LSM1301
GENERAL BIOLOGY

Ecology

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Learning objectives

- To describe how **heterogeneity of abiotic conditions** has arisen and how they affect the **distribution of terrestrial biomes**
- To describe the **types of temperature regulation** and **life history strategies**
- To describe **population growth** and the limits to growth
- To define an organism's **niche** and the different types of **species interactions** in a community
- To describe the **flow of energy** and cycling of materials in ecosystems
- To understand how human activities **impact the environment** and reflect on how these may be mitigated

Learning activities

- Pre-lecture
  - Watch videos on ecology crash course (7min) and climate change (14min)

    (LumiNUS > Multimedia > Pre-lecture video assignments > “Ecology:xxxxxxx”)
  - Take down notes and refer to lecture slides.

- Post-lecture
  - Take ungraded quiz to revise lecture material

    (LumiNUS > Quiz > “Ecology”

Outline

- Introduction
  - What is ecology
  - Environmental heterogeneity and biomes
- Ecology of individuals
  - Temperature and life history strategies
- Population ecology
  - Abundance, distribution and population growth
- Community and ecosystem ecology
  - Species interactions, community diversity and composition
  - Biogeochemical cycles, ecosystems and human well-being

What is ecology?

Ecology is the study of…

- the inter-relationships between living things and their environment
  - biotic and abiotic
- **where** organisms are found, **how many** occur there, and **why**
- impacts of human beings on natural systems

Ecological hierarchy

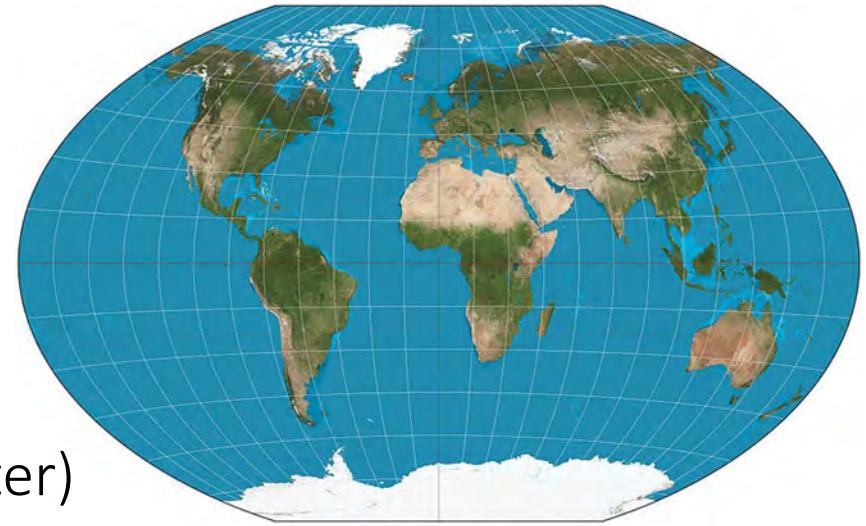
Ecology spans several organizational levels

- **Individuals** → individual organism in relation to its environment
- **Populations** → interbreeding members of a single species living in a given place
- **Communities** → multiple species living and interacting in a given place
- **Ecosystem** → all the interacting organisms and their non-living environment in a given place
- **Biome** → distinct biological communities that have evolved in response to similar non-living environments across the Earth
- **Biosphere** → all life on Earth

Environmental heterogeneity

Temporal and spatial heterogeneity

The earth is a dynamic, heterogeneous environment



Different parts of the planet have:

- Unequal amount of sunlight (available energy)
- Unequal amount of rainfall and nutrients
- Different geological features (e.g. land areas, freshwater)

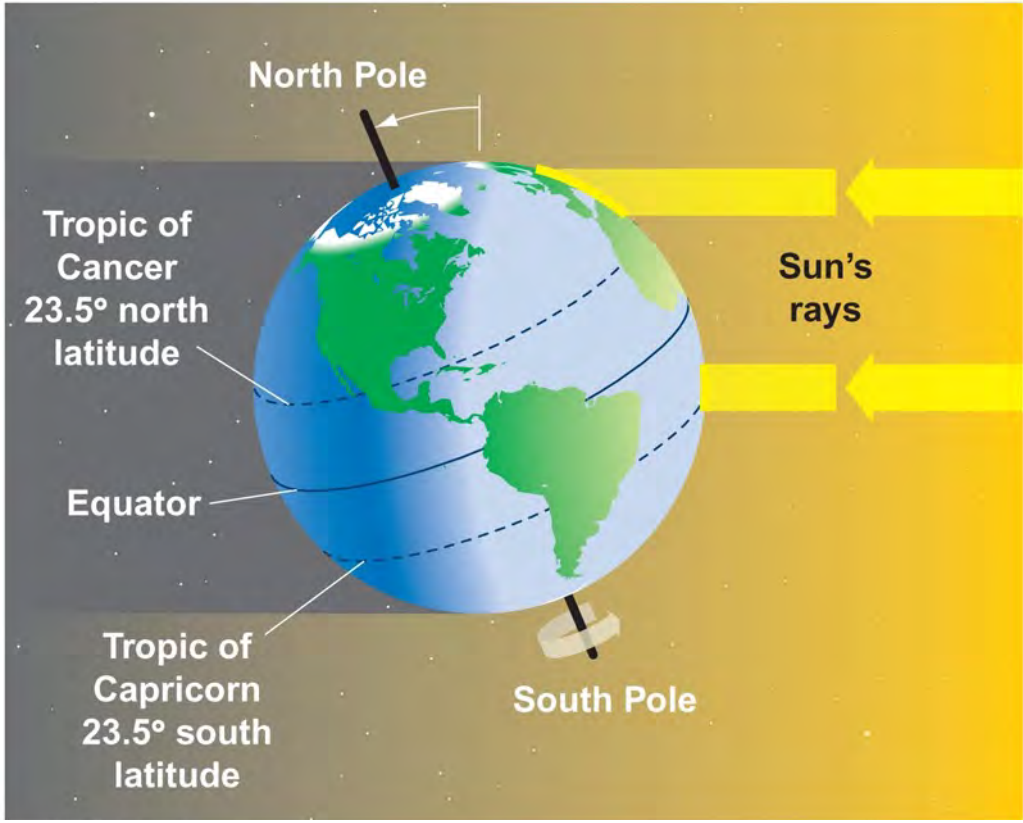
Environmental heterogeneity

The earth is round and its axis is tilted:

- Parts of the earth are tilted away or towards the sun (23.5^{o})
- Areas near equator receive more sunlight throughout the year

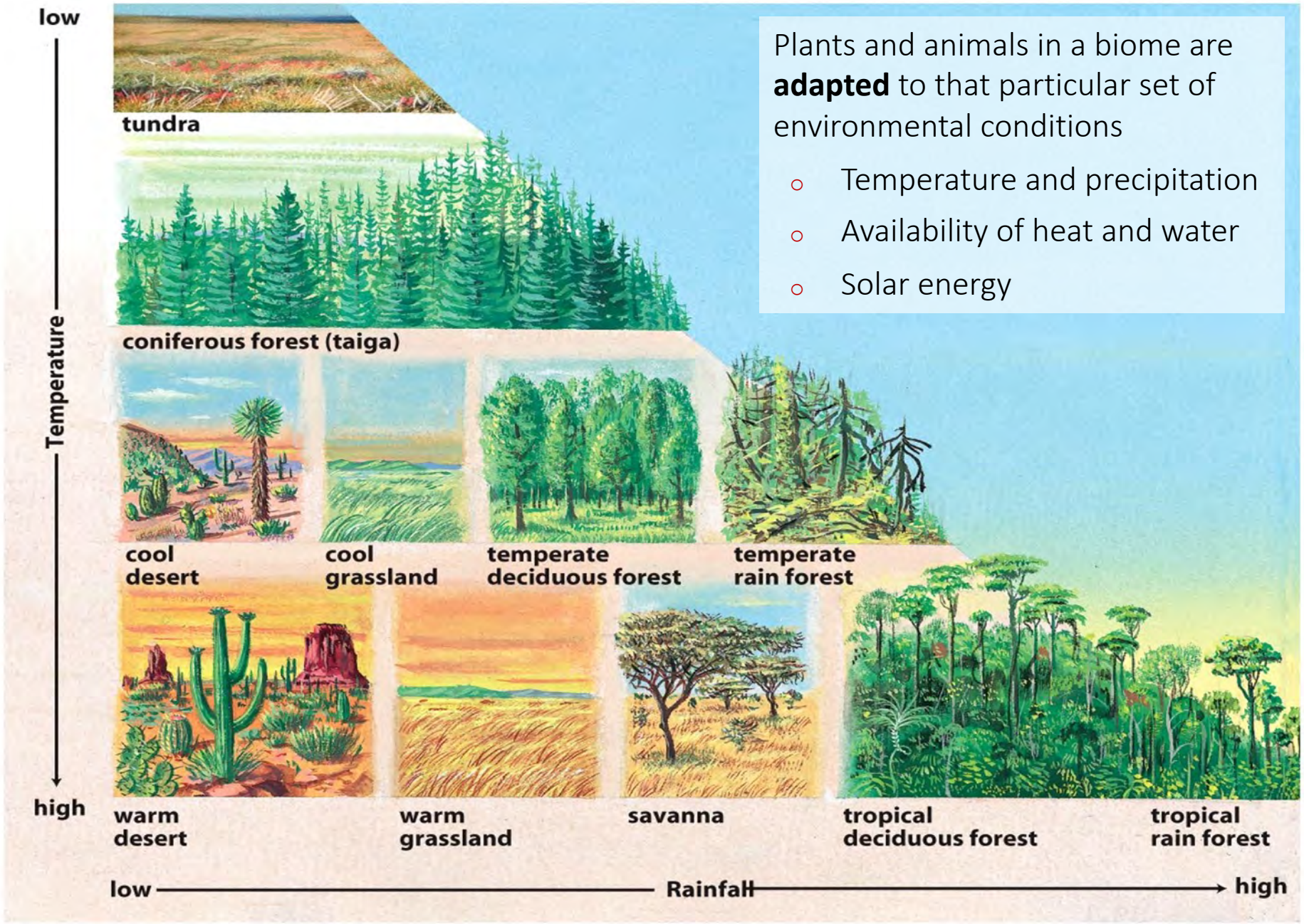
The earth orbits the sun:

- Amount of solar energy changes seasonally
- Predictable change in day length and temperature



Biomes

- Biomes are regions of the earth with similar environmental conditions and characteristic organismal communities
- Geographic distribution corresponds closely to variation in climate

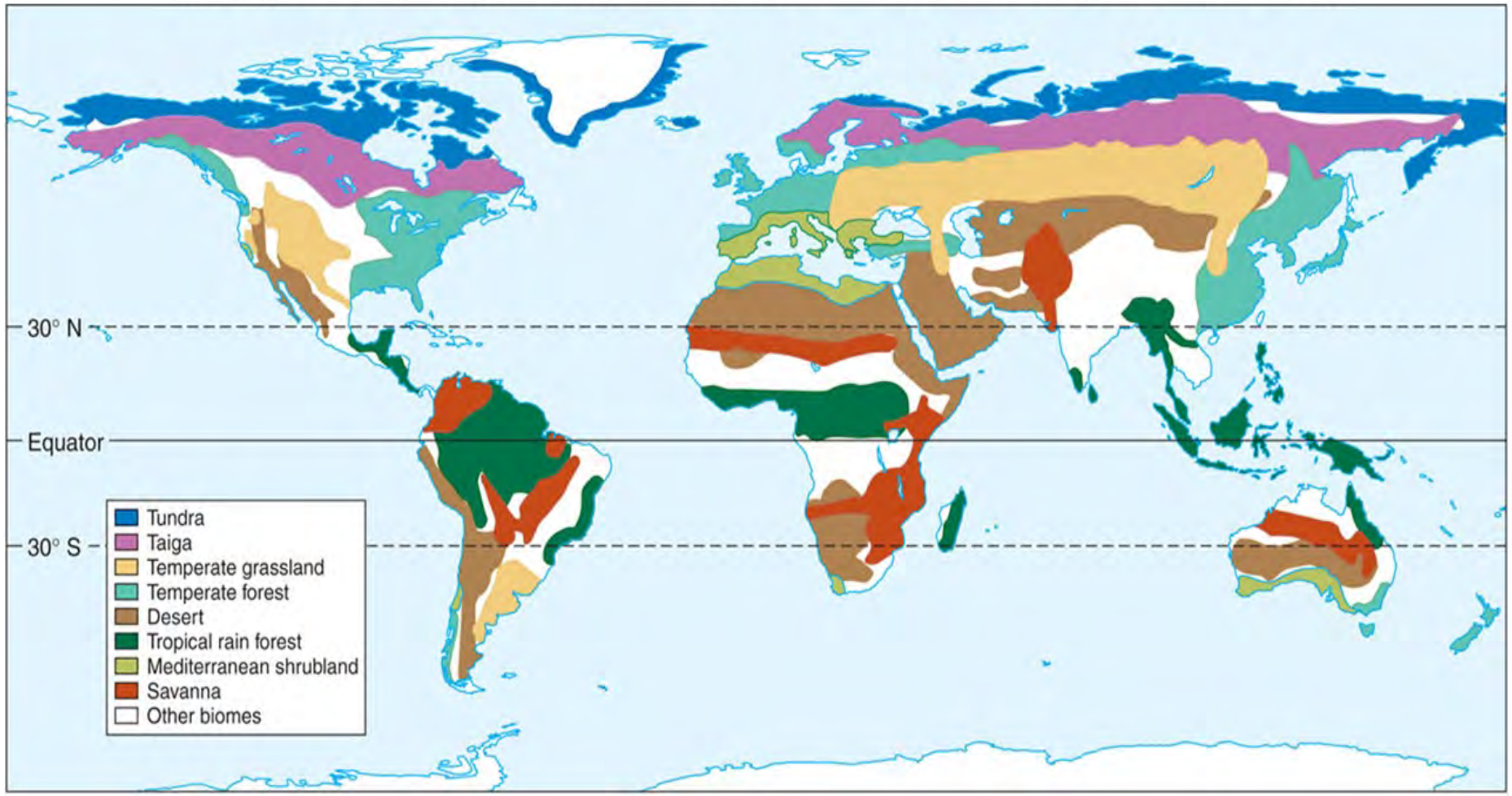


Plants and animals in a biome are **adapted** to that particular set of environmental conditions

