4.2 m
Power:	2'800 watts
Launch date:	April 24, 1990
Focal length:	57.6 m
Collecting area:	4.5 m^2 .

The Hubble Space Telescope (HST) is a space telescope that was launched into low Earth orbit in 1990, and remains in obseration. With a 2.4 – meter mirror, Hubble's four main instruments observe in the near ultraviolet, visible, and near infrared spectra. The telescope is named after Edwin Hubble (s. p. 494).

Hubble's orbit outside the distortion of Earth's Atmosphere allows it to take extremely high-resolution images with neglible background light. Hubble has recorded some of the most detailed visible-light images ever, allowing a deep view into space and time. Many Hubble observations have led to breakthroughs in astrophysics, such as accurately determining the rate of expansion of the Universe.

The HST is one of the NASA's Great Observatories, along with the Compton Gamma Ray Observatory, the Chandra X – ray Observatory, and the Spitzer Telescope.

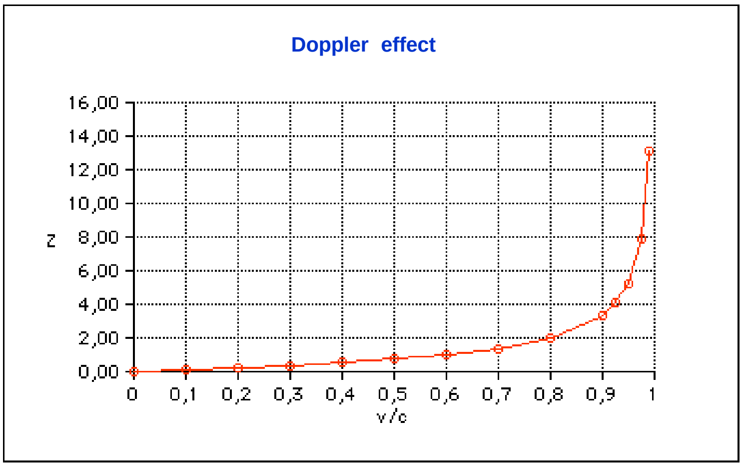
10-A-4-1

Relativistic Redshift of Light of Galaxies

If the escape velocity v is much smaller than the velocity c of light, one obtains the relative Doppler shift $z = \Delta\lambda / \lambda = v / c$ (s. p. 493). For very large velocities v, however, the relativistic time dilation must be taken into account. The velocity v(z) is then given by:

$$v(z) = H_0 \cdot d(z) = \frac{(1+z)^2 - 1}{(1+z)^2 + 1} \cdot c \qquad \text{or} \qquad d(z) = \frac{(1+z)^2 - 1}{(1+z)^2 + 1} \bullet \frac{c}{H_0}$$

$$\text{with} \qquad z = \Delta\lambda / \lambda = [(c + v) / (c - v)]^{1/2} - 1$$



10-A-5-1

References: Chapter 10

R-10-0

10.0 Atmospheres: General

R.10.0.0 **p. 405: Atmosperes of Planets and Exoplanets (Title)**

R.10.1.1 p. 406: **10.1 Atmospheres of the Planets of our Solar System (Title)**

R.10.1.2 pp 407: Atmosphere: Definion and Layers (Planets - Moons - Stares) - http://en.wikipedia.org/wili/Atmosphere

R.10.1.3 p. 408: Atmospheres of Inner Planets

a) The Inner or Terrestrial Planets - http://www.e-education.psu.edu/astro801/content/111_p4.html
b) Atmospheres of the Planets - http://www.universetoday.com/35796/atmosphere-of-the-planets/
c) Picture of Inner Solar System: www.google.ch/science (Names of Planets added by P. Brüesch)

R.10.1.4 p. 409: Atmospheree of Moons of our Solar System

a How Many Moons are in the Solar System ? - http://www.universetoday.com/15516/how-many-moons-….
b) Which Moons have Atmospheres ? www.fromquarkstoquasars.com>Missions

R.10.1.5 p. 410: Atmosphere of the outer Solar System - Giant Gas-Planets

a) Picture: www.google.ch/search (Names of Planets added by P. Brüesch)
b) Atmosphäre (Astronomie) - http://de.wikipedia.org/wiki/Atmosph%C3%A4re_(Astronomie)
c) Gasplanet - http://www.wikipedia.org/wiki/Gasplanet

R.10.1.6 p. 411: Structure and Atmosphere of the Sun

a) Windows too the Universe - The Solar Atmosphere
http://www.windows2universe.org/sun/solar_atmosphere.html
b) How the Sun Works - http://science/howstuffworks.com/sun4./htm
c) The Sun's Atmosphere - http://www.astronomy.ohio-state.edu/~ryden/ast/62_1/notes4.html
d) Space tornado power the atmosphere of the Sun
http://www.sciencedaily.com/release/2012/06/120628131402.html
e) Sonne - http://de.wikipedia.org/wiki/Sonne
f) Aufbau und Aktivität der Sonne - http://www.helles-koepfchen.de/artikel/2895.html
g) Lexikon - http://www.redshift-live.com/de/kosmos-himmelsjahr/lexikon/Sonnenatmosph%C3%A4re.htm
h) Sonne – LEIFI Physik - http://www.leifiphysik.de/themenbereiche/sonne
Bild links: Space tornadoes power the atmosphere of the Sun
http://phys.org/news/2012-06-space-tornadoes -power-atmosphere-sun.html

R-10-1

R.10.1.7 p. 412: Solar System: Distances, Masses and Revolution Periods of the Planets

a) (Found under images in www.google.search: Images)
Figure Text translated from German to English by P. Brüesch
b) Why do the planets go around the Sun?
http://spaceplace.nasa.gov/review/dr-marc-silar-system/planet-orbits.html
c) Ecliptic Plane - http://hyperphysikcs.phy-astr.gsu.edu/hbase/eclip.html
d) Orbital inclination - https://en.wikipedia.org/wiki/Orbital_inclination
e) Ecliptic - https://en.wikipedia.org/wiki/Ecliptic
f) Ian Stewart: «The Great Mathematical Problems» - Copyright @ Joat Enterprices, 2013
Chapter 8: Orbitales Chaos - The Three-Body Problem – Contains also a discussion of the orbits of the Planets
g) Die Welt der Planeten - Google Books - Max Wilhelm Meyer - http://books.google.ch/books?isbn=3846072516
h) «Gemeinsame Bahnebene der Planeten des Sonnensystems» - Die Ekliptik - John Cirillo

R.10.1.8 p. 413: Planet Tables

a) Planeten-Tabelle: Astrokramkiste - http://www.astrokramkiste.de/planeten-tabelle
b) Planet Tables - http://www.astromynotes.com/tables/tablesb.htm
c) Observations of the Magnetic Fields Inside and Outside the Solar System: From Meteorites….
By Jacques P. Vallé - http://ned.ipac.caltech.esu/level/5March03/Vallee_contetns.html (Section 2.2)

R.10.1.9 p. 414: Velocities and distances of the Planets from the Sun

a) Solar System Data - Hyper Physics - http://yperphysics.phy-astr.gsu.edu/hbase/solar/soldata.html
b) Astrokramkiste - www,astrokramkiste.de/planeten-geschwindigkeit
For clarity, the Figure descriptions have been translated to English and slightly modified).
c) Keplersche Gesetze - http://de.wikipedia.org/wiki/Keplersche_Gesetze
d) Astronomische Daten - www.keplerstern.de/Berechnungen/Grundlagen_2A-pdf
The data for the semi-axes a and b of the ellipses show that the excentricities are small. With the exception of the Planets Mercury and Mars, also the velocities in the perihelion and aphelion are only weakly different.

