Animal Environmental Science

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Welcome

This is the website for **"Animal environmental science"**. To understanding individual animals, we have to understand the relationship they have with their environment. This book will focus at the interaction between animals and the environment.

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(Snow Monkey Niseko, Kutchan-chō, Japan)

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Chapter 1

Introduction

All living creatures constantly interact with the environment. To understanding individual animals, we have to understand the relationship they have with their environment. Also, animals affect the environment. From birth to death, an animal generates carbon dioxide, methane, feces, and urine. The excretes from the animal are built with molecules such as carbon, nitrogen, sulfur, and phosphorus, and are recycled within and between ecosystems.

Figure 1.1: Alaskan Malamute has the heat-conserving features. To retain heat you want the least body surface area compared to body volume.

Chapter 2

Animal and environment

2.1 External environment

Animal never separates from the stimuli from outside. Basically, animals can find food, shelter, protection, and mates from the environment called *habitat*. The animal habitat includes both phisical (non-living) and biotic (livinig) components (Table 2.1).

Animal habitat is constantly changed over time. Not only natural disasters (eruption of volcano, earthquake, tsunami, and wildfire), also human activity can affect the animal habitat. Unlike the wildlife, the environment of domesticated animals (such as cow, pig, poultry, and dog) that raised in the facility are controlled by the human. In the domestic animals, the external environment includes both physical (e.g. housing, feeder, paddock, fence, and noise) and biotic (e.g. human, mate, and feed ingredients) components.

2.1.1 Biome

A biome is a community of plants and animals that have common characteristics for the environment they exist in (Figure 2.1). They can be found over a range of continents. Biomes are distinct biological communities that have formed in response to a shared physical climate.

The principal biome-types are:

1. Tundra
2. Taiga
3. Deciduous forest
4. Grasslands
5. Desert
6. High plateaus
7. Tropical forest
8. Minor terrestrial biomes

Holdridge (1947; 1967) classified climates based on the biological effects of temperature and rainfall on vegetation under the assumption that these two abiotic factors are the largest determinants of the types of vegetation found in a habitat (Figure 2.2).

The three axes of the barycentric subdivisions are:

1. Precipitation (annual, logarithmic)
2. Biotemperature (mean annual, logarithmic)

Table 2.1: Components of habitat (physical and biotic)

Physical	Biotic
Temperature	Plant matter
Humidity	Predators
Oxygen	Parasites
Wind	Competitors
Soil	Individuals of the same species
Light intensity	
Elevation	

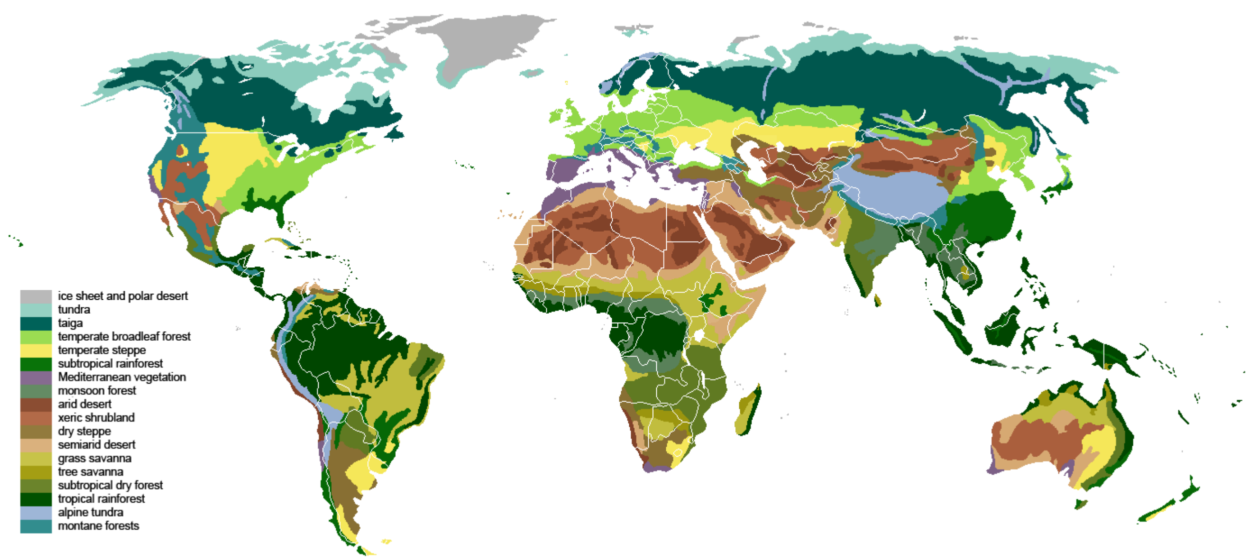

Figure 2.1: Mapping terrestrial biomes around the world

3. Potential evapotranspiration ratio (PET) to mean total annual precipitation.

Further indicators incorporated into the system are:

1. Humidity provinces
2. Latitudinal regions
3. Altitudinal belts

2.2 Internal environment

> "The living body, though it has need of the surrounding environment, is nevertheless relatively independent of it." — Claude Bernard

Higher animals have complex systems that respond to stimuli to perform their essential body functions. When the animal receives the signals from the sensory organs, they produce a local reflex action and/or react in the central nervous system. Weak signals produce no responses, but strong stimuli change the physiological or behavioral status of the animal.