- Temperature and precipitation
- Availability of heat and water
- Solar energy

Biomes

Convergent evolution across biomes



Biomes Summary Chart

Pronghorn of North America

Antelope of Africa and Eurasia

Biome	Location	Climate	Soil	Plants	Animals
Desert	midlatitudes	generally very hot days, cool nights; precipitation less than 10 inches a year	poor in animal and plant decay products but often rich in minerals	none to cacti, yuccas, bunch grasses, shrubs, and a few trees	rodents, snakes, lizards, tortoises, insects, and some birds. The Sahara in Africa is home to camels, gazelles, antelopes, small foxes, snakes, lizards, and gerbils
Tundra	high northern latitudes	very cold, harsh, and long winters; short and cool summers; 10-25 centimeters (4-10 inches) of precipitation a year	nutrient-poor, permafrost layer a few inches down	grasses, wildflowers, mosses, small shrubs	musk oxen, migrating caribuou, arctic foxes, weasels, snowshoe hares, owls, hawks, various rodents, occasional polar bears
Grassland	midlatitudes, interiors of continents	cool in winter, hot in summer, 25-75 centimeters of precipitation a year	rich topsoil	mostly grasses and small shrubs, some trees near sources of water	american grasslands include prairie dogs, foxes, small mammals, snakes, insects, varous birds. African grasslands includeelephants, lions, zebras, giraffes.
Deciduous Forest	midlatitudes	relatively mild summers and cold winters, 76-127 centimeters (30-50 inches) of precipitation a year	rich topsoil over clay	hardwoods such as oaks, beeches, hickories, maples	wolves, deer, bears, and a wide variety of small mammals, birds, amphibians, reptiles, and insects.
Taiga	mid- to high latitudes	very cold winters, cool summers,; about 50 centimeters (20 inches) of precipitation a year	acidic, mineral-poor, decayed pine and spruce needles on surface	mostly spruce, fir, and other evergreens	rodents, snowshoe hares, lynx, sables, ermine, caribout, bears, wolves, birds in summer
Tropical Rainforest	near the equator	hot all year round, 200-400 centuimeters (80-100 inches) of rain a year	nutrient-poor	greatest diversity of any biome; vines, orchids, ferns, and a wide variety of trees	more species of insects, reptiles, and amphibians than any place else; monkeys, other small and large mammals, including in some places elephants, all sorts of colorful birds

Ecology of individuals

Plant and animal populations are adapted to local conditions through natural selection

- The structure and functions of each organism reflects its adaptations to its native environment
- When an organism is adapted to one set of environmental conditions, it often will not do well in others

Ecology of individuals

Factors that affect organisms can be characterized into abiotic or biotic

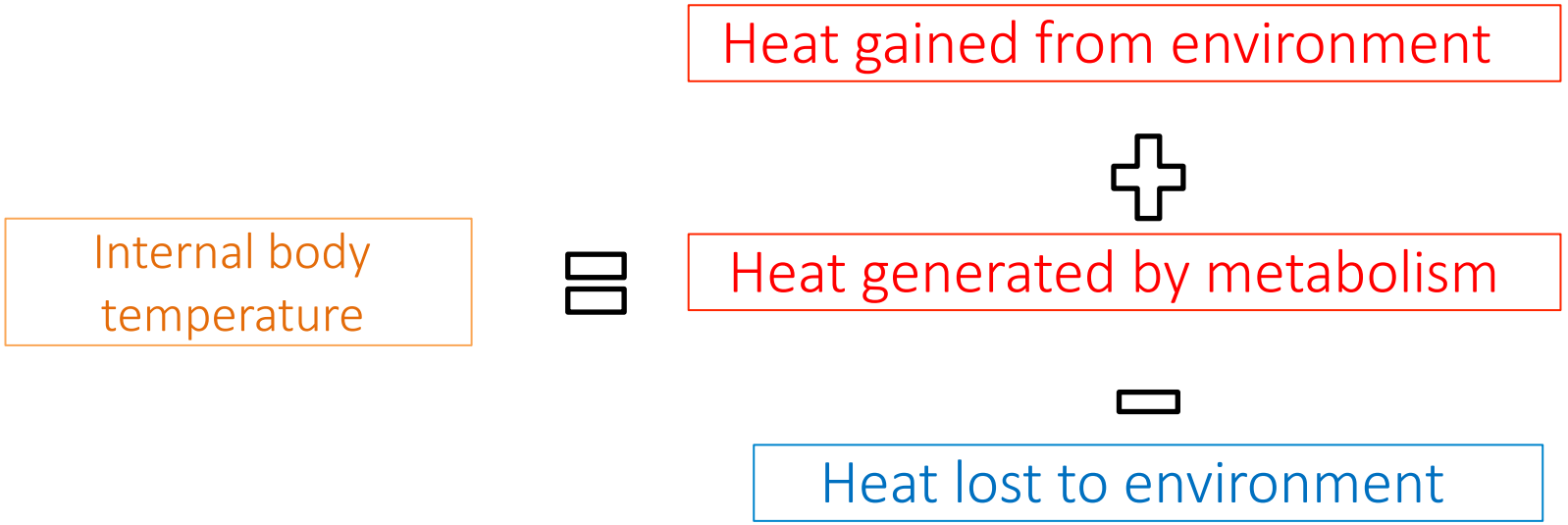
- Affect physiological performance and availability of essential resources
- Scientists sometimes classify organisms into broad groups to describe similar strategies for dealing with their environments
  - Examples of important environmental factors:

Abiotic	Biotic
Temperature Light intensity Precipitation Humidity pH Salinity	Food plants Prey Competitors Predators Parasites Mutualists

Temperature strategies

Temperature is an important environmental factor affecting organisms

- Must maintain internal temperatures and water balance near optimum range through **homeostasis**
- Adaptations to external temperatures can be seen in anatomy, physiology and behaviour



Temperature strategies

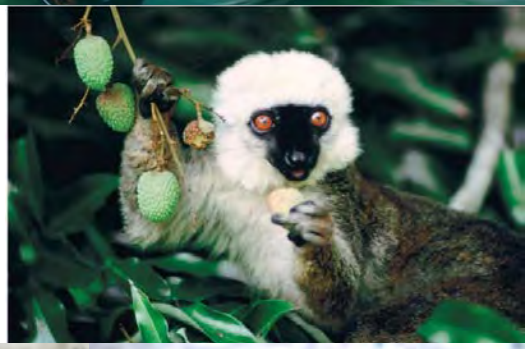
Animals have two general temperature regulation strategies

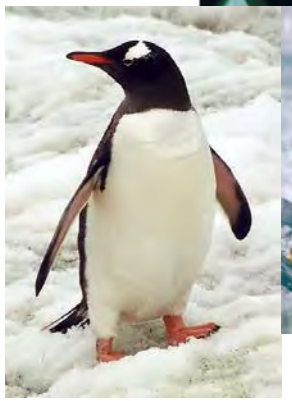
- **Ectotherms**: acquire heat from external sources; have a variable body temperature
  - Become active only when warm enough
  - Low metabolic rate, don't need to eat often
  - Poor oxygen supply, restricted to short bursts of activity
  - Poorly insulated, limited optimal range of temperatures

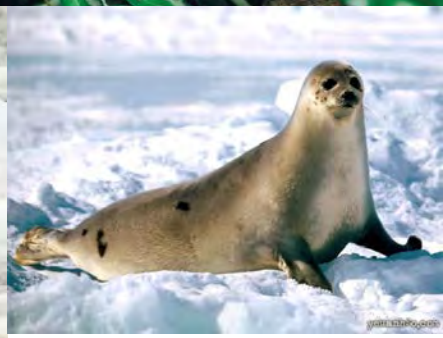
Temperature strategies

Animals have two general temperature regulation strategies

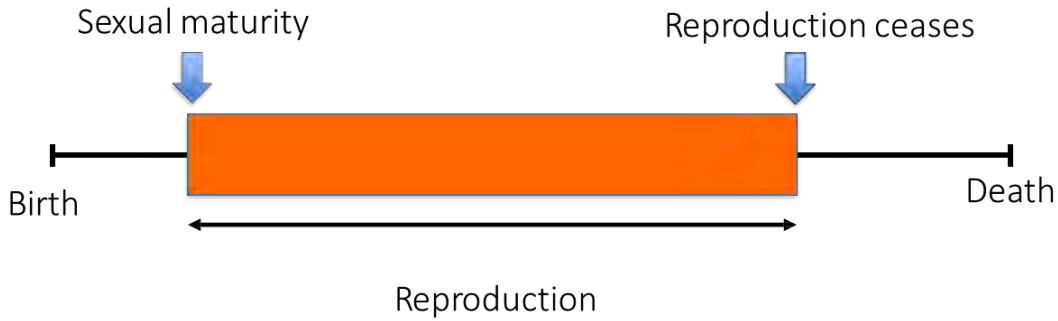
- **Endotherms**: acquire heat from internal sources; have more constant body temperature
  - Maintain constant body temp through metabolic heat
  - Can maintain high level of energy through aerobic respiration, but need to eat more
  - Insulated, can survive at wider temperatures







Life history



All events in an organisms life, particularly those which that influence reproduction

- Mode of reproduction: sexual or asexual
- When and how often to reproduce
- Number and size of offspring
- Parental care or none

Reproduction represents an important energy investment for organism

- Organisms balance reproduction against other requirements
- Different environments can favour different reproductive strategies

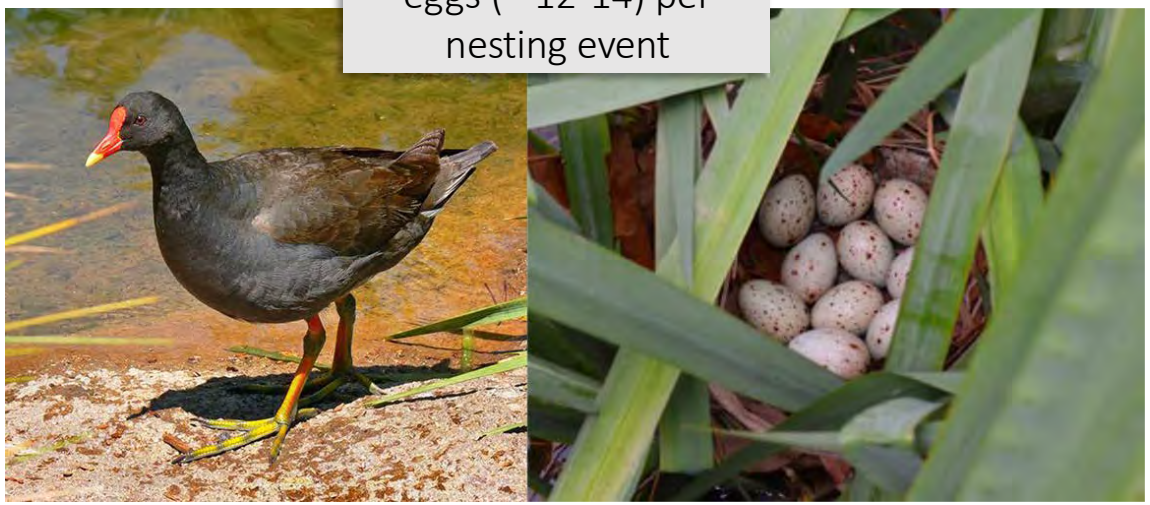
Life history strategies

Strategies have inherent trade-offs for certain characteristics

- Example: relationship between size and number of offspring

Brown kiwi birds lay a single egg that can be up to 20% of the female's body weight

Moorhens lay multiple eggs (~ 12-14) per nesting event

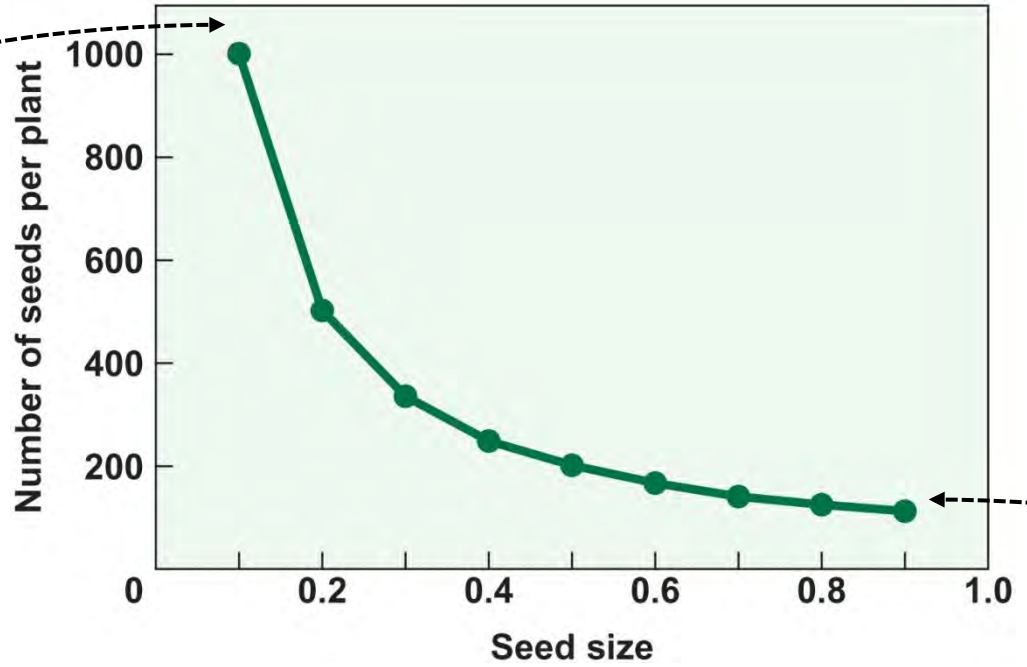


Life history strategies

Strategies have inherent **trade-offs** for certain characteristics

- Example: relationship between size and number of offspring

Seeds of epiphytic orchids
(0.8ug)



Seeds of coconut palm
(1.5kg)