R.10.1.10 p. 415: Most important Gases of our Planets
Daten summarized from: www.astrokramkiste.de/planeten-tabelle Iranslated to Englisch by P. Brüesch

R.10.1.11 p. 416: Numerical Excentricities of Orbits of Planets around the Sun
www.keplerstern.de/Berechnungen/Grundlagen_2A-pdf - Histogram constructed from numeical Data by P. Brüesch

R-10-2

10.2 The Planets of our Solar System: Properties of the Atmospheres

R.10.2.0 p. 417: **10.2 The Planets of our Solar System: Properties and Atmospheres (Title)**

Liste der Planeten des Sonnensystems
(List of the Planets of our Solar System)
https://de.wikipedia.org/wiki/Liste_der_Planeten_des_Sonnensystems

R.10.2.1.0 pp 418 – 422:: **10.2.1 The Planet Mercury: Title (The Roman messanger of the Gods)**

R.10.2.1.1 p,. 419 : Mercury (Planet)
a) Mercury (planet): http://en.wikipedia.org/wikiMercury_planet
b) Merkur (Planet): http://www.wikipedia,org/wiki/Merkur_(Planet)

R.10.2.1.2 p. 420: Elliptic Orbit of Planet around the Sun

a) Scale Figure of Mecury Orbit (from Literature Data: P. Brüesch) (Semi-axis a and b, excentricity e, numerical excentricity ε, Distances from Sun and average velocity).
b) Merkur - http://www.ajoma.de/html/merkur,html

R.10.2.1.3 p. 421: Mercury 's Atmosphere– 1

a) a) http://www,space.com/18644-mercury_atmosphere.html
b) Mercury (Planet) : http://en.wikipedia.org/wikiMercury_planet
c) Mercury Facts - Nine Planets - http://nineplanets.org
c) Text aus: «Ein Rätsel der Merkur-Atmosphäre gelöst»

R.10.2.1.4 p. 422: Mercury - Atmosphere – 2

a) Atmosphere of Mercury - http://en.wikipedia.org/wiki/Atmosphere_of_Mercury
b) Ein Rätsel der Merkur – Atmpsphäre gelöst
http://www.raumfahrer.net/news/astronomie/04062009203212.shtml
c) Mercury's Atmosphere - http://www,space.com/18644.mercury-atmosphere.html
d) Figur: Zusammensetzung der «Atmosphäre»
Astrokramkiste – Atmosphäre Merkur - www.astrokramkiste.de/merkur-atmosphaere
e) Bild: Oberfläche von Merkur - www,astrokramkiste.de/merkur

R-10-3

R.10.2.2.0 p. 423: 10.2.2 The Planet Venus (Title) - Paintings of Sandro Boticelli (1445 – 1510)

R.10.2.2.1 p. 424: The Planet Venus – General

a) Venus - https://en.wikipedia.org/wiki/Venus
b) Venus Facts – Interesting Facts about the Panet Venus
http://space-facts.com/venus/
c) Venus (Planet) - http://de.wikipedia.org/wiki/Venus_(Planet)
d) Bild links: aus: www.google.search: Images
e) Bild rechts: Venus – Erde: Grössenvergleich: www.gppgle.ch/search - image

R.10.2.2.2 p. 425: More Data and Properties of Venus

a) Venus – Wikipedia, the free encyclopedia - https://en.wikipedia.org/wiki/Venus
b) Ref. R.10.2.1.c): Venus (Planet)

R.10.2.2.3 p. 426: The Layers of the Atmosphere of Venus

a) Atmosphere of Venus - http://en.wikipedia.org/wiki/Atmosphere_of_Venus
b) Venus …Earthh's not really sister planet
http://cde.nwc.edu/SC12108/course_documents/solar_system/innerplanets/venus/venus.htm
(Figur: Temperatur – Höhe – Druck: p. 5 in diesem Artikel)

R.10.2.2.4 p. 427 The Composition of the Venus Atmosphere

a) Venus - Overview - Atmospjere - http://burro.astr.ewru.edu/stu/advanced/beus.hrml
b) Picture from: www.google.ch/search unter «Composition of Venus Amosphere»

R.10.2.3.0 p. 428: 10.2.3. The Planet Earth - Gaia

R.10.2.3.1 p. 429: The Earth

a) Earth; https://en.wikipedia.org/wiki/Earth
b) Erde: http://de.wikipedia.org/wiki/Erde
c) Gaia - Encyclopedia Mythica - http://www.pantheon.org/articled/g/gaia.html - Picture from Google

R-10-4

R.10.2.4.0 p. 430: 10.2.4. The Planet Mars (Title)

R.10.2.4.1 pp 431 - 434: Mars

a) Mars - http://en.wikipedia.org/wiki/Mars - Picture: p. 431
b) Mars (Planet) - http://de.wikipedia/wiki.org/wiki/Mars_(Planet) - Pictures: pp 431, 432
c) Atmosphere of Mars - http://en.wikipedia.org/wiki/Atmosphere_of_Mars
d) Atmosphere of Mars - http://www.davoddarling.info/encyclopedia/M/Larsatmos.htmml - Picture: p. 433
e) Mars - Overview - http://burro.astr.cwru.edu/stu/advanced/mars.html --Picture: p. 434
f) Atmosphere of Mars - http://www.universetoday.com/22587/atmosphere-of-mars/ - p ≈ 6 hPa

R.10.2.4.2 p. 433: The Atmosphere of the Planet Mars

Atmosphere of Mars - http://www.daviddarling.info.encycopedia/M/Marsatmos.html
Text and Graph with Temperature and Pressure ae a function of altitude

R.10.2.4.3 p. 434: The Atmosphere of the Planet Mars

a) Atmosphere of Mars - http://en.wikipedia.org/wiki/Atmosphere_of_M
b) Mars: Figur zur Atmosphäre: Elemental Composition of Mars
http://burro.astr.cwru.edu/stu/advanced/mars.html
c) Mars (Planet) - http://de.wikipedia/wiki.org/wiki/Mars_(Planet)
d) Atmosphere of Mars and the Search for Life
Lecture 14: The Atmosphere on Mars
Prof. Robert L. Nowack
Tabelle der chemischen Zusammensetzung
http://web.ics.purdue.edu/~nowack/geos105/lect14-dir/lecture14.html

R.10.2.5.0 p. 435: 10.2.5 The Planet Jupiter (Title)

R.10.2.5.1 p. 436: General Data and Properties
Jupiter (Planet): http://de.wikipedia.org(wiki/Jupiter_(Planet)

R.10.2.5.2 p. 437: Jupiter: The Atmosphere of Jupiter - 1
Jupiter: http://en.wikipedia.org/wiki/Jupiter (in English)

R-10-5

R.10.2.5.3 p. 438: The Atmosphere of Jupiter – 2

a) http://burro.astr.cwru.esdu/stu/advanced/iupiter.html (left-hand Picture)
b) Atmospheres of Jupiter and Saturn – Vertical Structure (Bild rechts)
http://zebu.uoregon.edu(~/imamura/121/lecture-13/iupiter_atmosphere-htm
c) Jupiter: Giant of the Solar Planets - http://pages.uoregon.edu/jimbrau/astr121/Notes/chapter11.html
(Right-hand picture: Figure retouchiert;);
Picture from «Layers of Jupiter's Atmosphere» → Pictures
d) Welcome to Space - http://www.welcometospaceblocg.com/2012/01/jupiter.html

R.10.2.6.0 p. 439: **10.2.6 The Planett Saturn (Title)**

R.10.2.6.1 p. 440: The Planet Saturn – General

a) Saturn - http://en.wikipedia.org/wiki/Saturn
b) Saturn - Rings, Moons, Exploration – Crystallinks
http://www.crystallinks.com/saturn.html
c) Saturn (Planet) - http://de,wikipedia.org/wiki/Saturn_(Planet)