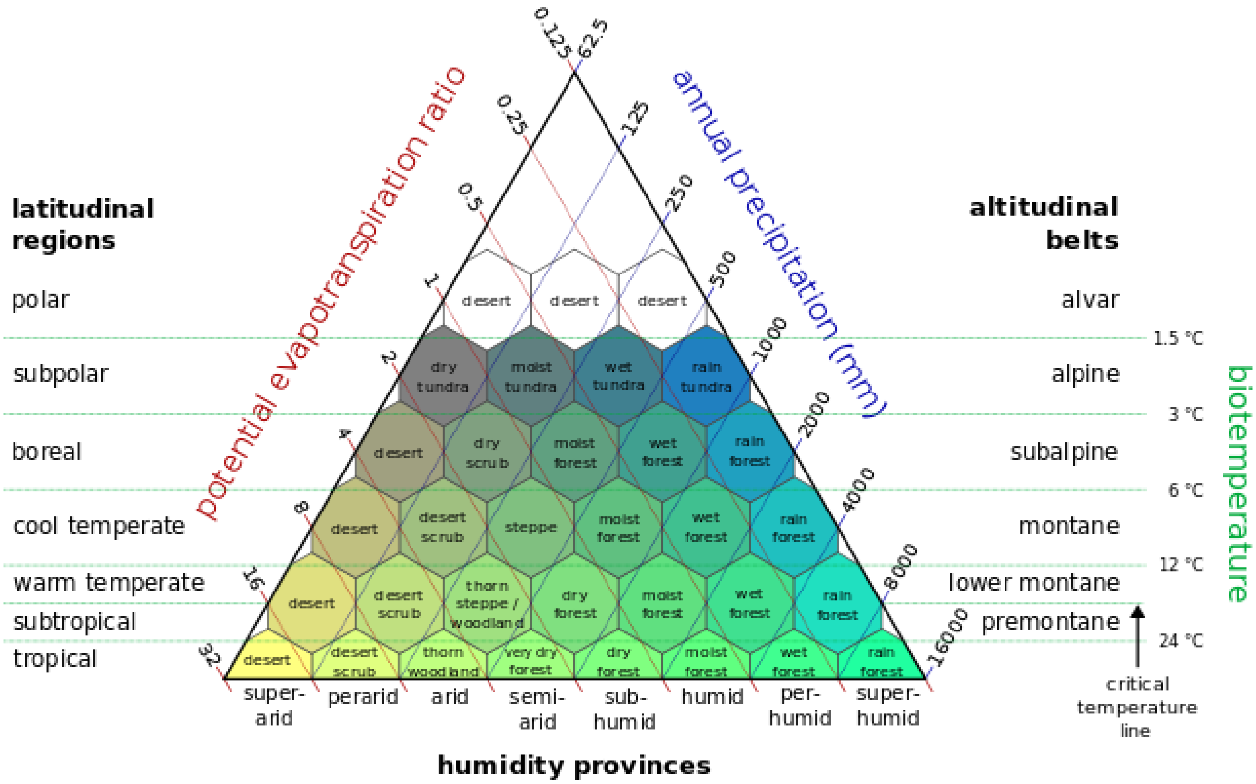

Figure 2.2: Holdridge life zone classification scheme.

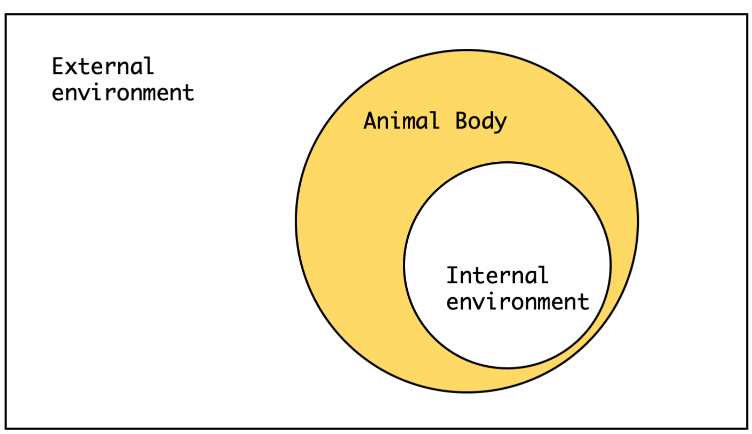

Figure 2.3: External and internal environment

Table 2.2: List of homeostatic control variables

Control variables
Core temperature; Blood glucose; Iron levels; Copper regulation; Levels of blood gases; Blood oxygen content; Arterial blood pressure; Calcium levels; Sodium concentration; Potassium concentration; Fluid balance; Blood pH; Cerebrospinal fluid; Neurotransmission; Neuroendocrine system; Gene regulation; and Energy balance

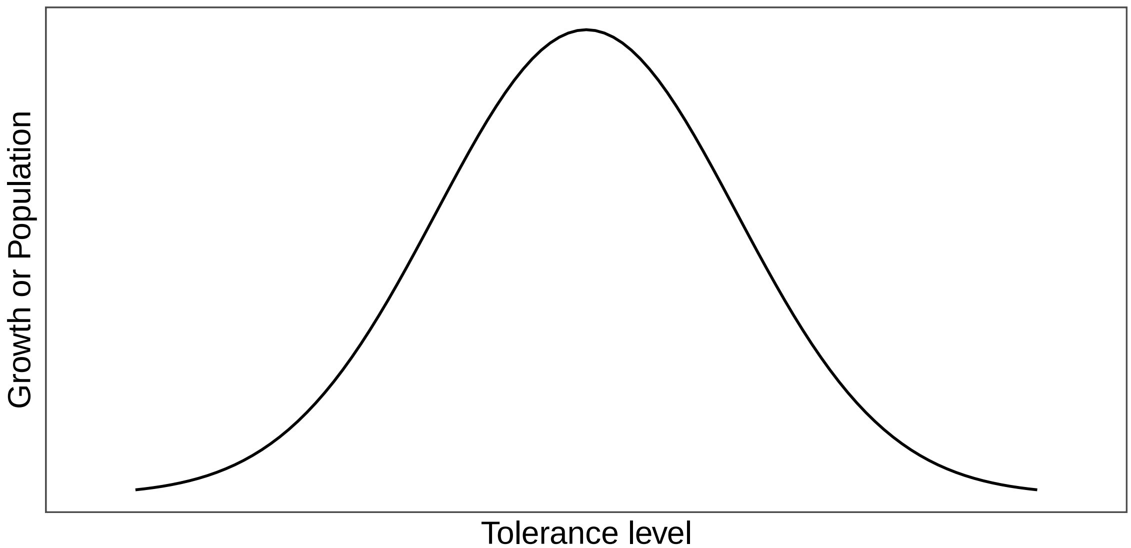

Figure 2.4: Shelford's law of tolerance

2.2.1 Shelford's law of tolerance

> "Each and every species is able to exist and reproduce successfully only within a definite range of environmental conditions." — Ronald Good

Although external environments are continuously changed, if animals in the normal status, they keep the composition of the extracellular fluid (internal environment) constant to maintain their life. We call it *homeostasis*.