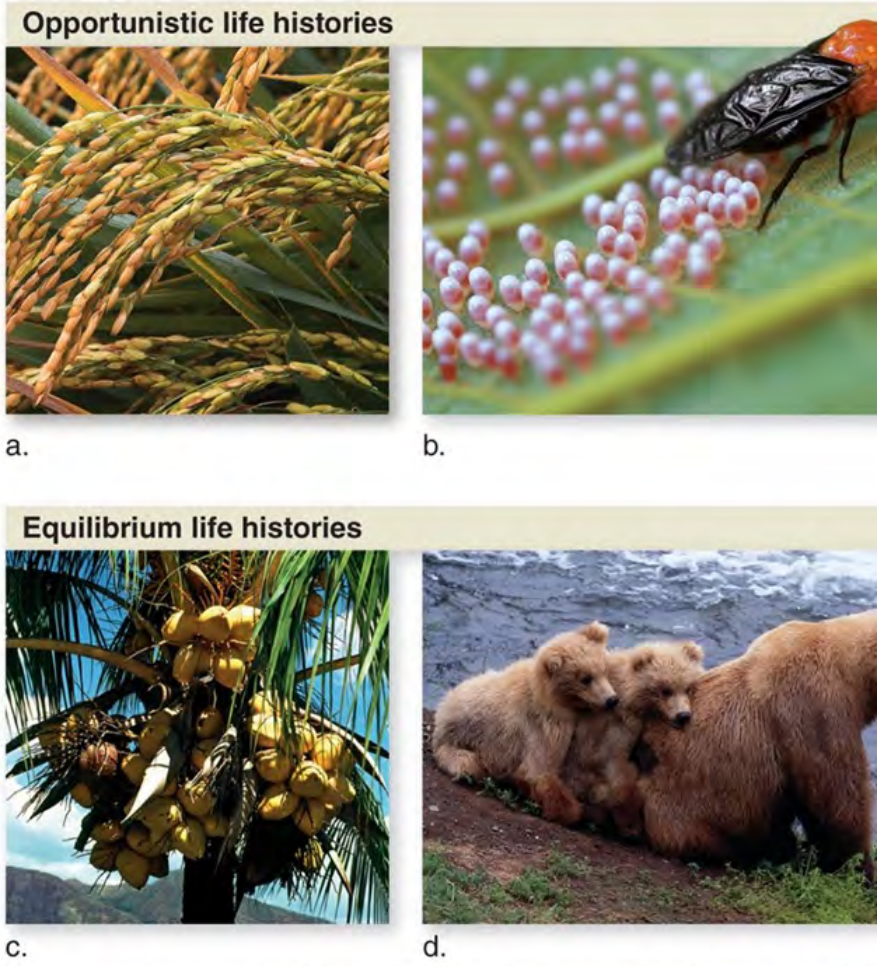
Life history strategies

Opportunistic life history (**r-selected**)

- Favours traits that maximize *number of offspring*
- Adults short-lived, reproduce at an early age and have many offspring that receive little care
- Inhabit **unstable/unpredictable environments** where resources are not limiting

Equilibrium life history (**K-selected**)

- Favours traits that improve *offspring quality*
- Adults long-lived, late-maturing, produce few offspring that receive extended parental care
- In **stable environments** with some level of competition



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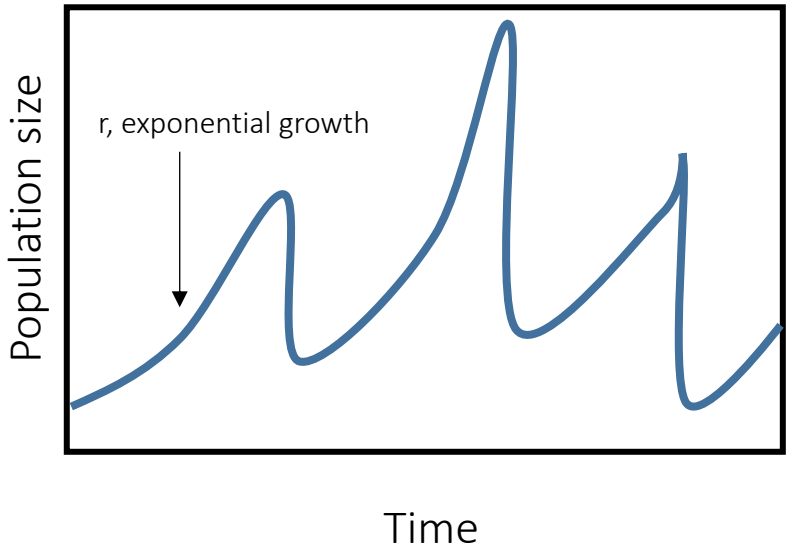

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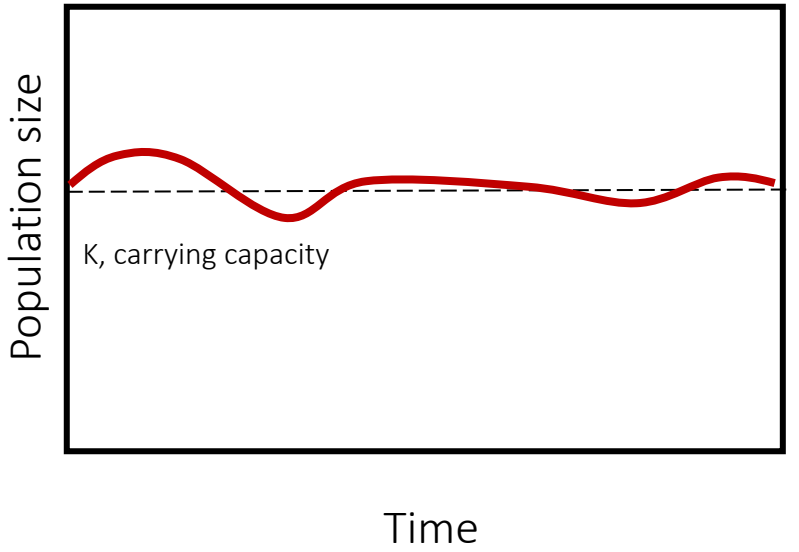
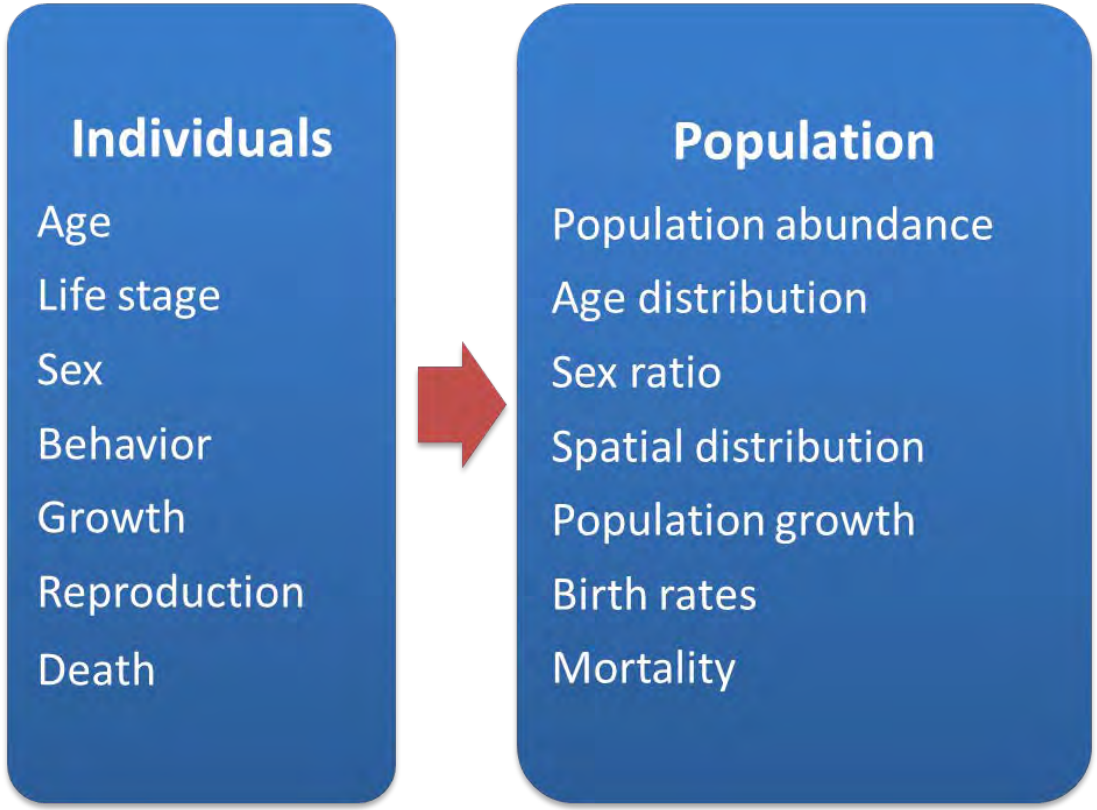


Population ecology

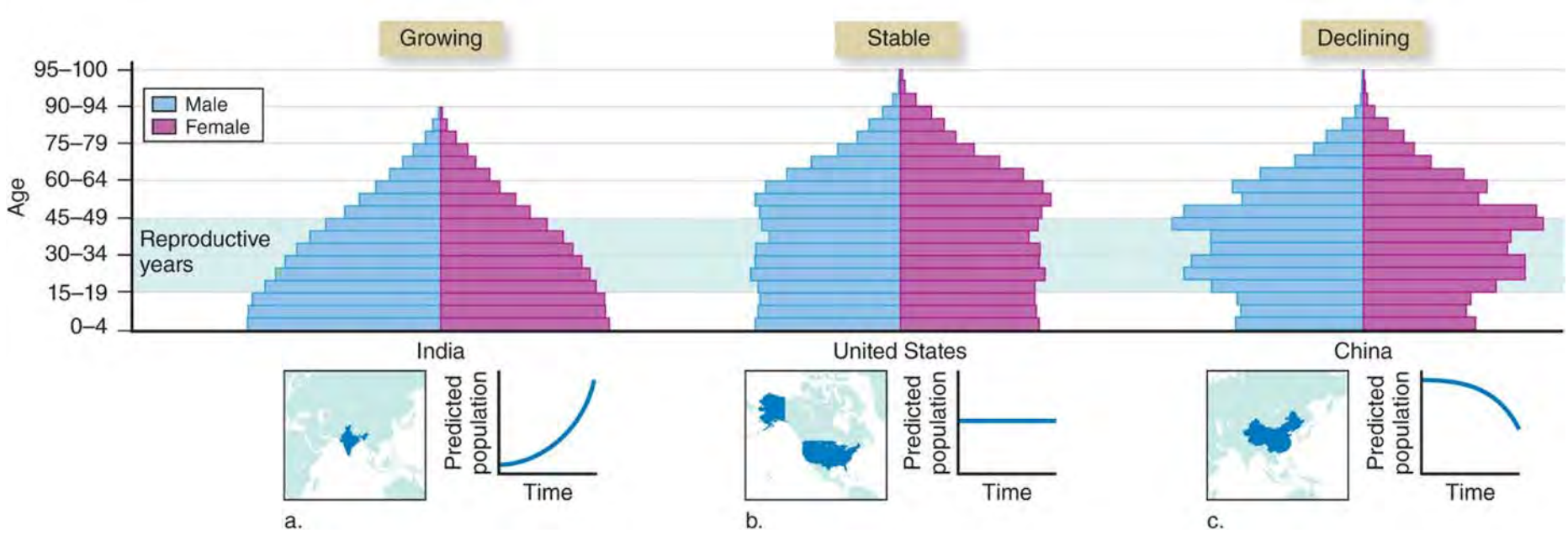
A population is a group of individuals of the same species inhabiting a given area with potential to interbreed

- Population properties are derived from the characteristics of individual organisms



Population ecology

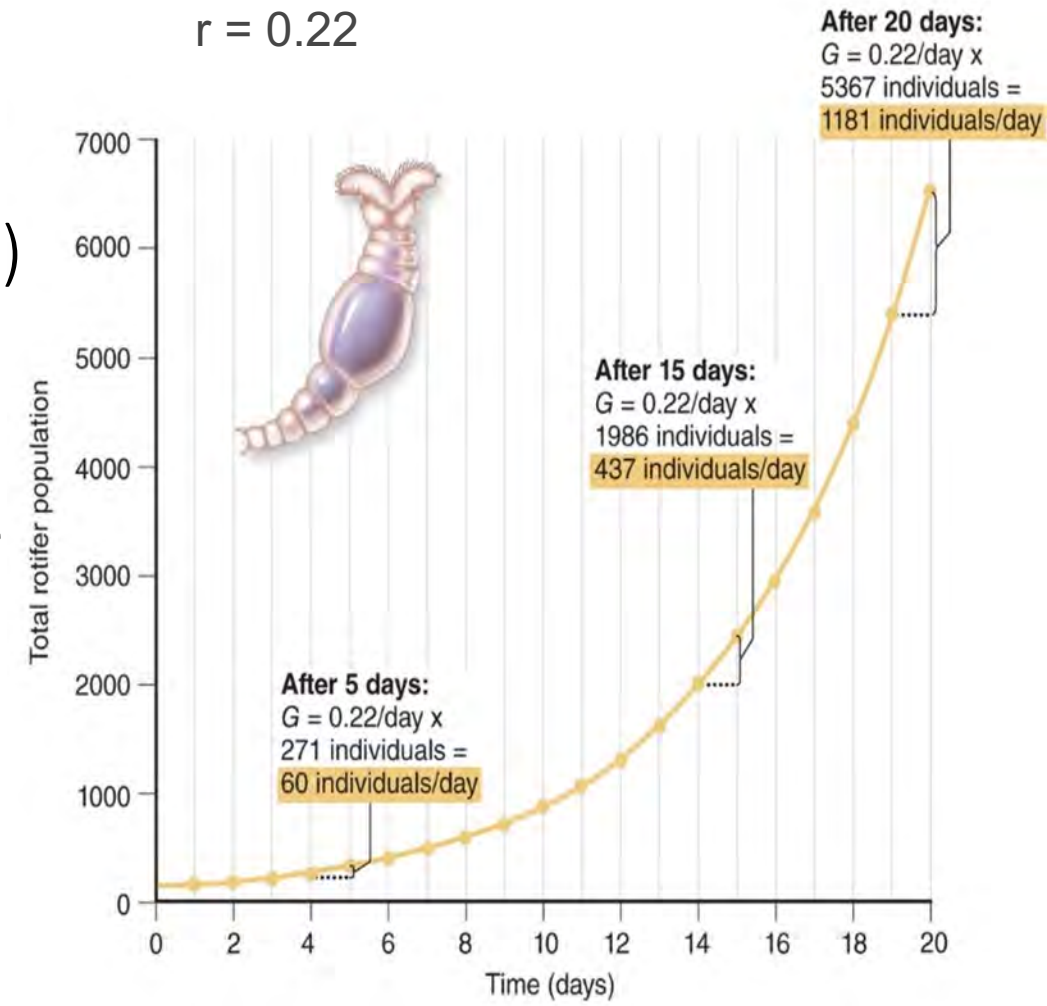
- A population has an **age structure**
  - proportion of individuals in different age groups & life stage categories
  - visualized as a pyramid
  - helps to roughly estimate current & future growth