R.10.2.6.2 p. 441: Structure and chemical composition of Saturn

a) Inside Saturn - Atmosphere and panetary composition
Top image: Atmosphere and Planetary Composition
http://www,entschantedlearning.com/subjects/astronomy/planets/saturn/saturninside.shtml
b) Lower picture: Chemical composition of Saturn - http://burro.astr.cwru.edu/stz/advanced/saturn.html

R.10.2.6.3 p. 442: The Atmosphere of Saturn

a) Saturn's Atmospheric Composition
Picture on the left side and Text: Saturn's Atmospheric composition
http://www.castlerock.wednet.edu/HS/stello/Astronomy/TEXT/CHAISSON/BG307/HTML/BG3075.htm
(The three pairs of horizontal and vertical blue dashed lines have been added by P. Brüesch (s. p. 442).
b) Saturn's Atmosphere - (right-hand Picture and Text)
http://astronomy.nju.edu.cn/~lixd/GA/ATA/ATA12/HTML/AT41202.htm

R-10-6

R.10.2.6.4 p. 443: South Pol Storm and hexagonal Jet stream at North Pole

a) Spectacular storm rages on Saturn's South Pole
http://www.newscientist.com/article./dn/10499-spectacular-storm-rages-on-saturns-south-pole?feedId=cassoni/hugens_rss20
b) Riesensturm am Saturn-Südpol - http://www.astronews.com/news/artikel/2006/11/0611-010.shtml
c) Saturn's hexagon - http://en.wikipedia.org/wiki/Saturn's_hexagon
d) Has the mystery of Saturn's 20'000 mile wide hexagonal storm solved ?
Researchers believ it could be controlled by a giant jet stream
http://www.dailymale.co.uk/sciencetech/article-26001784/Has-mystery_Saturns-hexagonal-storm-solved_Researchers-believe-extraterrestrial-jet-steam.h…
e) Das Hexagon am Saturn: im Labor reproduziert !
http://scienceblogs.de/astrodicticum-simple/2010/04/10/das hexagon-am-saturn-im-labor-reproduziert/

R.10.2.6.5 p. 444: The Rings of Saturn

a) NASA - Saturn's A Ring From the Inside Out - Cassini: Unlocking Saturn's Secret
http://www.nasa.gov/mission_pages/cassini/multimedia/pia05075.html
(contains picture with ring system)
b) Saturn: Rings - https://solarsystem.nasa.gov/planets/profile.cfm?Object=Saturn&Display_Rings
c) Rings of Saturn - http://en.wikipedia.org/wiki/Rings_of_Saturn
d) Planet Saturn - Eine Welt der Ringe und Monde
http://www.hoerlitzer-sternfreunde.de/html/saturn.html
e) Ringe des Saturns - http://de.wikipedia.org/wiki/Ringe_des_Saturn

R.10.2.7.0 **p. 445: 10.2.7 The Planet Uranus (Title**

R.10.2.7.1 p. 446, 447: General – Structure – Chemical Composition

a) Ice giants - https://en.wikipedia.org/wiki/IIce_giant
b) Uranus: http://en.wikipedia.org/wiki/Uranus
c) Uranus: http://burro.astr.cwru.edu/advanced/uranus.html
d) Inside Uranus - http://www.enhancedlearning.com/subjects/astronomy/planets/uranus/iranusinside.shtml
e) Uranus: (Planet) - http://de.wikipedia.org/wiki/Uranus_(Planet)

R-10-7

R.10.2.7.2 p. 448: Rotation axis Orbit - Extreme Seasons

a) Uranus - TEACH Astronomy - http://m.teachastronomy.com/astropedia/article/Uranus
b) Uranus: The Magician - http://www.physics.purfue.edu/astr2631/SStour/uranus.html
c) Chapter 13.3 Uranus and Neptun in Bulk - Masses and Radii - Rotation Rates http://lifeng.lamost.org/courses/astrotoday/CHAISSON/AT313/HTML/AT31303.HTM
d) Der Planet Uranus - http://home.arcor.de/jensss/Uranus.html
e) URANUS: http://www.gutekunst-astro-bio.de/Uranus.html

R.10.2.7.3 p. 449: Atmosphere of the Planet Uranus– 1

a) Atmosphere of Uranus - https://en.wikipedia.org/wiki/Atmosphere_of_Uranus
b) Atmosphere of Uranus - http://www.universetoday.com/18859/atmosphere-of-uranus/
c) Uranus (Planet) - Text und Bild links: Natural color of Uranus - http://de.wikipedia.org/wiki/Uranus_(Planet)

R.10.2.7.4 p. 450: Atmosphere of the Planet Uranus – 2

a) Uranus - http://en/wikipedia.org/wiki/Uranus
b) Atmosphäre des Uranus – Astropage.eu - http://www.astropage.eu/index.php?page_uranusatmosphere http://www.astropage.eu/index.php?page_uranusatmosphere
c) Uranus (Planet) - Troposphäre und Stratosphäre - http://de.wikipedia.org/wiki/Uranus_(Planet) (Text of p. 450)

R.10.2.7.5 p. 451: Atmosphere of the Planet Uranus- 3 and Ring-system

a) Uranus' Thermosphere - http://www.windows2universe.org/uranus/atmosphere/U_atm_structure_thermo.html
b) Uranus' Thermosphere Temperature Profile - http://www.windows2universe.org/atmosphere/U_thermosphere_2..
c) Uranus: Moons - http://solarsystem.nasa.gov/planets/ptofile.cfm?Object=Uranus%Display=Sats
d) Thermosphäre und Korona (Text) - http://de.wikipedia.org/wiki/Uranus_(Planet)

R.10.2.8.0 **p. 452: 10.2.8 The Planet Neptune**

R.10.2.8.1 p. 453: The Planet Neptune - General

a) Neptune - http://en.wikipedia.org/wiki/Neptune
b) Neptun (Planet) - http://de.wikipedia.org/wiki/Neptun_(Planet)

R.10.2.8.2 p. 454: Neptune's Interior and chemical composition

a) Text: Reference R.10.1.8.1 - a)
b) Neptune's Interior: Upper Picture - https://solarsystem.nasa/gov./multimedia/display.cfm?ID=283
c) Neptune - Lower Picture: «Neptunian Elemental Composition» www.burro.astr.cwru.edu/stu/advanced/neptune.html
d) Der Aufbau von Neptun - http://www.hs.uni-hanburg.de/DE/Ins/Bib/neptun.html

R.10.2.8.3 p. 455: Atmosphere of Planet Neptune – 1

a) http://astronomyoneline.org/SolarSystem/NeptuneIntroduction.asp?Cate=SolarSystem&SubCate= Neptune&SubCate2=NT01
AstronomyOnline.org: Figur der Temperatur als Funktion der Höhe: T(h)
b) Neptun's Atmosphere: Composition, Climate & Weather
Text zu Figur von T(h) - www.space.com/18922-neptune-atmosphere.html

R.10.2.8.4 p. 456: Atmosphere of Planete Neptune – 2

a) Neptune – Voyager 2
Left-hand picture; contrast- enhanced image - April 1989
nssdc.gsfc.nasa.gov/imgcat/html/object-pagelvg2-p34595.html
b) Atmosphere of Neptune: Text zu p. 456: http://www.universetoday.com/21584/atmosphere-of-neptune
c) Neptune's Atmosphere and the great dark spot
http://www.enhancedlearning.com/subjects//astronomy/planets/neptune/atmosphere.shtml
d) A look at what Neptune's Atmosphere is made of
http://www.windows2universe.org/neptune/atmospjere/N_atm_compo_overview.html
e) Planet der wilden Stürme : www.goerlitzer-sternfreunde.de/html/neptune.html (Bild rechts auf p. 456)