However, the capacity to maintain the homeostasis is broken when the animals let the harsh environments and differ by their species. **Animals may be limited in their growth and their occurrence by the minimum, maximum, and optimum condition** (Shelford, 1931) (Fig. 2.4).

The optimum range of environmental condition may differ within the same organism, and it is not necessarily fixed. They can change as:

- Change of seasons
- Change of environmental conditions
- Life stage of the organism

2.2.2 Adaptation

> "Changes in morphological, anatomical, physiological, biochemical and behavioral characteristics of the animal which promote welfare and favor survival in a specific environment." — Hafez

Hafez et al. (1968) defined an adaptation as above. The adaptation helps an animal survive in their external environment. The representative adaptive traits are:

1. Structural adaptation
2. Behavioral adaptation
3. Physiological adaptation

Structural adaptation is the changes in physical features (e.g. body shape, skin, and internal organs) of the animal. Behavioral adaptation is the changes in behaviors (e.g. searching for food, mating, vocalizations, and mitigation) of the animal. Physiological adaptation is the changes in the animal body functions such as growth, temperature regulation, and ionic balance. Sometimes, adapted animal create a new species (*speciation*).

2.2.3 Acclimatization

Acclimatization is the physiological changes induced by a complex of factors such as altitude, temperature, humidity, photoperiod, or pH. Acclimatization is the short-term process (hours to weeks) by comparison with adaptation (take place over many generations).

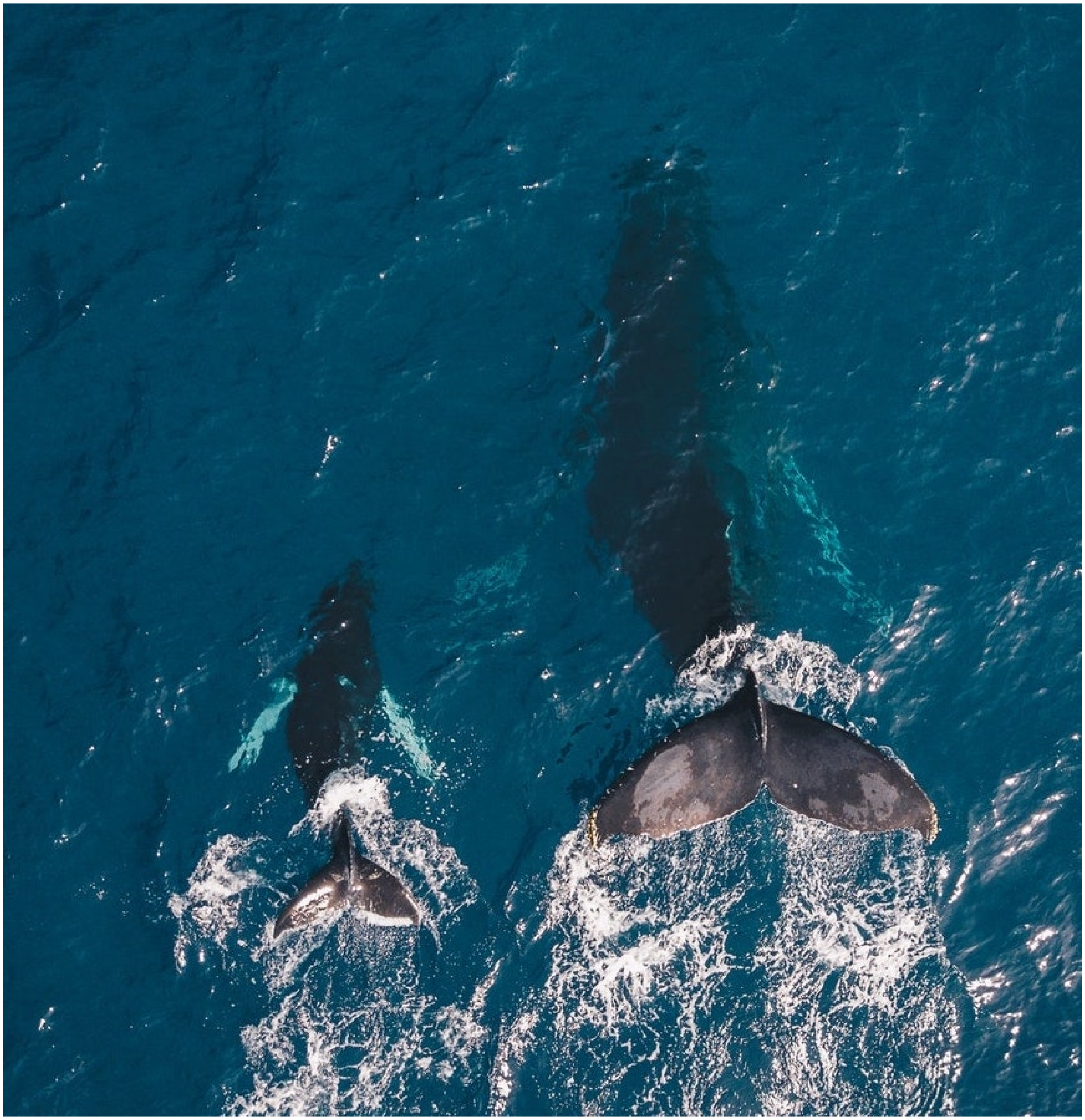

Figure 2.5: Migration is an example of a behavioral adaptation. Grey whales swim from the Arctic to Mexico every year.

Chapter 3

Temperature

Temperature is a quantity expressing of the amount of heat. Because a rate of every chemical reaction occurs in the animal's body is affected by the temperature, it is a very important factor to all animals. Like most chemical reactions, an enzyme-catalyzed reaction rate in the animal's body increases as the temperature is raised. However, extremely high or low temperature results in loss of activity or lose the structure for most enzymes (*denaturation*; Figure 3.1).

3.1 Poikilotherm and homeotherm

Key factors for animal surviving are to adapt to external environmental changes and maintain a consistent internal environment. The animal can be divided into two types for response to external temperatures: *poikilotherm* (cold-blooded animals) and *homeotherm* (warm-blooded animals). Examples of poikilotherms are most fish, amphibians, and reptiles. Their internal body temperature varies considerably according to their external environments. On the other hand, homeotherm maintains their thermal homeostasis regardless of the external temperature. The examples of homeotherm are birds and mammals.