Population growth

Populations have to capacity to increase indefinitely if resources (e.g. space and food) are unlimited

- Represented by exponential growth curve
- Number of new individuals is proportional to the size of the population
  - Growth resulting from repeated doubling
  - Per capita rate of increase, **r**, is the difference between the birth and death rate
  - Results in a J-shape curve



Population growth

In natural environments, populations rarely reach maximum growth rate

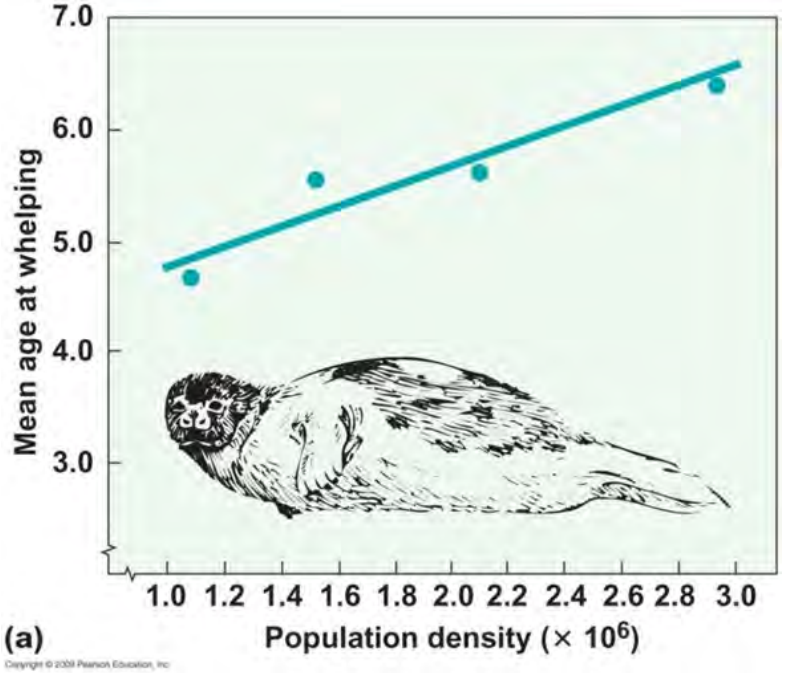
Environmental factors result in decreasing birth rates and/or increasing mortality and slow population growth

- **Density-dependent** factors (effects increase as a population grows)
  - Competition for limited resources like space, nutrients, light
  - Stress of crowded conditions reduces birth rate
  - Predation increases and disease spreads faster in a larger population
- **Density-independent** factors (effects unrelated to population density)
  - Mostly extreme abiotic events: Flood, volcanic eruption, severe weather

Population growth

Intraspecific competition between individuals in a population occurs when there is short supply of a common resource

- At high population densities, we expect:
  - **Increased mortality** as some individuals do not obtain the resources they need to survive
  - **Decreased fecundity** if females delay or defer reproduction because of the lack of resources



Community and ecosystem ecology

Community: group of interacting populations and species that are found a given place

- Some interactions between species are so strong they result in **coevolution**

Predator-prey

Competition

Two (or more) species reciprocally affect each evolutionary fitness

Mutualists

Host-parasite

Community and ecosystem ecology

Community: group of interacting populations and species that are found a given place

- Some interactions between species are so strong they result in **coevolution**

Organisms have their own ecological **niches** in their community

- Niche
  - All the resources a species exploits for its survival, growth, and reproduction
  - Includes habitat, diet, interactions with other organisms as well as abiotic factors where species live such as temperature and water availability
- 'Way of life' of a species

Species interactions

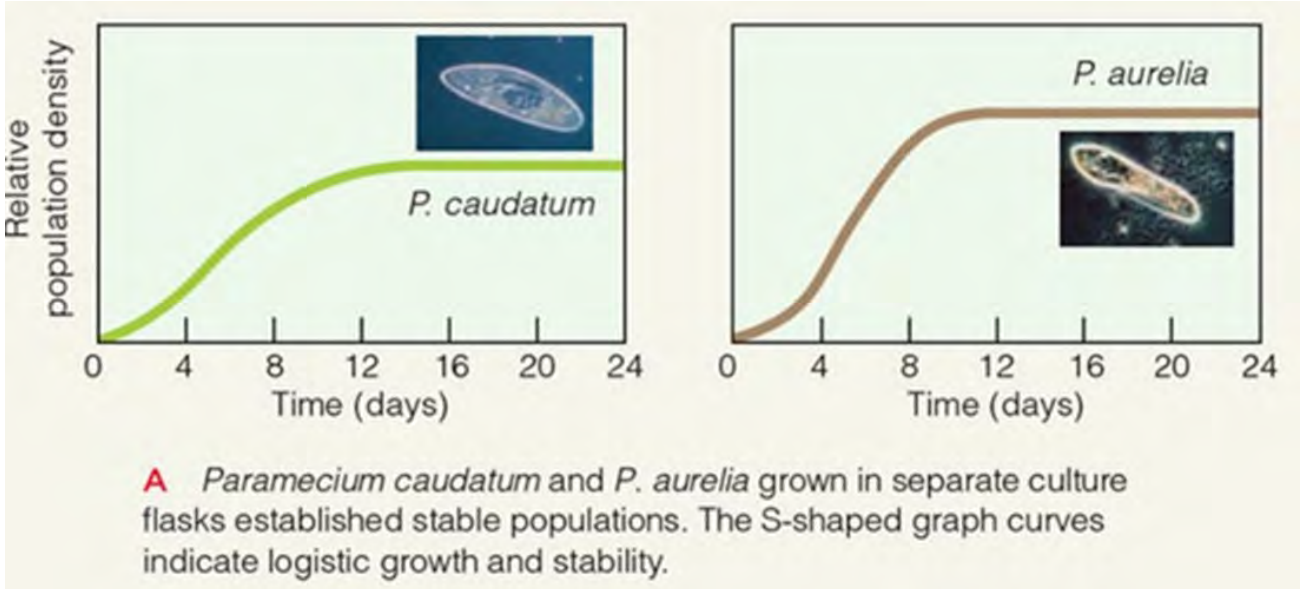
1. Competition

- Interaction between individuals, populations, or species that has negative results for both parties
  - Even if one side “wins”, it comes at a cost
- Competing usually for limited resources, e.g. food, space, shelter, mates etc.
  - **Intra**specific competition: Between members of own species
  - **Inter**specific competition: Between individuals of two species

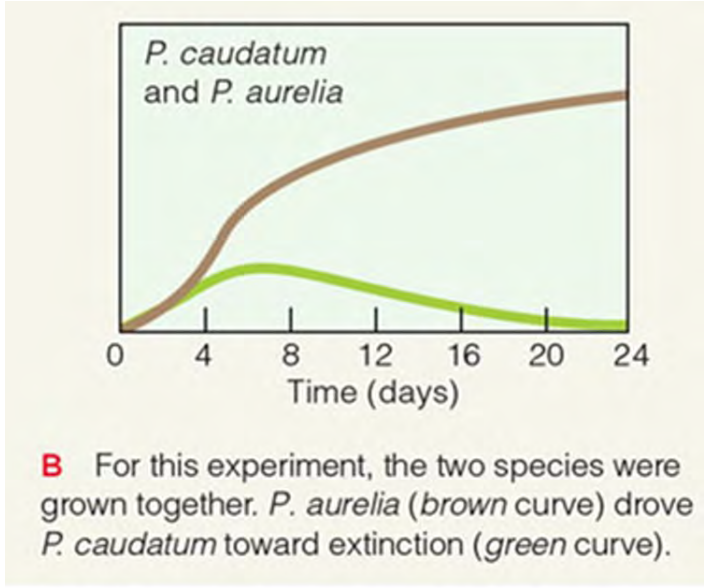
Species interactions

1. Competition

- **Competitive Exclusion Principle**
  - Two species that have the *exact same niche* cannot coexist indefinitely if they are competing for the exact same resources



A *Paramecium caudatum* and *P. aurelia* grown in separate culture flasks established stable populations. The S-shaped graph curves indicate logistic growth and stability.

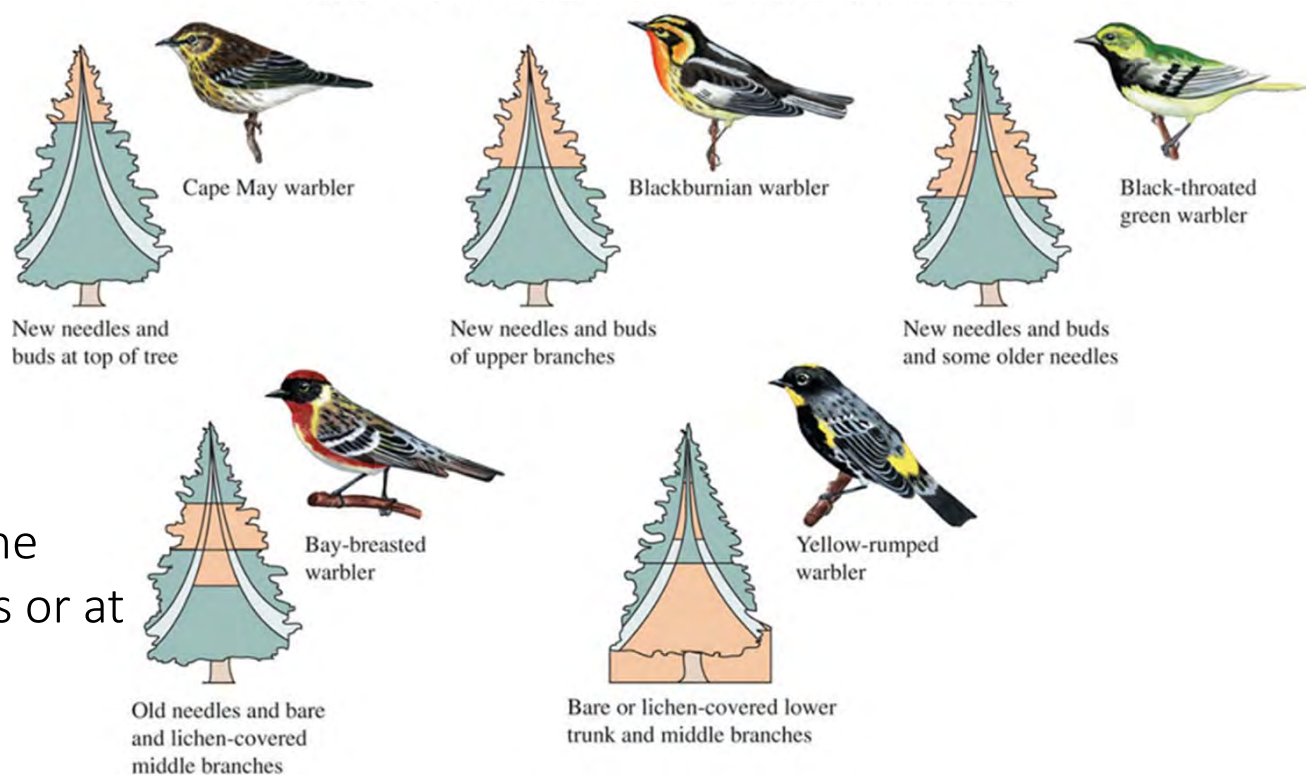


B For this experiment, the two species were grown together. *P. aurelia* (*brown* curve) drove *P. caudatum* toward extinction (*green* curve).