10.3 Exoplanets: History and Methods of Operation

R.10.3.1 Exoplaneten: Die Suche nach einer zweiten Erde
Sven Piper - 2. Auflage - Springer – Spektrum - 2011, 2014 (Sachbuch)

R.10.3.2 Elefanten im All - Unser Platz im Universum - Ben Moore
(Aus dem Englischen von Friedrich Griese und Monika Niehaus)
Copyright @ 2012 by Klein & Aber AG Zürich – Berlin

R.10.3.3 Exoplanet Atmospheres: Physical Properties - Sara Seager - Princeton University Press – 2014

R.10.3.4 a) Our Mathematical Universe - Max Tegmark - Penguin Books (2014)
b) Unser Mathematisches Universum - Max Tegmark - Ullstein (2014)

R.10.3.0.1 p. 458: Observation of Stars and the Surch of Exoplanets (Title)

R.10.3.1.1 p. 459: L'Univère populaire

a) Camille Flammarion https://en.wikipedia.org/wiki/Camille_Flammarion
b) Flammario engraving - https://en.wikipedia.org/wiki/Flammarion_engraving

R.10.3.1.2 p. 460: Giordano Bruno / Die Supernova of 1572

a) Libertes Philosophica: Giordano Bruno - visionary and heretic
https://forteanatheist.wordpress.com/2013/06/02/libertes-philosophica-giordano-bruno-visionary-and-heretic/
b) A Spotlight on the Giordano Bruno Society - http://www.thethinkersgarden.com
c) Giordano Bruno - http://de.wikipedia.org/wiki/Giordano_Bruno
d) Supernova (SN) von 1572 - Bild des Überrestes der Supernova (SN) 1572
http://en.wikipedia.org/wiki/SN_1572
e) Supernova - http://de./wikipedia.org/wi^ki/Supernova

R.10.3.1.3 p. 461: Astronomy in the 17th and 18th Century

a) Reference R.10.3.1 (pp 7 – 17)
b) Vom Augenrohr zum Weltraumteleskop - Jahr der Astronomie - Berliner Zeitung (31.8.2015)
http://www.berliner-zeitung.de/archiv/jahrjahr-der-astronomie--vor vierhundert Jahren-bewiesen-galileo-galilei.
und johnnes-kepler--dass-die-Erde-im-die…

R-10-10

R.10.3.1.4 p. 462: Importance of Parallax in Astronomy - Determination of the distance between the Sun and a Star

a) Astronomy 101 Specials: Measuring Distance via the Parallax Effect
http://www.eg.bucknell.edu/physics/astronomy/astr101/specials/parallax.html
b) Distance measurement in Astronomy
http://www.schoolphysics.co.uk/age14-16/Astronomy/text/Measuring _astronomical_distances/index.html
c) Stellar Parallax - HyperPhysics****Astrophysics - by R. Nave
Distance Measurement in Astronomy – HyperPhysics
http://www.hyperphysics.phy-astr.gsu.edu/hbase/…/distance.html...
d) How do astronomers measure the distance to Stars ? Is it accurate ?
e) from: Reference R.10.3.1 - Kapitel 1 . Geschichte der Planetensuche - p. 17
f) Der Sternhimmel ist dreidimensional - http://news.astronomie.info/sky/200606/thema.html
g) Picture and Text - http://www.avgoe.de/astr/Tei104/Entfernung.html
h) Angle Conversions - How to convert degrees to radians or radians to degress
http://www.teacherschoise.com.au/maths_library/angles/angles.htm
i) Winkel in Grad, Bogenminute und Bogensekunde - http://www.claus-schieber.de/astro/def/g/grad.htm

R.10.3.1.5 p. 463: Discovery of Exoplanets with the help of the Doppler - Effect
Text of right-hand picture improved for better readability
a) Doppler spectroscopy - https://en.wikipedia.org/wiki/Doppler_spectroscopy
b) Extrasolar Planets - http://lasp.colorado.edu/education/outerplanets/exoplanets.php
c) Die Suche nach extrasolaren Planeten
Die Radialgeschwindigkeitsmethode - http://www,corot.de/german/Exoplanet/Detektionsmethide.html
d) Planet 51 Pegasi b - http://de.wikipedia/org/wiki/51_Pegasi:b
e) Reference R.10.3.1 - pp 17, 32, 36

R.10.3.1.6 p. 464: The Transit-Method

a) Transit Method – Las Cumbres Observatory - http://lcogt.net/spacebook/transit-method
b) New 15 Earth-mass planet discovered with the new Transit Timing Variation Method
with Telescopes in Jena/Germany and Rozhen/Bulgaris - http://www.astro.uni-jena.de/wasp-3/
c) Magnitude (astronomy) - http://en.wikipedia/org/wiki/Magnitude_(astronomy)
d) Aus den Herzen der Sterne zu fernen Welten
http://www.uni-koeln.de/~lcarone/german/Exoplanet/Transitmethode

R-10-11

R.10.3.1.7 p. 465: Transit-Method and Resonance

a) Orbital resonance - http://en,wikipedia,org/wiki/Orbizaö_resonance
In celestial mechanics, an orbital resonance occurs when two orbiting bodies exert a regular, periodic gravitational influence on each other, usually due to their orbital periods being related by a ratio of two small integers
b) WASP-3 - http://en.wikipedia.org/wiki/WASP-3
c) WASP-3b - http://en.wikipedia.org/wiki/WASP-3b
d) Planet WASP-3c - http://exoplanet.eu/catalog/wasp-3_c/
e) New 15 Earth-mass planets discovered with the new Transot Time Variation method with telescopes in Jena/Germany and Rozhen/Bulgaria - http://www,astro.uni.jena/wasp-3
with Figure of Modell for WASP-3 – Planet
Figur von P. Brüesch zur Veranschaulichung durch Einfügung von Radien und Geschwindigkeiten ergänzt.
f) Welt der Physik: Mini. Exoplanet mit neuer Methode entdeckt
www.weltderphysik.de/de/.../mini.exoplanet.mit.neuer-methode-entdeckt/

R.10.3.2.0 p. 466: Discovery and Systematics of Selected Exoplanets (Title)

R.10.3.2.1 p. 467: Exoplanets in in the habitable Zone

a) NASA's Kepler Marks 1'000th Exoplanet Discovery; Uncover more small Worlds in habitable Zone
https://eee.nasa.gov/press20/2015/January/2015/january/nasa-s-kepler-marks-1000h-exoplanets-discovery...
b) Kepler Team Finds System with Two Potentially Habitable Planets
by Nancy Atkunson on April 18, 2013
http://www.universetoday.com/101489/kepler-team-finds-system-with-two-poteentially -habitable-planets/
(Text with diagram of habitable Zone)
c) Exoplaneten in der habitablen Zone fremder Sterne
http://www.raumfahrer.net/news/astronomie/19042013200621/shtml
d) Stern Kepler-22 http://de.wikipedia.org/wiki/Kepler-22
e) Stern Kepler-62: http://de.wikipedia.org/wiki//Kepler-62
f) Stern Kepler-69: http://de.wikipedia.org/wiki/Kepler-69

R.10.3.2.2 p. 468: Comments to Exoplanets in the habitable zone:
s. References in R.10.3.2.1)

R-10-12

R.10.3.2.3 p. 469: Exoplaneten: Radius as a function of mass for selected Exoplanets
Figure from: http://www,mpia,de/Public/menu_q2,php?Altuelles/PR/2013/PR_2013:05/PR_2013_05_de.html

R.10.3.2.4 p. 470: Exoplaneten: Comments to p. 469

a) Reference R.10.3.2.1 b), p. 467
b) Kepler-62 - http://en.wikipedia.org/wiki/Kepler-62
c) NASA's Kepler Discovery – Its Smallest «Habitable Zone» Planets to Date (April 18, 2013)
http://www.nasa.gov/mission_pages/kepler/news//kepler-62-kepler-69.html#.Ve6TP5Y98Yo
Contains information about Kepler-62e, Kepler-62f and other small «Habitable Zone» Planets
d) Kepler-62f - https://en.wikipedia.org/Keüler-62f