3.1.1 Poikilotherm

The term derives from the acient Greek language *poikilos* (; changeable) and *thermos* (; heat). The body temperature of poikilotherms varies considerably than those of homeotherms (Figure 3.2). They generally use solar radiation for maintaining their body temperature and have four to ten enzyme systems that can operate at different ambient temperature because the temperature affects the chemical reactions.

3.1.2 Homeoterm

Homeotherms can maintain body temperature independently from ambient temperatures by regulating the metabolic process. They preserve their body temperature by muscle contraction and brown adipose tissue is catabolized for heat production (Grigg et al., 2004). In hot environments, they use evaporative cooling (sweating or panting) for maintaining their body temperature. Most of the domestic animals are homeotherm.

In some homeoterms (bears, hedgehog, marmot, and so on) and poikilotherms (frogs, turtles, snake, and so on), they can enter the *hibernation* in the cold season: the body temperature is dropped, and the metabolic rate is depressed. Hibernating bears can recycle their body proteins and urine to avoid muscle loss.

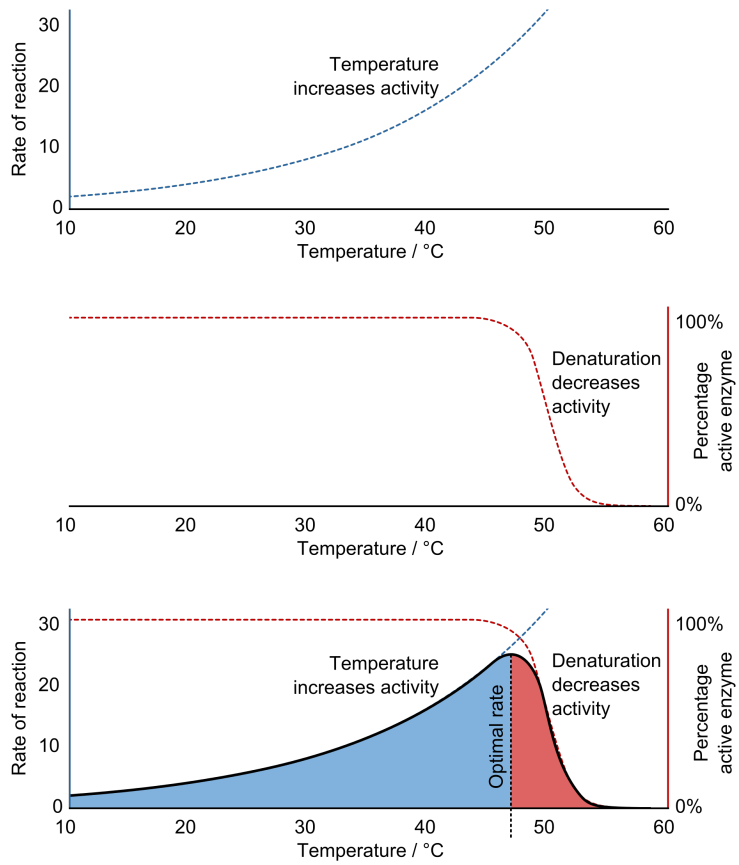

Figure 3.1: The effects of temperature on enzyme activity [@q10]. Top - increasing temperature increases the rate of reaction (Q10 coefficient). Middle - the fraction of folded and functional enzyme decreases above its denaturation temperature. Bottom - consequently, an enzyme's optimal rate of reaction is at an intermediate temperature.

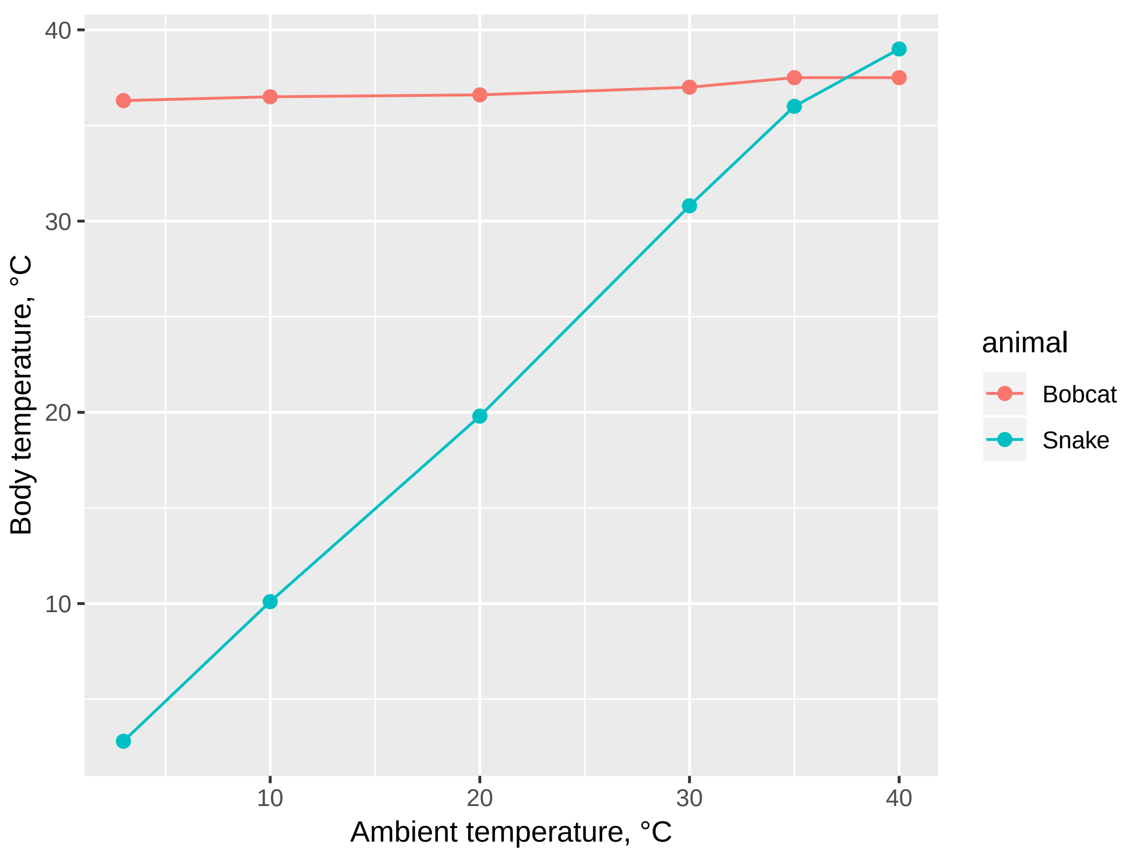

Figure 3.2: Comparison of body temperature response by snake (poikiloterm) and bobcat (homeoterm) to changing ambient temperature.