Species interactions

1. Competition

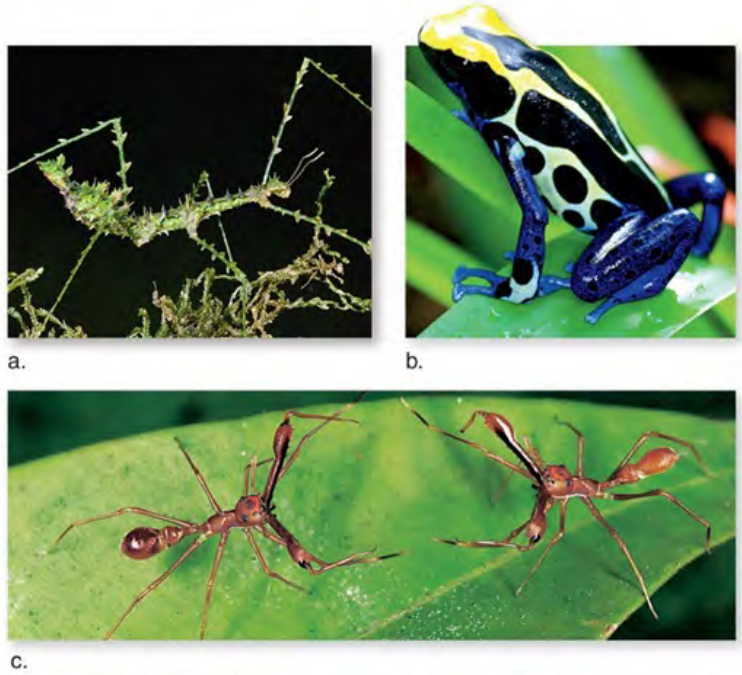
- Competition can lead to **resource partitioning**
  - Over long term, competition may cause evolutionary *shifts in niche*
  - Observations of multiple species using the same resource in a slightly different ways or at different times
  - This results in species with similar needs coexisting in the same habitat



Species interactions

2. Predator-prey interactions

- Predation is the consumption of one organism by another
  - True predators kill prey immediately on capture
- Predation exert strong selective pressure on prey to avoid being eaten
  - Camouflage
  - Warning colours
  - Weapons and structural defences
- Predators have to defeat prey defences



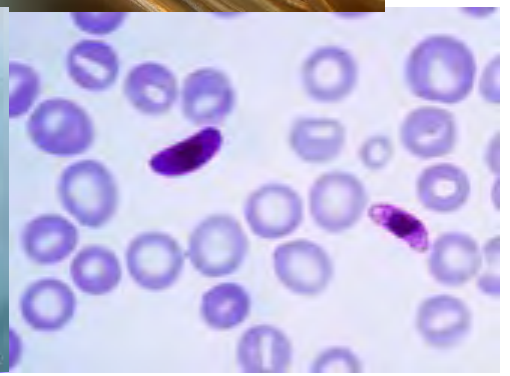
Species interactions

2. Herbivory

- Herbivores consume parts of plants, but usually do not kill it

3. Parasitism

- Parasites consume part of the host, but usually do not kill it
- Having parasites is harmful to the host
  - Can be externally or internally located
  - Usually much smaller than host
  - Usually attack 1 or very few hosts
- Predators have to defeat prey defences



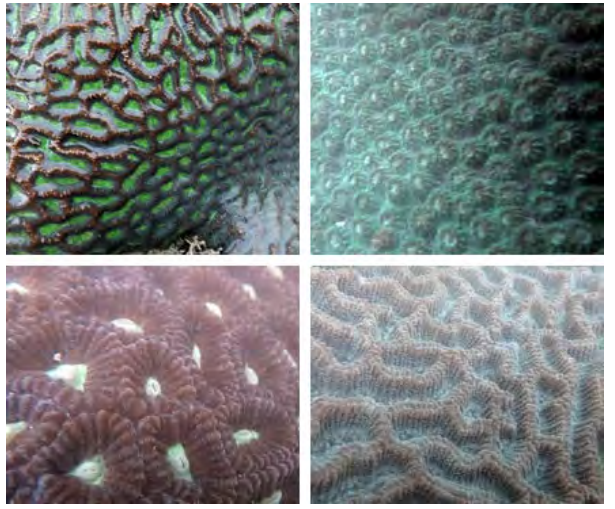
Species interactions

4. Commensalism

- Relationships in which one species benefits without significantly affecting the other

5. Mutualism

- Relationships that is beneficial to both species
- Strong coevolution between species



Energy flow

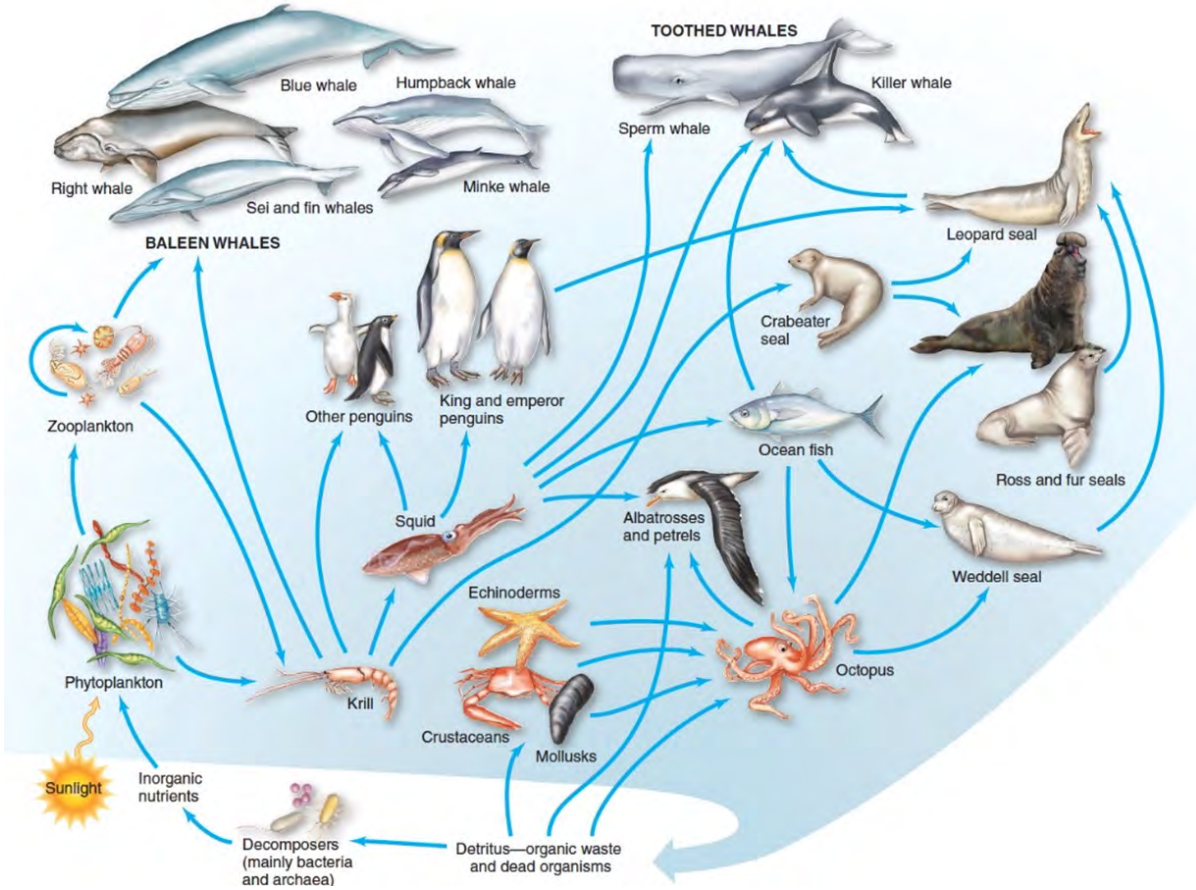
Algae → Zooplankton → Grouper → Barracuda

Food chains can depict the transfer of energy and nutrients between organisms

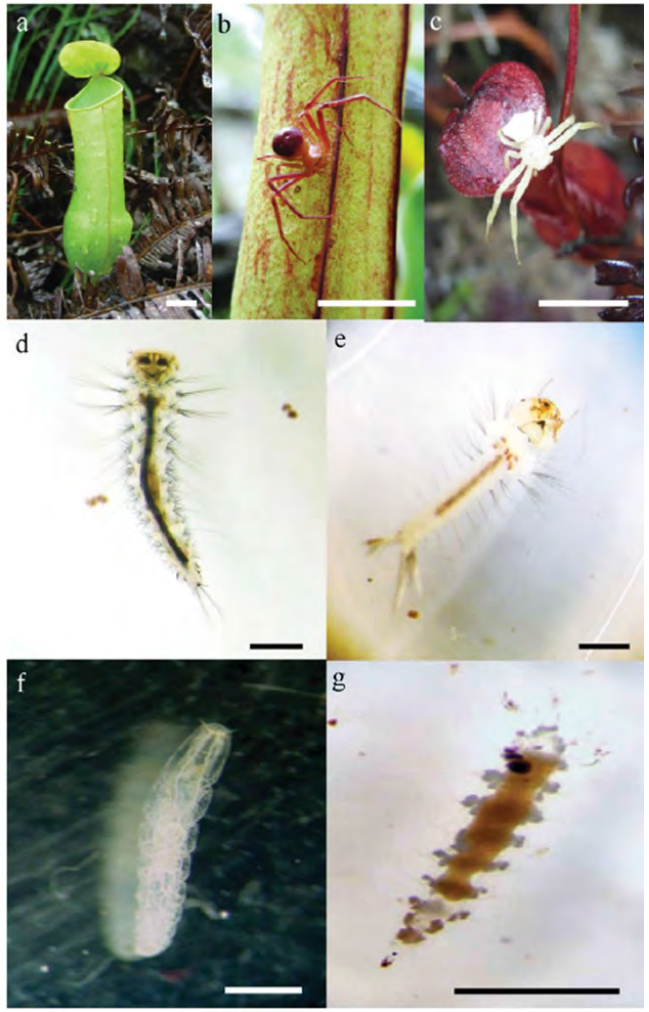
Trophic level describes an organisms' position in the food chain

- Primary producers
- Consumers
- Decomposers

A food web shows several interconnected food chains



Energy flow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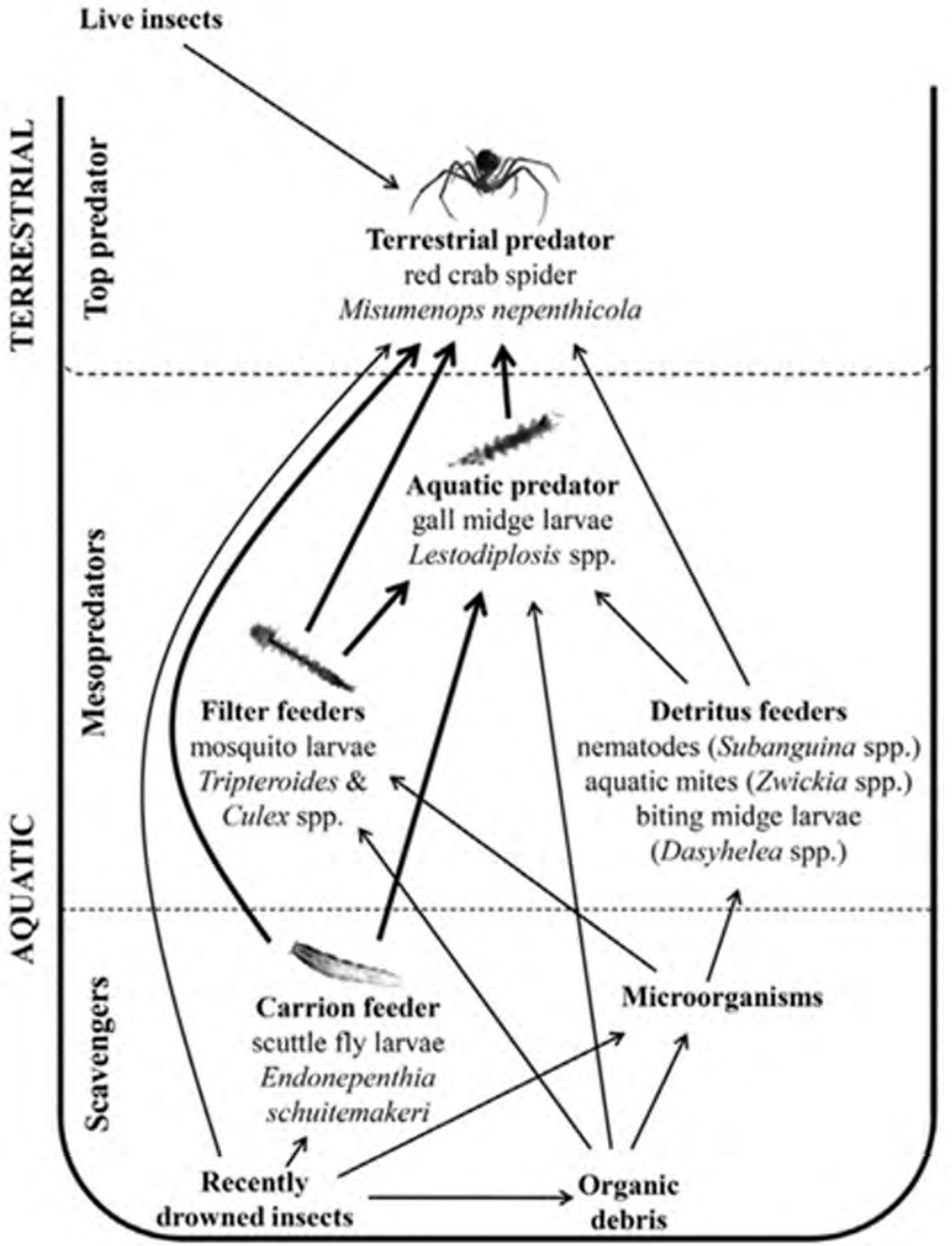

Live insects
TERRESTRIAL
AQUATIC
Top predator
Mesopredators
Scavengers
Terrestrial predator
red crab spider
Misumenops nepenthicola
Aquatic predator
gall midge larvae
Lestodiplosis spp.
Filter feeders
mosquito larvae
Tripteroides &
Culex spp.
Detritus feeders
nematodes (Subanguina spp.)
aquatic mites (Zwickia spp.)
biting midge larvae
(Dasyhelea spp.)
Carrion feeder
scuttle fly larvae
Endonepenthia
schuitemakeri
Microorganisms
Recently
drowned insects
Organic
debris

Energy flow

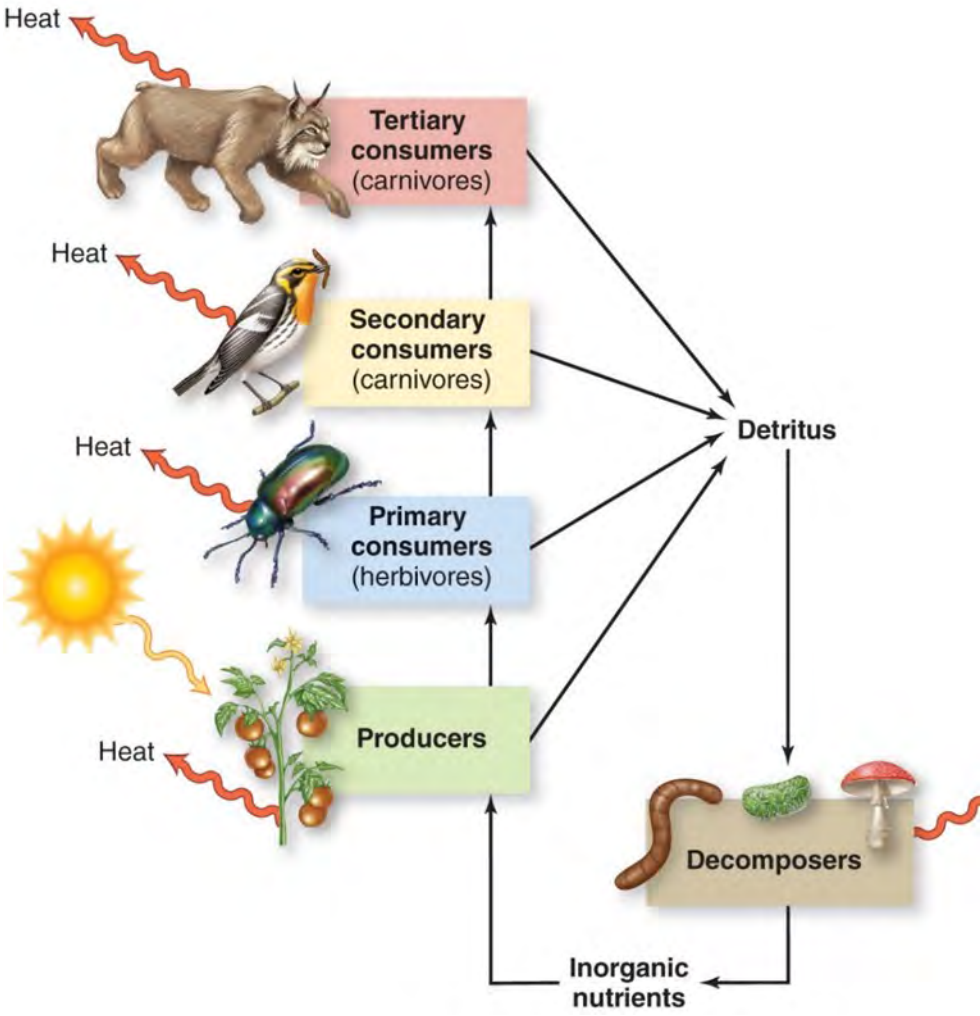
The amount of energy available to an ecosystem influences community diversity