R.10.3.2.5 **p. 471: Our Milky Way Galaxy (Title)**

R.10.3.2.6 pp 472 - 474: The Milky Way Galaxy

a) A Map of the Milky Way - http://www.atlasoftheuniverse.com
[Found under «The Milky Way - «Bilder»]
b) Astro - Info - http://www,wirzroland.ch/astr_info.htm
c) The layered Milky – Way Galaxy and Classification of Galaxies
d) Milky Way - https://en.wikipedia.org/wiki/Milky_Way
[This is an outstanding Overview about the subject !]
e) 10 Facts About the Milky Way - http://www.universetoday.com/22285/facts-about-the-milky-way
f) Das Milchstrassensystem - http://home.arcor.de/hpj/Weltall/Milchstrasse.html

R.10.3.2.7 p. 475 : Das Fermi – Hart Paradoxon

a) Fermi-Paradox: http://en.wikipedia.org/wiki/Fermi-paradox
b) An Explanation for the Absence of Extraterrestrials on Earth
Micharl H. Hart; Q. Jl R. astr. Soc. (1975) **16**, 128 – 1335
The Drake Equation versus the Fermi Paradox: Is Ther Intelligent Life out There? (April 2013)
http://www.noeticscience.co.uk/the-drale-eqiation-versus-the Fermi-paradox-is-there-intelligent-life-out-there
c) The Fermi Paradox: An Approach Based on Percolation Theory
Geoffrey A. Landis – NASA - http://www.geoffreylandis.com/percolation,htp/_
d) Fermi-Paradoxon: http://de.wikipedia.org/wiki/Fermi-Paradoxon

R-10-13

R.10.3.2.7 (cont.) e) p. 475: The Fermi Paradox: An Approach Based on Perculation Theory
Geoffrey A. Landis
NASA Lewis Research Center, 302-1; Cleveland, OH 44135.U.S.A
Published in of the British Interplanetary Science, London, Volume 51, p. 163 - 166 (1998)
«I proposes a model for the problem based on the assumption that long-term colonization of the Galaxy proceeds via «percolation» process similar to the percolation problem which is well studied in condensed-matter physics».

R.10.3.2.8 p. 476: The Drake equation and the Seager equation

a) Drake equuation - http://en.wikipedia/org/wiki/Drake_equation
b) Drake-Gleichung - http://de.wikipedia.org/wiki/Drake-Gleichung
c) Intelligent Life in the Universe - http://www2.astro.psu.edu/users/dfox/A001/Notes/lec37.html
(Contains 58 Literature citations and 9 «External links»)
d) Ref. R.10.3.1: pp 152. 153 in this Book
e) Ref. R.10.3.2: pp 220, 221 in this Book
f) A New Equation Reveals Our Exact Odds of Finding Alien Life…
The Seager Equation - i09.com/what-a-brand-new-equation-eveal--
[Ergebnisse beruhen auf den 30'000 entdeckten Sternen mit ihren Exoplaneten, die mit dem «Kepler Space Telescope» beobachtet wurden, also nicht auf den ca. 200 x 10^9 Sternen der Milchstrasse.
Seager studiert die **Atmosphären** von Exoplaneten. Suche von Exoplaneten mit Atmosphären, welche Gase wie Sauerstoff, CO_2 und Stickstoff enthalten; (s. auch pp 484, 485; 489].
g) The Drake Equation versus the Fermi Paradox: Is There Intelligent Life out There `?
http://www.noeticscience.co.uk/the-dfrake-equation-versus-the-Fermi-paradox-is-thereintelligenz-life-out-there?

R.10.3.2.9 pp 477, 479 Planetary Masses versus Time of Discovery

a) p. 477: Systemic - http://oklo-org/_
Graph of Planetary masses vs Year of discovery (1985 – 2013)
(Observations by Doppler effectt and Transit-Method)
b) p. 479: Extrasolarer Planet
http://de.wikipedia.org/wiki(Extrasolarer_Planet (Part of Text translated to English)

R-10-14

R.10-3.2.10 pp 478, 479: Masses vs Orbital semi-major axis of Exoplanets

a) Sara Seager – Research - http://seagerexoplanets.mit.edu/research.html
Figure of p. 478: Labeling of axes and Comments to Figure from P. Brüesch
b) Exoplanet - http://en.wikipedia.org/wiki/Exoplanet
p. 8 in present contribution: «Scatterplot showing masses and orbital periods of exoplanets discovered up to 2010 (with colors indicating method of detection.
c) Exoplanet: update . http://en.wikipedia.org/siki/Exoplanet
(contains discovered Exoplanets up to 2015)
d) Exoplanet - https://de.wikipedia.org/Wiki/Exoplanet

R.10.3.2.11 p. 480: Some important Earth-like Exoplanets

a) Popular Science - The Math: What Life on Kepler.62e Would Be Like ?
http://www.popsci.com/science/article/2013-04/what-life-kepler-62f-would-be-numbers-Kepler-62e
b) Earth Similarity Index - http://en.wikipedia.org/wiki/Kepler-62e
c) List of potential habitable exoplanets - http://en.wikipedia,org/wiki/List_of_potential_habitable_exoplanets
d) PHL – Planetary Habitability Laboratory
HEC: Dara of Potential Habitable Worlds - http://phl.upr.edu/projects/habitable-exopkanets-catalog/data
e) Kepler 62e und f. Zwei erdähnliche Exoplaneten?
http://weltenwetter2013.wordpress.com/2013/04/21/kepler-62-e-und-fzwei-erdähnliche-exoplaneten
f) Kepler-62e - http://de.wikipedia.org/wiki/Kepler-62e

R.10.3.2.12 p. 481: The planetary system Kepler 62 – Comparision with Soalr Sysrem

a) Kepler-62 - http://en.wikipedia/Kepler-62
b) Kepler-62 and the Solar System - http://www.nasa.gov/content/kepler-62-and-the-solar-system/_
c) Kepler-62e: Super-Earth and Possible Water World - http://www.space.com/24129-kepler-62e.html
d) Kepler-62f: A Possible Water World - http://www.space.com/24142-kepler-62f.html?cmpid=514648
e) System mit zwei vermutlich lebensfreundlichen Exoplaneten entdeckt – 16. April 2013
http://derstandard.at/1363708472171/System-mit-zwei-lebensfreundlichen-Exoplaneten-entdeckt

R-10-15

10.4 Atmospheres of Exoplanets

R.10.4.1 Europhysics News-The Magazin of the European Physical Society - The Atmosphere of Extrasolar Planets
Vol. 45, No. 1 2014; pp 23 – 27The Magazin Of the European Physical Society
Thérèse Encrenaz – LESIA, Observatoire de Paris – F-92190 Medon, France – DOI: 10.1051/epn/2014103

R.10.4.2 Exoplanet Atmospheres: Physical Properties - Sara Seager: Princeton University Press – 2014