Figure 3.3: Green frog on blue surface.

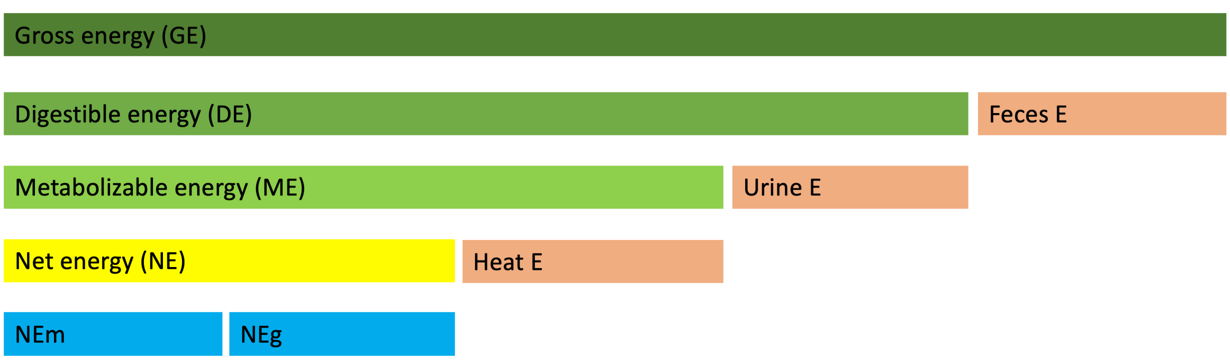

Figure 3.4: Overview of feed energy flow through the animal body

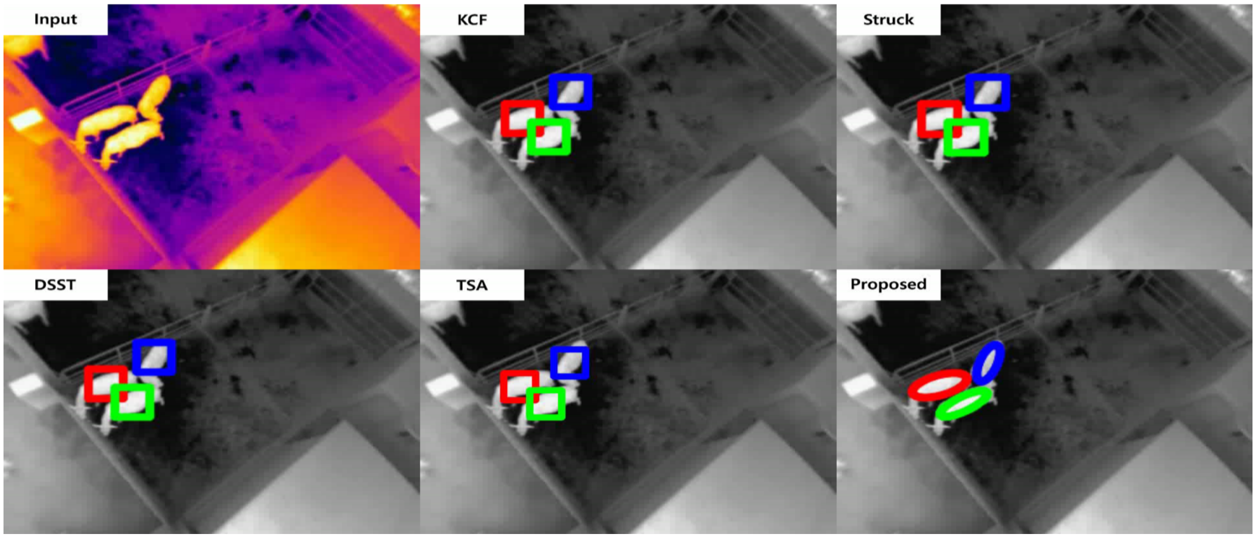

Figure 3.5: Infrared cameras image that cows generating the heats. @kim2018image developed the algorithms for tracking the cows using IR camera video.

Table 3.1: Normal body temperature of the domestic animals; Body temperatures may be 1°C above or below these temperatures.

Animal	Normal temperature (°C)	Animal	Normal temerature (°C)
Cattle	38.5	Donkey	38.2
Calf	39.5	Chicken	42.0
Buffalo	38.2	Camel	34.5-41.0
Sheep	39.0	Horse	38.0
Llama, alpaca	38.0	Pig	39.0
Goat	39.5	Piglet	39.8

3.1.3 Heterotherm

Heterotherms exhibit the characteristics of both poikilotherm and homeotherm. They can switch between poikilothermic and homeothermic strategies. In some bat species, for example, body temperature and metabolic rate are elevated only when they are active. When they at rest, metabolic rate is drastically dropped thereby the body temperature is decreased to the ambient temperature.

3.2 Thermoregulation

Thermoregulation is a process to maintain the internal temperature within certain boundaries. In homeotherms, thermoregulatory physiology is mainly controlled by nervous and endocrine systems. The core temperature of the animal is primarily regulated by the hypothalamus. If the ambient temperature is going to cold, they generate heat via metabolic processes to keep their body temperature. In contrast, in hot conditions, sweat glands release sweat for evaporates and the blood vessels going to wider for increasing the blood flow to the skin.