- Solar energy is used by autotrophs to manufacture organic molecules through photosynthesis
  - Energy captured by primary producers becomes available to other organisms
- Ecosystems that receive more energy can support higher diversity and biomass of organisms

Energy flow

Ecosystems require constant energy input

- Transfer of energy in **trophic levels** is never 100% efficient
  - Limited consumption and assimilation
  - Consumer respiration, heat and waste production
- The proportion of energy from biomass of lower trophic level that is transferred to the next is usually around 10%

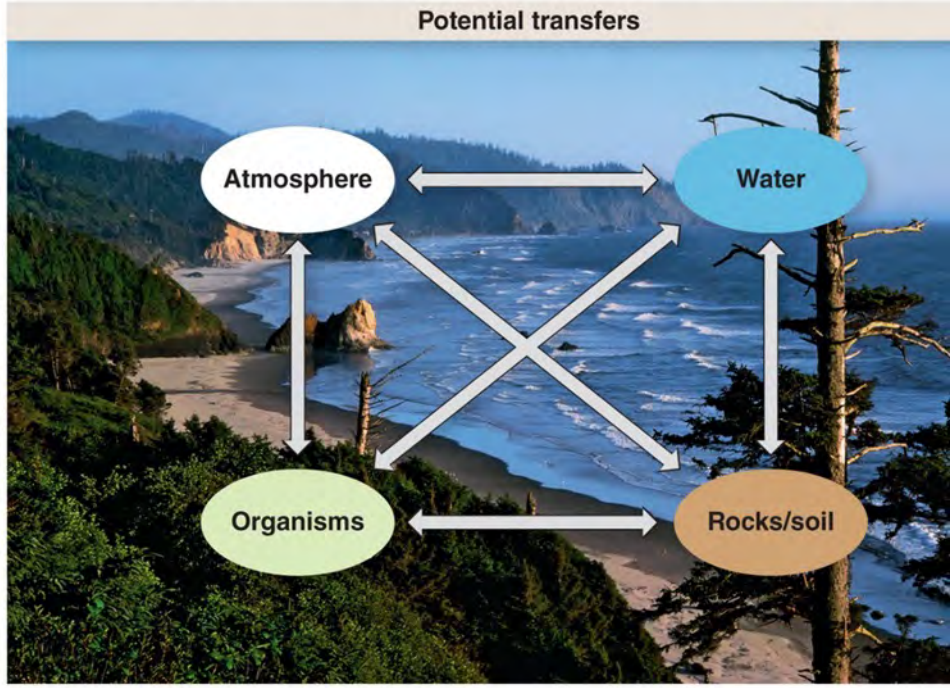


Biogeochemical cycles

All matter cycles = the earth is a closed system and there is no new supply of materials

Actions of geology, meteorology and living things results in cycling and recycling of matter within ecosystems

- Water cycle
- Carbon cycle
- Nitrogen cycle
- Phosphorus cycle

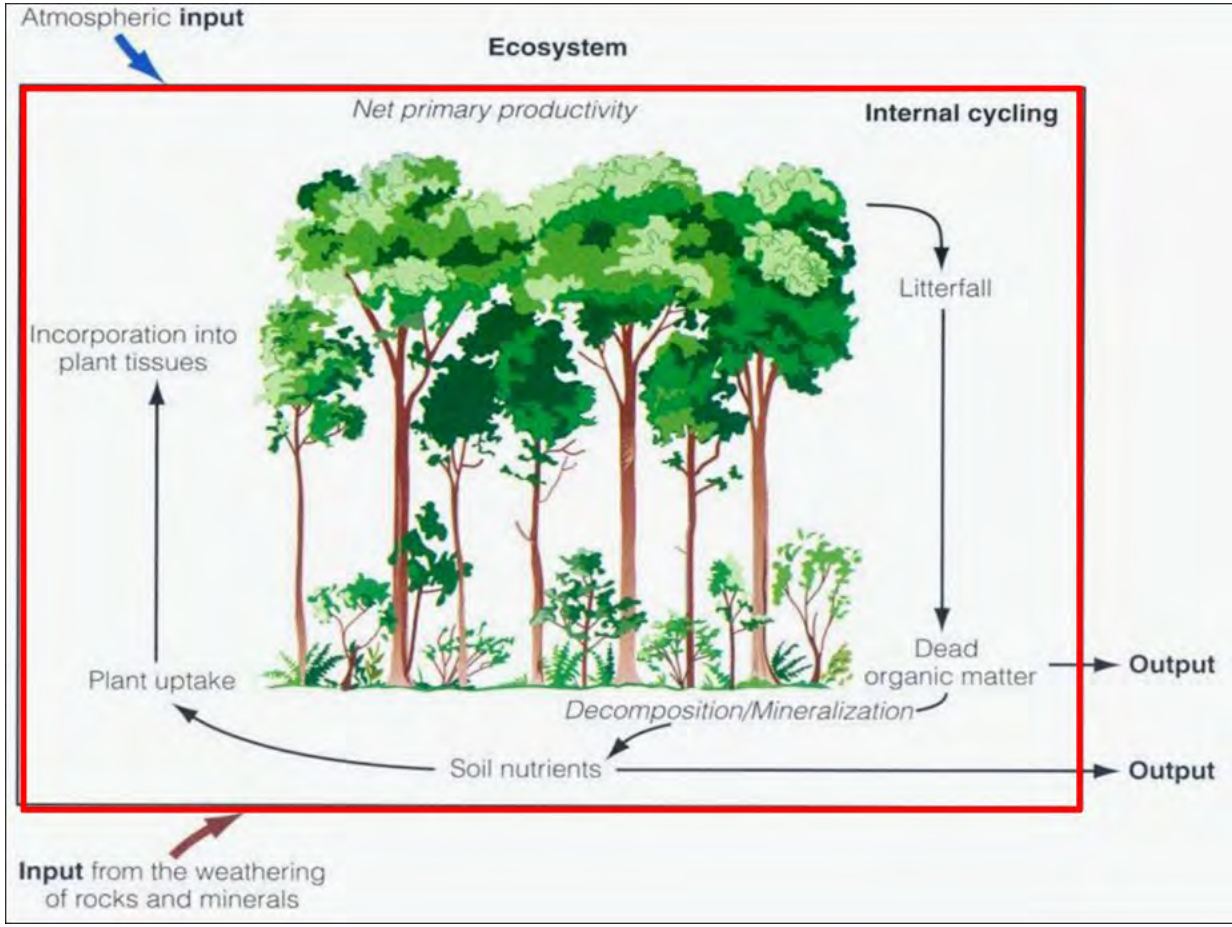


Biogeochemical cycles

Physical and biological properties of communities and ecosystems are tightly linked and inseparable

Most ecosystems cycle matter internally

Healthy ecosystems are self-regulating and self-maintaining

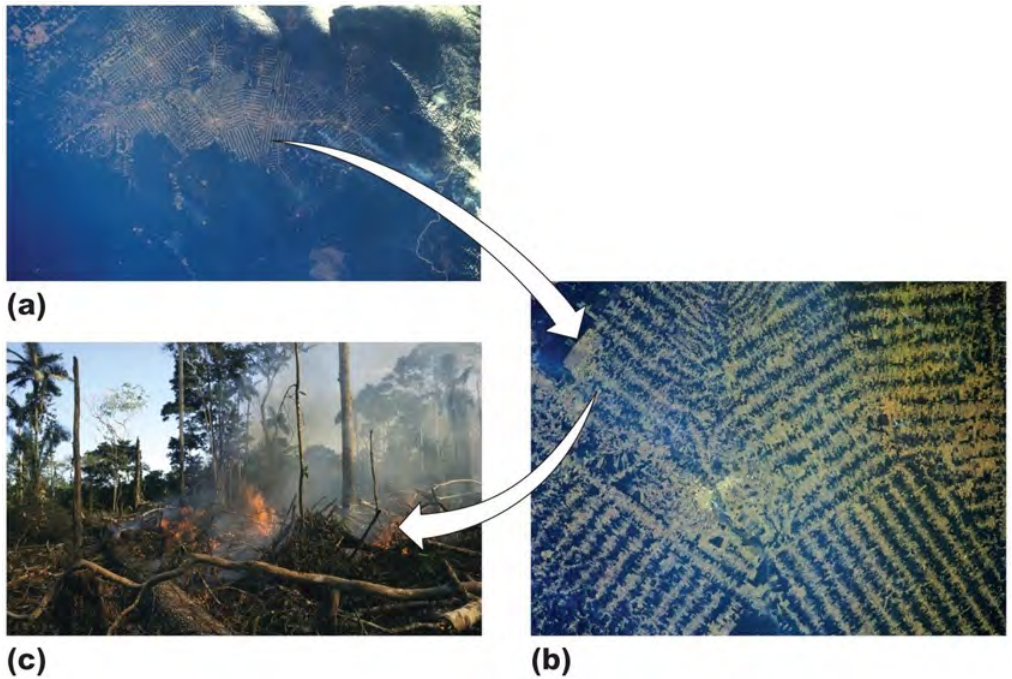


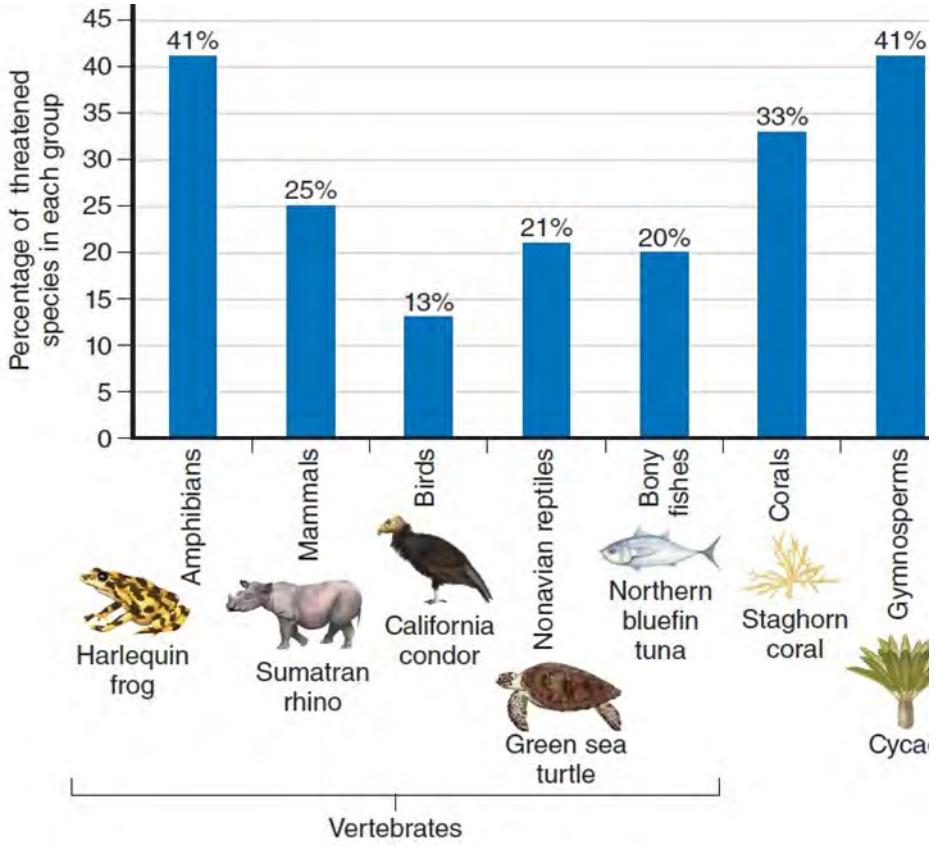
Ecosystems and human well-being

- Natural ecosystems provide us with many essential services - processes through which sustain human life
  - E.g. Clean air, carbon storage, water filtration, raw materials
- Represents our natural capital = potential to feed, clothe, shelter, cure future generations
- Intact biodiversity is the foundation to healthy ecosystems