R.10.4.3 **p. 482: Atmospheres of Exoplanets (Title)**

R.10.4.4 pp 483 - 484: Atmosphären von Exoplaneten

a) Extraterrestrial atmospheres - http://en.wikipedia.org/wiki/Exrreaterrestrial_atmospheres
b) Atmospheric observations could reveal mass of Earth-like worlds (Januar 2014)
http://physicsworld.com/cws/article/news/2014/jan/08atmospheric-observations-could-reveal-mass-of-earth-like-worlds (contains Illustration of «Hot Jupiter before his Sun)
c) MIT EAPS: New technique measures mass of exoplanets: News & Events
Jennifer Chu at MIT News: December 19, 2013 - http://eapsweb.mit.edu/news/2013/weight-word
(Description of scientific work of Julien de Wit and Sara Seager)
d) p. 483: Atmosphere of Jupiter - http://en.wikipedia.org/wiki/Atmosphere_of_Jupiter
Definition of Thickness of Absorpthere and surface of Gas Planets
e) Exoplaneten: Ein neuer Weg zur Planetenmasse - von Robert Gast (2013)
http://www.sterne-und-weltraum.de/news/ein-neuer-weg-zurplanetenmasse/1218609
(Beschreibung der Methode zur Erforschung der Atmosphären nach Julien de Wit und Sara Seager)
(mit künstlerischer Darstellung des Planeten HD 189733b mit seiner Atmosphäre vor seinem Stern HD 189733)

R.10.4.5 p. 485: Absorption of Starlight by the Atmosphere of Exoplanets - 1

a) Reference R-10.4.4 b)
b) The Planet HD 189733 b - https://en.wikipedia.org/wiki/HD_189733_b
c) Der Planet HD 189733 b - http://de.wikipedia.org/wiki/HD_189733

R.10.4.6 p. 486: Absorption of Starlight by the Atmosphere of Exoplanets - 2

Water in the Atmosphere of extra-solar planets
http://coelsblog.wordpress.com/2014/01/08/water.in.the-atmosphere-of-solar-planets/
Figure: Absorption of Starlight by the Atmosphere of Exoplanets

R-10-16

R.10.4.7 p. 487: Zwei junge Astronomen erforschen die Atmosphären für Exoplaneten

a) Heinz Mayer-Leibnitz-Preis für Lisa Kaltenegger
http://www.mpg.de/5811190/heinz_mayer-leibnitz-preis_lisa_Kaltenegger
b) Atmosphären von Exoplaneten
Ein Interview mit Prof. Dr. Kevin Heng - [PDF] www.exoclime-net/download/file/fid/67

R.10.4.8 p. 488: Planetary Radii vs Orbit Period
Earth-size exoplanets in habitable orbits are common - The Figure has been slightly modified.
Physics Today - January 2014, pp 10 – 12 - Bertram Schwarzschild

Actual Figure from Internet - The Figure has been slightly modified..
Publication is also contained in: [PDF] www. geo.umass.edu/…/Exoplanets%20Schwar,..

R.10.4.9 p. 489: Planeten mit Biosignatur-Gasen: Astrobiologie – Sara Sieger.

a) Astrobiology: Enter the Seager Equation
by Paul Gilster on September 11, 2013 - http://www.centauri-dreams.org/?p=28976
b) The Drake Equation Revisited: Interview with Planet Hunter Sara Seager
By Devin Powell, Astrobiology Magazine / September 04, 2013
http://www.space.com/22648-drake-equation-alien-life-seager.html
c) An Astrophysical View of Earth-Based Metabolic Biosignature Gases – Review Article
Sara Seager, Matthew Schrenk, and William Bains
ASTROBIOLOGY – Volume 12, Number 1, 2012 - dspace.mit.edu/openaccess-disseminate/1721…/7307…
d) Ref. R.10.3.1: Sven Piper – Exoplaneten; Kapitel 6: pp 73 – 79
e) Ref. R.10.3.3: Sara Sieger–Exoplanet Atmospheres - Chapter Eleven Atmospheric Biosignatures; pp 229 – 236
Chapter Eleven . Atmospheric Biosignatures; pp 229 – 236
f) Sara Seager ist dem Leben im All auf der Spur
http://www.wiwo.de/technologie/sternstunde/forschung/sternstunde-sara-seager-ist-dem-leben-im-all-auf-der-spur/8471976.html
g) Extrasolare Planeten - Auf der Suche nach fremden Welten
Dominique M. Fluri, ETH Zürich - April 2012
www.physik.ethz.ch/~helm/.../DFluri_FV_Exoplaneten.pdf ; Abschnitt 4.2; Spektrale Signatur von Leben
h) An Equation to Estimate Probability of Identifying an Inhabited World the Next Decade
Sara Seager, MIT – 2013 (PDF) - www.cfa.harvard.edu/events/.../Seager.pdf

R-10-17

R.10.4.10 p. 490: The Janes Webb Space Telescope

a) James Webb Space Telescope
From Wikipedia, the free encyclopeia - http://en.wikipedia.org/wiki/James_Webb_Space_Telescope
b) James Webb Space Telescope
aus Wikipedia, der freien Enzyklopädie
http://de.wikipedia.org/wiki/James:Webb_Space_Telescope
(Bilder der Oberseite und Unterseite des James Webb Space Telescope)
c) James Webb vs Hubble – Astrodicticum simplex
http://scienceblogs.de/astrodicticum-simplex/2010/06/16/james-webb-vs-hubble

R-10-18

10.5 Galaxies and Univers

R.10.5.0 **p. 491: Galaxies and Universe (Title)**

R.10.5.1 p. 492: The observable Universe

a) Observable Univese - https://en.wikipedia.org/wiki/Observable_universe
b) How many Stars are in the Universe ?
http://www.skyandtelescope.com/astronomy-resources/how-many-stars-are-there/
c) How Many Planets Are There In The Universe ?
https://mathspace.co/learn/world-of-maths/algebra-and-units-and-modelling-18013/how-many-planets-are-there-in-the-universe-771/
d) The Universe Beyond Our Reach - (Contains Figure reproduced in this page)
http://scienceblogs.com/startswithabang/2012/12/28//the-universe-beyond-our-rach/
e) How Many Stars Are In There in The Universe ?
http://www.esa.int/Our_Activities/Space_Science/Herschel/How_many_stars_are_there_in_the_Universe
f) What is the average number of planets per star ?
https://www.quora.com/What-is-the-average-number-of-planets-per-star

R.10.5.2 p. 493 Origin and Expansion of the Universe

a) Big Bang: http://en.wikipedia.org/wiki/Big_Bang
b) Edwin Hubble - http://en.wikipedia-org/wiki/Edwin_Hubble
c) Newton Model of Expanding Universe - http://hyperphysics.phy-astr.gsu.edu/hbase/astro/expuni.html
d) BIG BANG - Autor: Simon Singh
Der Ursprung des Kosmos und die Erfindung der modernen Naturwissenschaft
Deutscher Taschenbuchverlag (2004)
e) Urknall: http://de.wikipedia.org/wiki/Urknakk
f) Die Geburt des Universums - Kapitel 1: Expansion, Strahlungs- und Materiedichte
http://www.joergreasag.privat.t-online.de/mybk4htm/chap25.htm
g) Left-hand picture: Schematic representation of the expanding Universe
http://astronomy.swinburne.edu.au/~gmackie/BigBang/universe.html
h) Right-hand picture in: The Flattness Problem – Inflation Flattens the Universe – JPEG.Image
http://archive.ncsa.illinois.edu/Cyberia/Cosmos/Flattness/Problem.html
i) The Flattness Problem - http://archive.ncsa.illinois.edu/Cyberia/Cosmos/Flattness/Problem.htm

R-10-19

R.10.5.3 p. 494: The Hubble Law

a) The Expanding Universe and Hubble's Law
http://www.physicsoftheuniverse.com/topics:bigbang_expanding_html
b) Figure: Hubble-Law: Velocity of Expansion vs. Distance
http://m.teachastronomy.com/astropedia/article/The-Hubble-Relation - (Figur von P. Brüesch leicht retouchiert)
http://en.wikipedia.org/wiki/Flatness_problem
c) The Hubble Expansion - http://astro.berkeley.edu/~mwhite/darkmatter/hubble.html
d) Das Hubble-Gesetz und kosmologische Entfernungsbestimmung - Univ. Regensburg- Fakultät für Physik)
Ausbildungsseminar zur Kosmologie – im Wintersemester 07 / 08 – Sebastian Putz
(Bild von Hubble auf p. 4)
www.physik.uni-regensburg.de/.../KosmologischeEntfernungen.pdf
e) Hubble-Konstante - http://de.wikipedia.org/wiki/Hubble-Konstante
f) Rotverschiebung - http://de.wikipedia,org/wiki/Rotverschiebung