In poikilotherms, they use external sources of temperature to keep their body temperatures (Table 3.2). To regulate their body temperature, they sometimes climbing the trees, entering the warm water, lying on the cool ground, or lying in the sun. There are some methods for thermoregulation in poikilotherms: *convection*, *conduction*, and *radiation*. Convection is the transfer of heat via the movement of molecules within fluids

Table 3.2: Cooling and heating methods for poikilotherms

Methods	Cooling	Heating
Convection	Increasing blood flow to body surfaces	Entering a warm water or
Conduction	Lying on cool ground; Staying wet in a river, lake or sea; Covering in cool mud	Lying on a hot surface
Radiation	Get away from the sun	Lying in the sun; Folding s

(gases or liquids). Conduction is the transfer of heat via the direct molecular collision. Radiation is the transfer of heat in the form of waves or particles (sunlight is the most familiar forms of radiation). Once there's a thermal equilibrium between the animal and environment, the thermal exchange will be stopped.

3.3 Temperature humidity index (THI)

The productivity of domestic animals is primarily affected by air temperature, and altered by wind, humidity, and radiation. Temperature–humidity index (THI) is a combination of temperature and humidity that is a measure of the degree of discomfort experienced by an individual in warm weather (a.k.a. discomfort index). This unitless index was first introduced by Thom (1959) to describe the effect of ambient temperature on humans but has been adapted to describe thermal conditions that drive heat stress in dairy cattle (De Rensis et al., 2015). Temperature-humidity index for dairy cow is calculated as

$$THI = (0.8 * T) + [H * (T - 14.4)] + 46.4$$

where T is the air temperature and H is the relative humidity. The THI is a useful tool for predicting the heat stress of cows, however, it does not account for solar radiation and wind speed which can affect the heat load of cattle.

3.4 Effects heat stress on the animal production and health

Homeotherms have optimal temperature zones for production within which no additional energy above maintenance is expended to heat or cool the body. The range for lactating dairy cows is estimated to be from -0.5 to 20°C (Johnson, 1987).

3.4.1 Dairy cattle

Heat stress decreases milk production. Lactating dairy cows have an increased sensitivity to heat stress compared with nonlactating (dry) cows, due to milk production elevating metabolism (Purwanto et al., 1990). Moreover, because of the positive relationship between milk yield and heat production, higher yielding cows are more challenged by heat stress than lower yielding animals (Spiers et al., 2004).

When a cow becomes heat stressed, an immediate coping mechanism is to reduce DMI, causing a decrease in the availability of nutrients used for milk synthesis (West, 2003; Rhoads et al., 2009). Simultaneously, there is an increase in basal metabolism caused by activation of the thermoregulatory system. Mild to severe heat stress can increase metabolic maintenance requirements by 7 to 25% (NRC, 2001).

Heat stress decreases reproductivity. The decrease in conception rates during summer seasons can range between 20 and 30%, with evident seasonal patterns of estrus detection (De Rensis and Scaramuzzi, 2003). Elevated environmental temperatures negatively affect the cow's ability to display natural mating behavior, as it reduces both the duration and intensity of estrous expression (Orihuela, 2000). A reduction in estrous behavior has been argued to be the result of reduced DMI and the subsequent effects on hormone production (Westwood et al., 2002). Decreased milk production and declining reproductive success are the most commonly examined components of a heat-stressed dairy cow's health.

Temp	% Relative Humidity																				
°F	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
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89	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
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92	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
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113	83	84	86	87	89	91	92	93	95	96	98	99	101	102	104	105	107	108	110	111	113
114	83	85	86	88	89	92	92	94	96	97	99	100	102	103	105	106	108	109	111	112	114
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117	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	85	87	89	90	92	94	96	97	99	101	102	104	106	107	109	111	112	114	116	117	119

Figure 3.6: THI chart for dairy cows. Yellow = Stress Threshold Respiration rate exceeds 60 BPM. Milk yield losses begin. Repro losses detectable. Rectal Temperature exceeds 38.5°C (101.3°F). Orange = Mild-Moderate Stress Respiration Rate Exceeds 75 BPM. Rectal Temperature exceeds 39°C (102.2°F). Red = Moderate-Severe Stress Respiration Rate Exceeds 85 BPM Rectal Temperature exceeds 40 °C (104°F). Purple = Severe Stress. Respiration Rate 120-140 BPM. Rectal Temperature exceeds 41 °C (106°F)