Ecosystems and human well-being

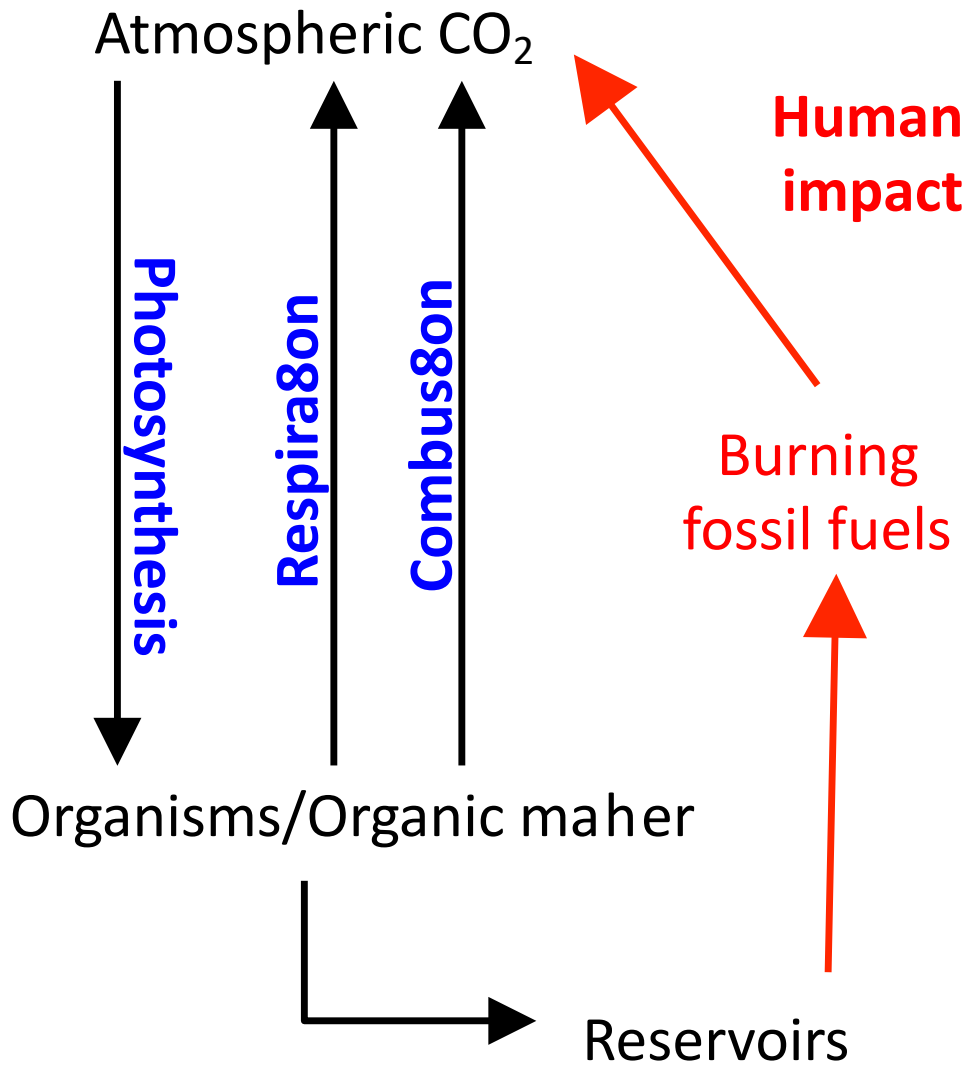
- Human activities interfere with natural processes and relationships in ecosystems
- Disruption of natural cycles leads to altered degraded states
- Many plants and animals threatened with extinction



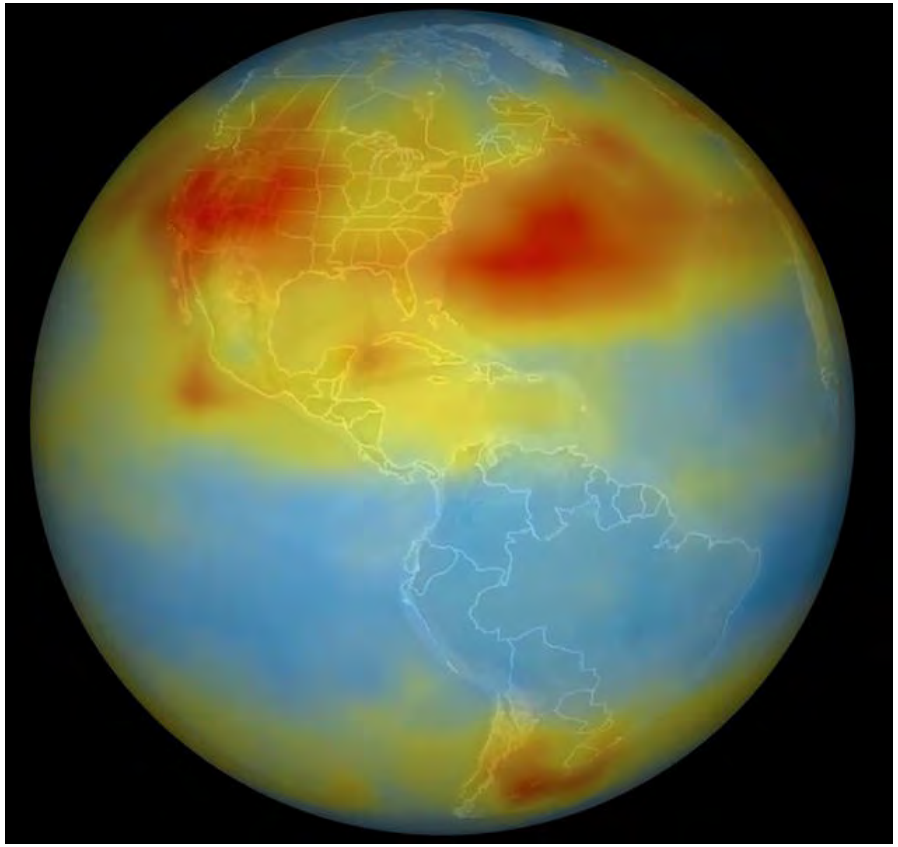


Ecosystems and human well-being

- Humans are having a large impact on nutrient cycles, especially carbon, nitrogen and phosphorus
- Increased carbon dioxide levels leads to an enhanced greenhouse effect, trapping more heat and raising temperature levels
- Many far-reaching consequences for climate, sea levels, ocean acidification, species distributions, etc.

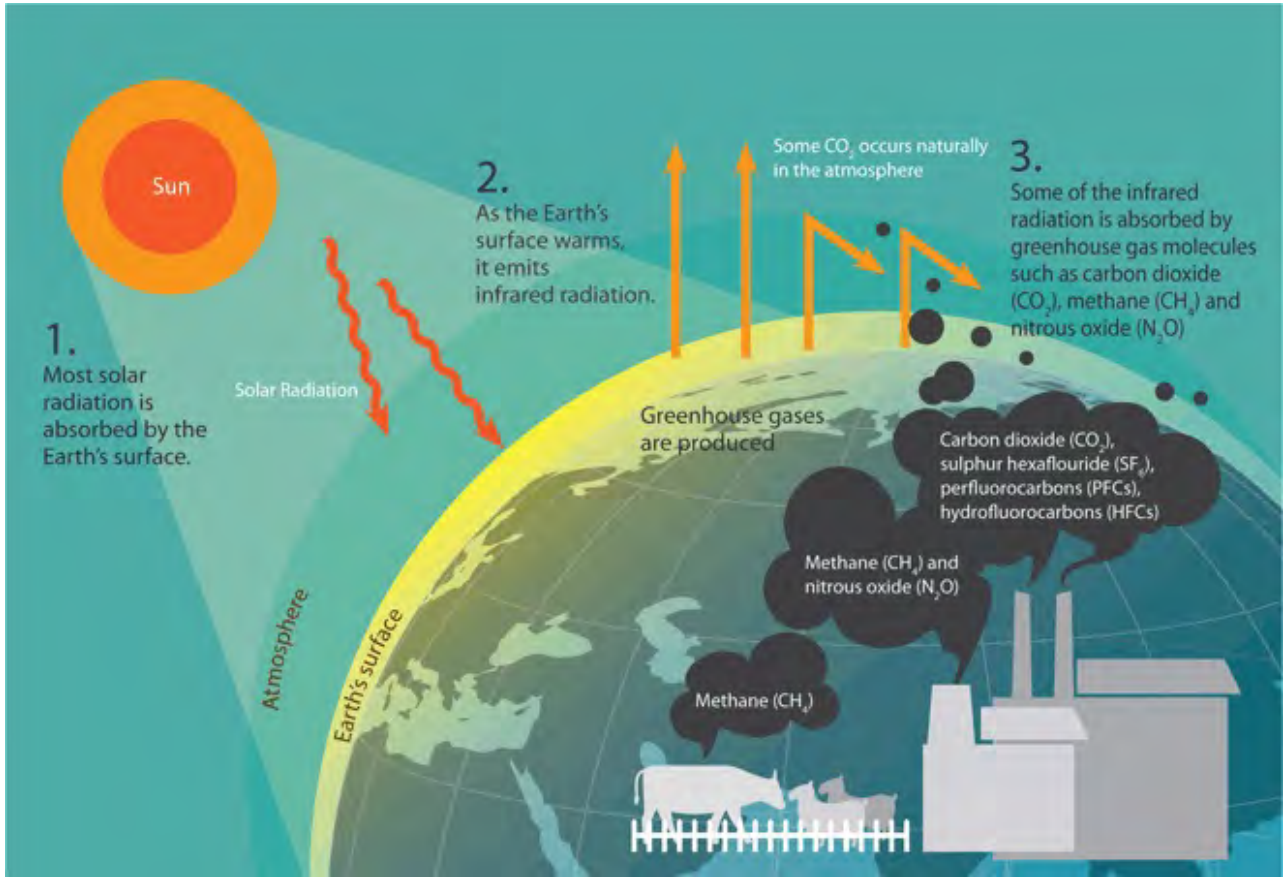


Climate change



AIRS instrument on NASA's Aqua spacecraft shows high carbon dioxide concentrations in the Northern Hemisphere.

The Enhanced Greenhouse Effect



Climate change

Australia's weird weather is getting even weirder

Fires, heat, drought, and flooding are nothing new. But climate change is making them worse.

By Umair Irfan | Jan 15, 2020, 3:50pm EST

SHARE

Australia's climate is prone to extremes, but ongoing warming has made them worse, fueling the ongoing bushfires across the country. | Saeed Khan/AFP via Getty Images

Obituary: Great Barrier Reef (25 Million BC-2016)

Climate change and ocean acidification have killed off one of the most spectacular features on the planet.

By: Rowan Jacobsen Oct 11, 2016

Sustainability

IN FOCUS: Massive floods and typhoons in Southeast Asia drive home the need to adapt to climate change

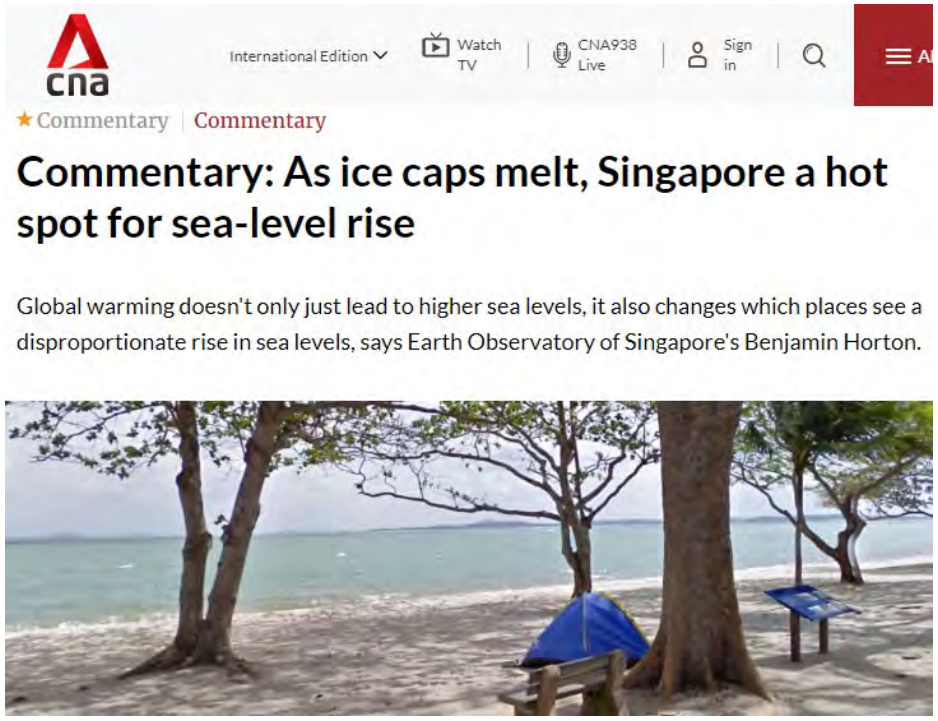
The region has been hit hard by year-end extreme weather events but developing adaptation policies is still at an early stage.

Typhoon Rai caused widespread destruction across many parts of the Philippines. (Photo: Aiah Fernandez)

Jack Board
@JackBoardCNA

05 Feb 2022 06:00AM
(Updated: 05 Feb 2022 06:00AM)

Climate change and Singapore

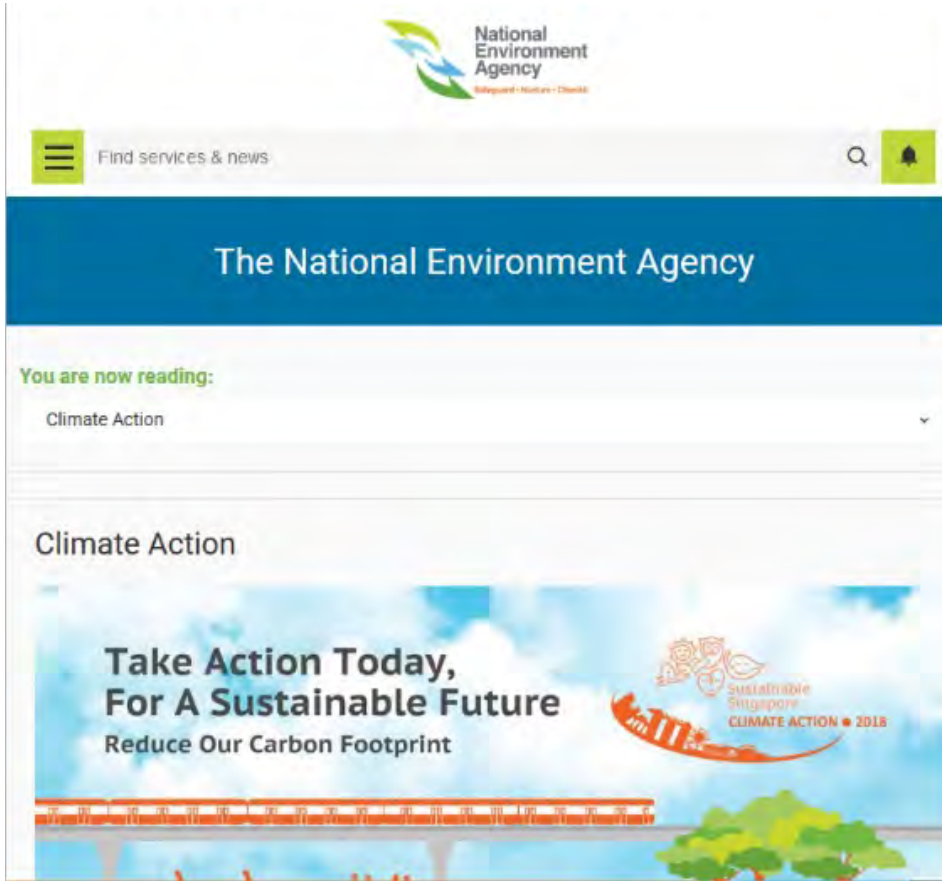


https://www.channelnewsasia.com/news/commentary/climate-change-in-singapore-outlook-floods-haze-warming-11841934