R.10.5.4 p. 495: Raisin cake model of the Universe and Hubble's Law

a) Expanding Universe - Hubble law and the expanding Universe
Contains picture and Text to: A rising loaf of raisin bread
http://hyperphysics.phy-astr.gsu,edu/hbase/astro/hubble.html (Text and Figure slightly modified by P. Brüesch)
b) Rosinenkuchenmodell in: Das Universum
[PDF] www.tphys.uni-heidelbrtg.de/~huefner/ENTPGYS/V14-Kosmologie.pdf
c) Wim de Boer, Karlsruhe – Kosmologie VL, 25.10.2012 - Einteilung der VL
www-ekp.physik.uni-karlsruhe.de/~debour/html/…/VL2_Hubble_sw.pdf

R.10.5.5 p. 496: Big Bang and Expansion of the Universe

a) Speed of Universe's Expansion Measured Better Than Ever
http://www.space.com/17884-universe-expansion-speed-hubble-constant.html
b) Cosmic background radiation - https://en.wikipedia.org/wiki/Cosmic_background_radiation
c) Hintergrundstrahlung - https://de.wikipedia.org/wiki/Hintergrundstrahlung
d) Hydrogen – Helium Abundance (on the Universe)
http://hyperphysics.phy-astr.gsu.edu/base/astrohydhel.html
e) Singularität (Astronomie)
https://de.wikipedia.org/wiki/Singularität%C3%A4t_(Astronomie)

R-10-20

R.10.5.6 p. 497: Interstellar Gas: An extremely diluted «Atmospgere» - 1

a) Interstellar Gas Clouds - http://astronomy.swin.edu.au/cosmos/I/interstellar+gas+cloud
b) Interstellares Gas - http://www.uni-protokolle.de/Lexikon/Interstellares_Gas.html
c) The Interstellar Medium: Gas - http://spiff.rit.edu/classes/phys230/lectures/ism_gas.htm
d) Interstellare Materie - http://de.wikipeia.org/wiki/Interstellare_Materie
e) Molekülwolke - http://de.wilipedia.org/wiki/Molek%C3%BClwolke
f) Kosmische Raffinerie - Forschung / Aktuelles / 2012 / Kosmische Raffinerie (Cosmic Refinery)
http://www.mpg.de/6633008/Pferdekopfnebel - Picture: Horsehead Nebula in the Constellation Orion
g) Gigantische Chemiereaktionen: Molekulare Riesenwolken im interstellaren Raum - Molekül-Mix 3
[PDF] www.chap.ethz.ch/publicrelations/publikationen/.../NM3.5Riesenw.pdf
von Barbara Brauckmann (2002): Departement Chemie und Angewandte Biowissenschaften - ETHZ

R.10.5.7 p. 498: Ref. g) of p. 497): Gigantische Chemiereaktionen: Molekulare Riesenwolken im interstellaren Raum

[PDF] (Gigantic chemical reactions: Molecular giant Clouds in interstellar Space)
Brackmann, Barbara. Laboratorium für Physikalische Chemie – ETHZ Hönggerberg
www.chap.ethz.chpublicrelations/publikationen/.../NM3.5Riesenw.pdf
[Tabelle 1: « Das interstellare Medium aus (molekularen) Gasen und Staubpartikeln».
Konzentrationen und Temperaturen; Vergleich mit Daten der Atmosphäre an der Erdoberfläche]
(Tables with remarkes from P. Brüesch; new presentation)

R.10.5.8 p. 499: Intergallactic Gas: An extremely diluted «Atmosphere» - 2

a) Outer space http://en.wikipedia.org.wiki/Outer_space
http://en.wikipedia.org.wiki/Outer_space
b) Space and Astrophysics – Research
http://www.tp4.ruhr-uni-bochum.de/forschung.php?lang=en
c) Distant quasar illuminates a filament of the cosmic web
http://new.ucsc.edu/2014/01/cosmic-web-html
d) Galaxy filement - http://en.wikipedia.org/wiki/Galaxy_filement
e) Planck discovers filament of hot gas linking two galaxy clusters
http://phys.org/news/2012-11-planck-filament-hot-gas-linking.html
[contains picture of wispy network of clusters, filaments and voids known as the cosmic web]

R-10-21

R.10.5.8 p. 499 (cont)

f) Intergalaktisches Medium
http://de.wikipedia.org/wiki/Intergalaktisches_Medium
Philipp Richter: Professor für Astrophysik, Universität Potsdam (Deutschland)

g) Ein Ueberblick über das Arbeitsgebiet der Astrophysik II
http://www,astro.physik.uni-potsdam.de/~www/research/astro_2_de.html

R.10.5.9 p. 500: **The Little Prince**
Antoine de Saint-Exupéry
With Illustrations of the Author
Translated by T.V.F. GUFFE
PENGUIN BOOKS
Reprinted in Peguin Classics - 2000
798-0-14-118562-0

R-10-22

Appendix: Chapter 10

R-A-0-1 p. 10-A-0-1: Vincent van Gogh - «Stary Night»

R-A-1-1 p. 10-A-1-1: Goethe , Johann Wolfgang - from Faust. Prologue In Heaven - Prolog im Himmel
http://www.babelmatrix,org/works/de/Goethe_Johann_Wolfgang_von/FAUST._Prolog_im_Himmel/en/4219_Faust_Prolog_in_Heaven

R-A-1-2 p. 10-A-1-2: Kepler's Laws

a) Kepler's law of planetary motion - https://en.wilipedia.org/wiki/Kepler%27s_laws-of_planetary_morion
b) Kepler's Three Laws - https://en.wikipedia.org/.../Kepler's_law_pf_planeta...
c) Kepler's Laws - http://hyperphysics.phy-astr.gsu.edu/hbase/kepler.html
d) Deriving Kepler's Laws from the Inverse-Square Law - Micheal Fowler, Uva
http://galileo.phyx.vitginia.edu/classes/152mlfi.spring02/Leplers/laws.htm
e) Johannes Kepler (1571 – 1630) - http://de.wikipedia.org/wiki/Johannes_Lepler
f) Kepler'sche Gesetze - http://de.wikipedia.org/wiki/Keplersche_Gesetze
g) Planetenbahnen und Himmelsmechanik - http://www.labrellnet/astronomie/_sites/planetenbahnen.aspx

R-A-1-3 p. 10-A-1-3: Simplification: Circular Orbits of the Planets around the Sun - 1
Radial acceleration - https://physics.tutorvista.com/motion/radial-acceleration.html (Text and Figure from P. Brüesch)

R-A-1-4 p. 10-A-1-4: Simplification: Circular Orbits of the Planets around the Sun – 2

a) BBC – KS3 Biteseize Science – Astronomy and space science, Page 3
Right-hand Figure:
b) Radial acceleration a_r for Planets calculated from $a_r = (G\ M_S) / R^2$ calculated by P. Brüesch
c) Left-hand Figure: Radial acceleration of the Earth
Terrestrial examples for «Low Earth Orbits»: Calculations and Figure by P. Brüesch
d) Mathematics of Satellite Motion - The Physics Classroom - www.physicscsclassroom - u614C3.gif

R-A-2-1 p. 10-A-2-1: Water in the Atmosphere of jung Venus ?