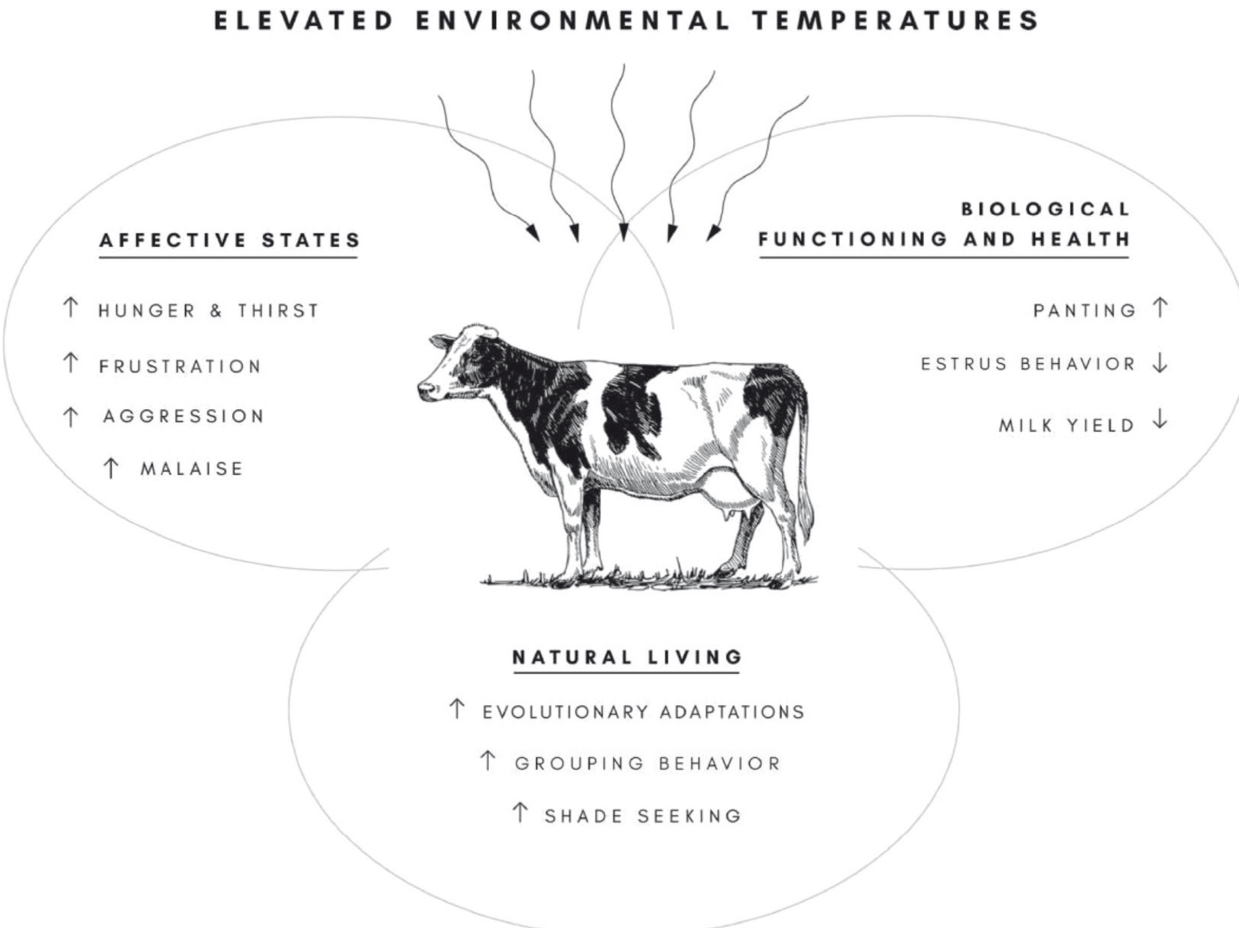


Figure 3.7: The relationship between the immediate effects of environmental heat stress and the 3 key constructs of animal welfare: (1) the biological functioning (and health) of the animal, (2) the affective states the animal is experiencing, and (3) the naturalness of its life under current heat management strategies (Polsky et al., 2017).

Alterations in housing and management strategies have attempted to mitigate the heat stress. Basically, various cooling options for dairy cows exist based on the principles of convection, conduction, radiation, and evaporation.

1. **Fan installations**, which facilitate air movement and increase convection, have been used to reduce environmental temperatures and mitigate heat stress by decreasing respiratory rate and rectal temperature and increasing DMI (Armstrong, 1994).

2. **High-pressure mist injected into fans** (which function to cool the microclimate air that the cows inspire) or large water droplets from low-pressure sprinkler systems that completely wet the cow by soaking the hair coat.

3. **Physical structures** that provide shade such as trees, roofs, or cloth can create more hospitable microclimates for cows because of the reduction in solar radiation exposure and decline in ambient temperature.

4. **Barn orientation** (depending on geographic location) can also help mitigate heat stress by reducing the insolation and stall surface temperature.

3.4.2 Beef cattle

As temperatures heat up during the summer cattle producers need to assess the heat stress that their cattle are under. Typically pastured cattle are not as susceptible to heat stress as feedlot cattle. Pastured cattle have the ability to seek shade, water and air movement to cool themselves.

Compared to other animals cattle cannot dissipate their heat load very effectively. Cattle do not sweat effectively and rely on respiration to cool themselves. Cattle should not be worked during times of extreme heat and only early in morning when it is hot.

Cattle's core temperature peaks 2 hours after peak environmental temperature. It also takes at least 6 hours for cattle to dissipate their heat load. Therefore, if peak temperature occurred at 4:00 pm cattle will not have recovered from that heat load until after 12:00 am and it will be later than that before cattle have fully recovered from the entire days heat load. Special attention should be paid to cattle with increased risk of heat stress including heavy cattle, black cattle and respiratory compromised animals.

3.4.2.1 Heat stress management

1. The water requirements of cattle increases during heat stress. Cattle lose water from increased respiration and perspiration. **Consumption of water** is the quickest method for cattle to reduce their core body temperature.

2. Heat production from feed intake peaks 4 to 6 hours after feeding. Therefore heat production in cattle fed in the morning will peak in the middle of the day when environmental temperatures are also elevated. **Changing the ration** indicates that lowering the energy content of diet will decrease the heat load. The general recommendation is to reduce the diet energy content by 5 to 7%.

3. **Increasing the air flow** can help cattle cope with extreme heat events. Wind speed has been shown to be associated with ability of cattle to regulate their heat load.

4. **Sprinklers** can be used to cool cattle during times of stress. Sprinklers increase evaporative cooling and can reduce ground temperature. Sprinklers should thoroughly wet the animal and not just mist the air in order to cool the animal. Sprinklers should be placed away from feed bunks and waterers. Cattle need to be introduced to sprinklers prior to extreme heat.

3.4.3 Swine

Most animals can transfer internal heat to the outside of the body by sweating and panting. These are the two most important tools for the maintenance of body temperature and form their inbuilt evaporative cooling system. However, pigs do not sweat and have relatively small lungs. Due to these physiological limitations and their relatively thick subcutaneous fat, pigs are prone to heat stress. Today's modern pig genotypes produce considerably more heat than their predecessors (new genetic lines of pigs produce nearly 20% more heat than their counterparts in the early 1980s.).

The two obvious symptoms observed when pigs are exposed to heat stress are increased respiration rate and loss of appetite. If the pig exposed to 35°C for 24 hours significantly damaged the intestinal defense system and also increased plasma endotoxin levels. It can provide an opportunity for infection as pathogenic bacteria can invade the body more easily.

3.4.3.1 Heat stress management

- Increase ventilation and airflow and regularly check cooling system.
- Reduce stocking density if possible.
- Maintain drinking water temperature as low as possible (around 10°C is ideal but difficult to achieve).
- Avoid feeding between 10:00 to 16:00 (the hottest period of the day).
- Supplement electrolytes and antioxidants through the water supply.
- Minimise excess non-essential amino acids and fibre (minimising intestinal fermentation and therefore heat production).
- Increase availability of antioxidants through the diet such as vitamin E and betaine.

3.4.4 Poultry

High temperature affects the physiological functions of poultry birds at any stage of life which in results affects the poultry production performance. Modern commercial poultry produces more body heat due to their fast metabolism. This makes birds more sensitive to environmental temperature. In addition, the chicks are highly sensitive to heat stress because they don't have sweat glands.