Source: Ministry of the Environment and Water Resources

SINGAPORE'S CLIMATE	DAILY TEMPERATURE	FREQUENCY OF WARM DAYS & NIGHTS	RAINFALL	WIND	SEA LEVEL RISE
OBSERVED CHANGES	From 1948 to 2016, annual mean temperatures rose at an average rate of 0.25°C per decade 	Since 1972, the number of warm days and nights has increased, and the number of cool nights has decreased 	From 1980 to 2016, annual total rainfall rose at an average rate of 101mm per decade 	General wind patterns influenced by northeast and southwest monsoons. There are no clear trends for wind speed as it is dependent on the environment 	Between 1975 to 2009, the sea level in the Straits of Singapore rose at the rate of 1.2mm to 1.7mm per year 
FUTURE CLIMATE PROJECTIONS	Daily mean temperatures are projected to increase by 1.4°C to 4.6°C 	More warm days and warm nights for February to September throughout the 21st century 	The contrast between the wet months (November to January) and dry months (February and June to September) is likely to be more pronounced. Intensity and frequency of heavy rainfall events is expected to increase as the world gets warmer 	Singapore will continue to be influenced by the northeast and southwest monsoons with potential increase in wind speeds during northeast monsoon season 	Sea levels are projected to rise by up to about 1 metre 

Climate change and Singapore

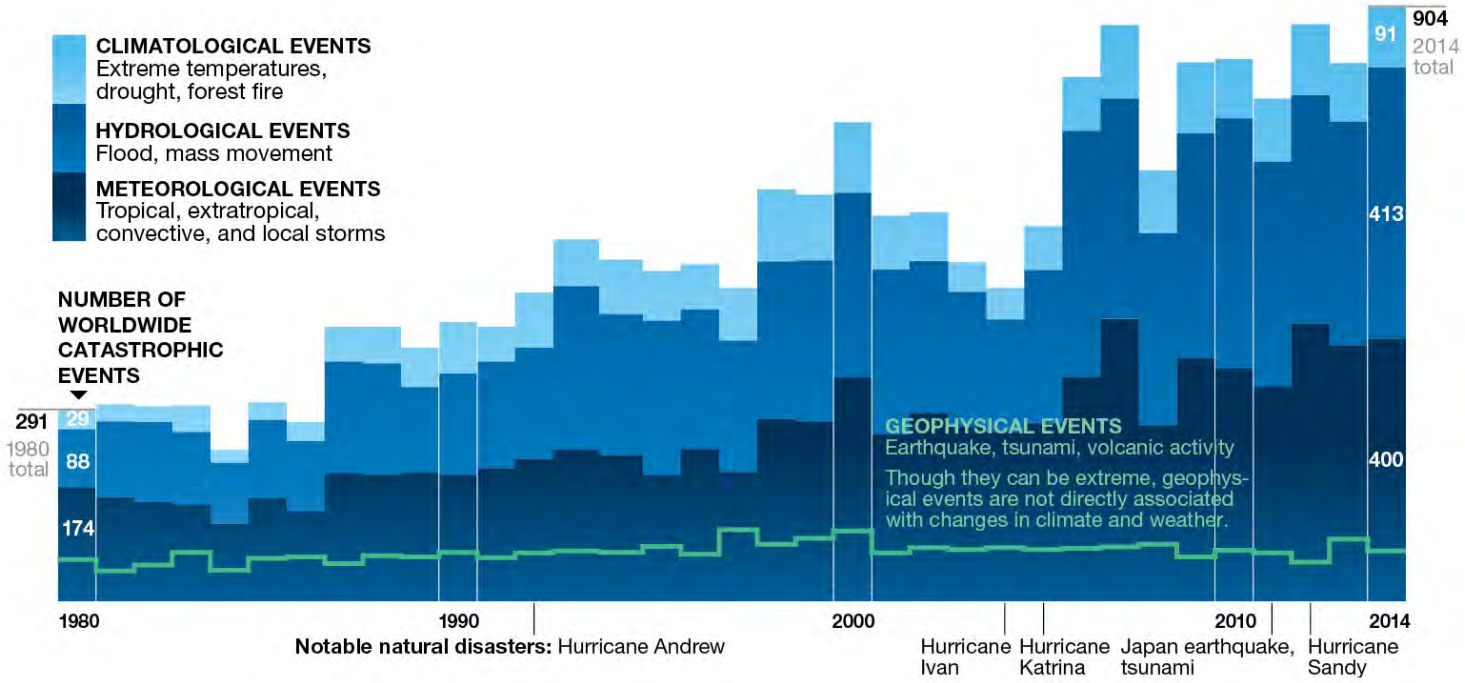


Climate change and Singapore

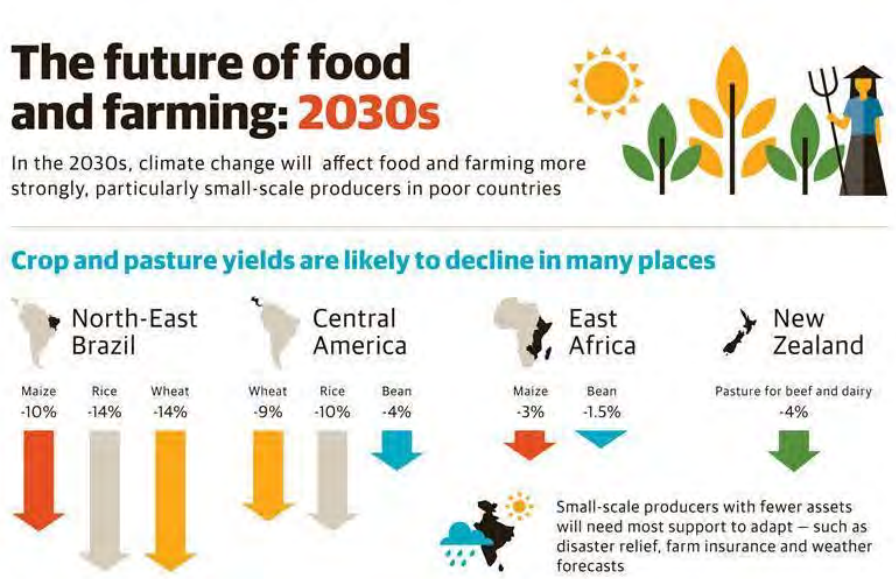
- Higher temperatures
  - Thirteen out of the past 15 years have been the warmest in Singapore's historical record since 1929
- Rainfall patterns and water resources
  - Prolonged dry periods and periodic flash floods
- Rising sea level
  - Due to thermal expansion of sea water volume and from melting land ice
  - Average sea level around Singapore's coasts increasing steadily (1.2 - 1.7mm per year). Projected to increase to about 1m by 2100
- Biodiversity loss
  - Increase in 1.5-2.5^{o}C affects ecosystem processes such as soil formation, pollution absorption and nutrient storage
  - Several local species already affected e.g. mangrove mudskippers
- Effects on public health
  - Increase vector-borne disease during warmer periods

What will happen if we do nothing?

Extreme weather events



Threat to food security and farming



By Jack Board
@JackBoardCNA

Asia

How flies and maggots are being bred to eat your food waste and keep Singapore clean

24 Mar 2018 06:30AM
(Updated: 25 Mar 2018 03:35PM)

Bookmark

Baked pupae of the black soldier fly will be fed to Singapore's chickens and fish. (Photo: Pichayada Promchertchoo)

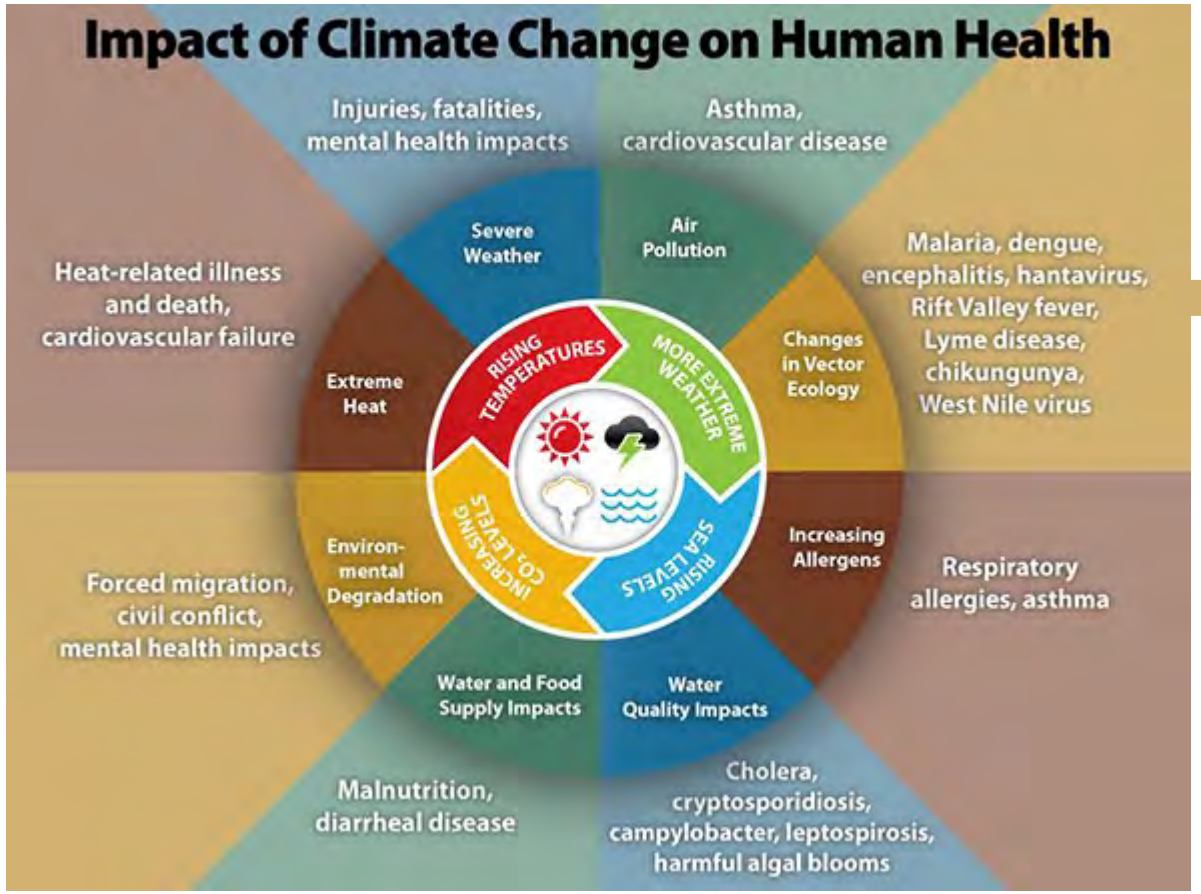
SINGAPORE: Imagine a packet of char kway teow which has seen better days. It's a gloomy colour and is literally crawling. There are maggots devouring what is a perennial Singapore dish.

Researchers develop blueprint for sustainable food system using black soldier flies

1 of 2

(From left) Professor Stephen Cairns, Assistant Professors Alexander Mathys and Nalini Puniamoorthy on Jan 25, 2022. ST PHOTO: JASON QUAH

What will happen if we do nothing?



State of the Planet

EARTH INSTITUTE | COLUMBIA UNIVERSITY

AGRICULTURE CLIMATE EARTH SCIENCES ECOLOGY ENERGY HEALTH SUST

CLIMATE, GENERAL EARTH INSTITUTE, HEALTH

How Climate Change Is Exacerbating the Spread of Disease

BY RENEE CHO | SEPTEMBER 4, 2014

17 81 Comments

Playing hooky to save the climate: why students are going on strike

Greta Thunberg's #FridaysforFuture movement has inspired kids in dozens of countries to demand action on climate change.

By Umair Irfan | Updated Feb 21, 2019, 10:15am EST

SHARE

Thousands of students went on strike in London on February 15, 2019, to protest their government's inaction on climate change. | Wiktor Szymanowicz/Barcroft Media/Getty Images

More than 15000 students in UK march calling for the urgent need for radical climate action
15 Feb 2019

Students in Paris demand greater action on climate change
22 Feb 2019

Students in Australia walked out of classes to hold a rally on climate change awareness
8 Dec 2018

Summary

- Ecological knowledge is **important**
- Helps explain many natural patterns observed & understand how they are linked
- Human activities rapidly changing environments & natural processes on a global scale (some processes are accelerating) negative consequences if impacts are not reduced
- Our actions today will determine the future for all life on earth tomorrow
- Take home questions:
  - What am I doing today that can have negative consequences for tomorrow?
  - What are sustainable practices that I can adopt?

Take home **practice** exam on Examplify

Exam format:
Non-Secure
Block Internet

Examplify

https://wiki.nus.edu.sg/display/DA/Download+and+Install+Examplify

Download software and take home e-exam, open book (90 min duration)

- Available for download: 18th February at noon
- Password will be shared on LumiNUS 18th February at noon
- Upload deadline: 23rd February at 6pm

**Other practice exams are available from CIT to test your system.
For information, refer to **Examplify Student Briefing.pdf** in Luminus

E-exam 1 on Examplify

Exam format:
Non-Secure
Block Internet

E-exam 1 will be held during lecture slot on 28th February (90 min)

- Available for download: 27th February at noon
- Password will be shared via Zoom 28th February at 1000h
- Upload deadline: 28th February at 1130h

ZOOM invigilation

- Mandatory second device
- Capture face,
  computer screen,
  keyboard