a) Where is the Water on Venus ?
http://www.vanderbitt.edu/AnS/physics/astrocourses/AST101/readings/water_on_venus.html
b) Viel Wasser in der Atmosphäre der jungen Venus
Text uind Bild von: «Auf der Venus gabs tatsächlich Wasser»
http://www.uniaktuell.ubibe.ch/conzent/umweltnatur/2007/venus/index_ger.html

R-10-A-1

R-A-2-2 p. 10-A-2-2: Earth's Moon

a) Earth's Moon - http://jtgnew.sjrdesign.net/solsys_planetes_earth_moon.html
b) Is There an Atmosphere on the Moon ?
https://www.nasa/gov/mission_pages/LADEE/news/lunar-atmosphere.html#.Vd8rxpY994s
c) Mond - http://de.wikipedia.org/wiki/Mond

R-A-2-3 p. 10-A-2-3: Habitable zones in Solar System
Weisst du wieviel Planeten stehen? – Astrodicticum Simplex - Veröffentlicht von Florian Freistetter, Juni 17,20
http://sciencebloggs.de/astrodicticum-simplex(2008/0617/weisst-du-wieviel-planeten-stehen

R-A-2-4 p. 10-A-2-4: The Jupiter Moon Europa

a) Europa (moon) - http://en.wikipedia.org/wiki/Europa_(moon)
b) Europa Moon – Conamara Chaos
http://www.space-pictures.com/view/pictures-of-planets/planet-jupiter/europa-moon/europa-moon--conamara-chaos.php
c) Europa (Mond) - http://de.wikipedia.org/wiki/Europa_(Mond)
d) Europas Chaosregionen: Viel Wasser im Eis
http://www.pro-physik.de(details/news/1396501/Europas_Chaosregionen_Voel_Wesser_im_Eis.html

R-A-2-5 p. 10-A-2-5: Remarks to the oblique axis of Uranus

a) Uranus - TEACH Astronomy - http://m.teachastronomy.com/astropedia/article/Uranus
b) Orbital resonance - http://en.wikipedia.org/wiki/Orbital_resonance

R-A.2-6 p. 10-A-2-6: Thermal Velocities and Escape Speeds of Atmospheric Molecules

a) Atmospheric escape - https://en.wikipedia.otg/wiki/Atmospheric_escape
b) Escape velocity - http://en.wikipedia.org/wiki/Escape_velocity
c) Is escape velocity dependent on mass captive object ?
http://www.madsci.org/archives/1998-03/888873174.Ph.rhtml
d) Atmospheric escape of gas molecules
http://physics.stckchange.com/question/34895/atmosphere-escape-of gas-molecules
e) Struktur der Atmosphäre
www.meteo.physik.uni-muenchen.de/lehre/.../Teil_T_WS2005-04.pdf
f) Maxwell – Boltzmann – Verteilung - https://de.wikipedia.org/wiki/Maxwell-Boltzmann-Verteilung

R-10-A-2

10-A-2-7 p. 10-A-2-7: The Heliosphere of our solar system

a) Heliosphere - http://en.wilipedia.org/wiki/Heliosphere
b) Heliosphere - by Abby Cessna on June 15, 2009 - http://www.universetoday.com/32519/heliosphere/
c) Voyager: The Interstellar Mission – found under: Heliosphere of our solar system
d) Heliosphäre - http://de.wilipedia.org/wiki/Heliospj%C3%A4re
e) Aufbruch zu den Sternen
Dr. Bernd Wöbke: Presse- und Oeffentlichkeitsarbeit – Max-Planck Institut für Sonnenforschung
idw – Informationsdienst Wissenschaft - https://idw-online.de/pages/de/news22982

R-A-3-1 p. 10-A-3-1: Doppler-Technique for the search of Exoplanets
s. Reference R.10.3.1.4- c), p. 463

R-A-3-2 p. 10-A-3-2: Orbit_of_a_Star_and_a_Planet_around_Center_of_mass
Figure and Text from P. Brüesch fom Literature data

R-A-3-3 p. 10-A-3-3: Exoplanets – Planetary masses versus Orbital periode
«A Batch of More Than 60 New Planets and Development of the Mass-Period Diagram» - by Dr. T. Yaqoob (2012)
http://exoplanetsdigest.com/2012/10/07/a-batch-of-more-than-60-new-planets-and-development-of-the-mass----
Figure of: «Planetare Masse vs Umlaufperiode» von Exoplaneten

R-A-3-4 p. 10-A-3-4 New Planets: «Verification by Multiplicity»

a) Mega Discovery! 715 Alien Planets Confirmed Using A New Trick On Old Kepler Data
By Elisabeth Howell on February 26. 2014
http://www.universetoday.com/109764/mega-discovery-715-alien-planets-confirmed-using-a-new-trick-...
b) Exoplanets - http://en.wikipedia.org/wiki/Exoplanet
c) List of Exoplanets discovered using Kepler spacecraft
http://en.wikipedia.org/wiki/List_of_exoplanets_discovered_using_the_Kepler_apacecraft
Contains the Histogramm of Exoplanet Dicoveries – gold bar displays new planets «verified by Multiplicity (2014)
d) Discoveries of Exoplanets - http://en.wikipedia.org/wiki/Discoveries_of_exoplanets
e) Kepler's Last Stand - Verification by Multiplicity - http://lostintransits.wordpress.com/ -
f) Kepler: 715 neue Exoplaneten entdeckt (27. Februar 2014 von Michael Kahn)
www.scilogs.de/go-for-lainch/kepler-715-neue-exoplaneten-entdeckt

R-10-A-3

R-A-3-5 p. 10-A-3-5: New Earth- like Planet Kepler 186f

a) NASA's Kepler Discovers First Earth-Size Planet in The «Habitable Zone» of another Star
http://www.nasa.gov/ames/kepler/nasa-krplrt-discovers-first-earth-size-planet-in-the-habitable-zone-of-another-..
b) Astronomers discover Earth-like planet
The Sydney Morning Herald – Technology - Nicky Phillips – April 18, 2014
http://www.smh.com.au/technology/sci-tech/astronomers-discover-eartlike-planet.20140417-zqvyu.html
c) Kepler – 186f - http://en:wikipedia,org/wiki/Kepler-186f
With picture: «Comparision of the Kepler 186f system and the Solar system 17 April 2014)]
d) How Many Planets Are In The Universe ?
http://scienceblogs.comstartswithabang/2013/01/05-how-many-planets-are-in-the-universe/
(Estimate: in the observable Universe there are about 10^{24} Planets)
e) Kepler - 186f - http://de.wikipedia.org/wiki/Kepler-186f
f) Neuer Spitzenkandidat unter den erdähnlichen Planeten
Zeit – 17. April 2014 - http://www.zeit.de/wissen/2014-04/planeten-exoplaneten-kepler-astronomie-weltraum
g) Erdgrosser Planet in bewohnbarer Zone entdeckt - Frankfurter Allgemeine – Wissen – 17.04.2014
http://www.faz.net/aktuell/wissen/weltraum/ferne-welten-erdgrosser-pöanet-in-bewohnbarer-zone-aufgespuert-12900773…

R-A-4-1 p. R-A-4-1: The Hubble – Telescope

a) Hubble Space Telescope - https://en.wikipedia.org/wiki/Hubble_Space_Telescope
b) Hubble – Weltraumteleskop - https://de.wikipedia.org/wiki/Hubble_Weltraumteleskop

R-A-5-1 p. 10-A-5-1: Relativistic Redshift of Light from Galaxis
a) Redshift - https://en.wikipedia.org/wiki/Redshift
b) Der Doppler-Effekt - Astrophysik – Weltall
Figur: relative Rotverschiebung z als Funktion von v/c - http://www.jgiesen.de/astro/stars/DopplerEffekt
c) Rotverschiebung: (mit relativistischer Herleitung) - http://de.wikipedia,org/wiki/Rotverschiebung

R-10-A-4