3.4.4.1 Heat stress management

- Semi-open buildings can help the ventilation.
- Maintain drinking water temperature as low as possible.
- A shiny surface reflects solar radiation more than a dark or rusty roof.
- Fat addition and excess essential amino acids in feed.
- Supplement of minerals (Fe, Zn, Se and Cr) and vitamins (vitamin A, C and E).
- Genetic selection strategies.

3.4.5 Canine

When a dog is exposed to high temperatures, heat stroke or heat exhaustion can result. Heat stroke is a very serious condition that requires immediate medical attention. Dogs do not sweat through their skin like humans. They release heat primarily by panting and they sweat through the foot pads and nose. If a dog cannot effectively expel heat, the internal body temperature begins to rise. Once the dog's temperature reaches 41°C damage to the body's cellular system and organs may become irreversible.

Signs of heat stroke are 1) increasing the rectal temperature, 2) vigorous panting, 3) dark red gums, 4) tacky or dry mucus membranes (specifically the gums), 5) lying down and unwilling (or unable) to get up, and/or 6) dizziness or disorientation.

3.4.5.1 Treatments for heat stroke

1. Move your dog out of the heat and away from the sun right away.

2. Begin cooling your dog by placing cool, wet rags or washcloths on the body.

3. Do not use ice or cold water. Extreme cold can cause the blood vessels to constrict, preventing the body's core from cooling and actually causing the internal temperature to further rise. When the body temperature reaches 39.5°C, stop cooling.
4. Offer your dog cool water, but do not force water into your dog's mouth.

3.4.5.2 Preventing the heat stroke

1. Never leave your dog alone in the car on a warm day, regardless of whether the windows are open. Even if the weather outside is not extremely hot, the inside of the car acts like an oven.

2. Avoid vigorous exercise on warm days.

3. Keep fresh cool water available at all times.

4. Certain types of dogs are more sensitive to heat – especially obese dogs and short-nosed breeds, like Pugs and Bulldogs (Figure 3.8).

Figure 3.8: Certain types of dogs are more sensitive to heat – especially obese dogs and short-nosed breeds, like Pugs and Bulldogs.

Chapter 4

Light

4.1 Sunlight

The main source of light on th earth is the sun. Sunlight provides the energy that green plants use to create sugars mostly in the form of starches, which release energy into the living things that digest them. This process of photosynthesis provides virtually all the energy used by living things. Some species of animals generate their own light, a process called bioluminescence. For example, fireflies use light to locate mates, and vampire squids use it to hide themselves from prey.

Daylight is the combination of all direct and indirect sunlight during the daytime. Daytime is the period of time each day when daylight occurs. **Daylight happens as the earth rotates, and either side on which the sun shines is considered daylight.** Illuminance is a measure of how much luminous flux is spread over a given area. The lux (symbol: lx) is the SI derived unit of illuminance.

4.2 Photoperiodic response

Photoperiodic response is the physiological reaction of organisms to the length of day or night. A number of biological and behavioural changes are dependent on the daylength. Together with temperature changes, photoperiod provokes changes in the color of fur and feathers, migration, entry into hibernation, sexual behaviour, and even the resizing of sexual organs.

In animals, the regular activities of migration, reproduction, and the changing of coats or plumage can be induced out of season by artificially altering daylight. Long periods of light followed by short periods will induce mating behaviour in species that normally breed in autumn (e.g. goats and sheep), while spring breeders (e.g. mink) will start the reproductive process when daylight is increased. Application of photoperiodism is common in the poultry industry, as daylight affects egg-laying, mating, and body weight of the fowl.

4.3 Seasonal breeding

Seasonal breeders are animal species that successfully mate only during certain times of the year. **These times of year allow for the optimization of survival of young** due to factors such as ambient temperature, food and water availability, and changes in the predation behaviors of other species. Related sexual interest and behaviors are expressed and accepted only during this period. Female seasonal breeders will have one or more estrus cycles only when she is “in season” or fertile and receptive to mating. Male seasonal breeders may exhibit changes in testosterone levels, testes weight, and fertility depending on the time of year.

Figure 4.1: Sunlight

Figure 4.2: Sheep breeds when the length of daylight shortens

Table 4.1: Light intensity in different conditions.

Illuminance	Example
120,000 lux	Brightest sunlight
111,000 lux	Bright sunlight
20,000 lux	Shade illuminated by entire clear blue sky, midday
1,000-2,000 lux	Typical overcast day, midday
400 lux	Sunrise or sunset on a clear day
0.25 lux	A full Moon, clear night sky
0.01 lux	A quarter Moon, clear night sky

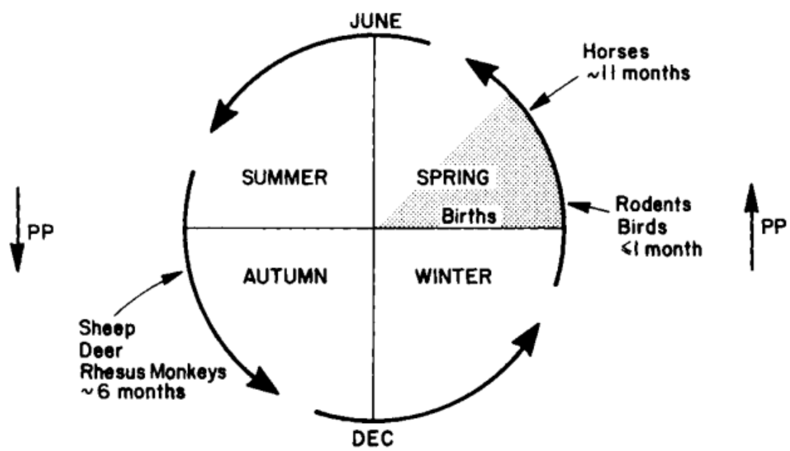


Figure 4.3: Timing of annual reproductive cycle of exemplary seasonal breeders. PP, photoperiod.

The hypothalamus is considered to be the central control for reproduction due to its role in hormone regulation. This is achieved specifically through changes in the production of the hormone GnRH. GnRH in turn transits to the pituitary where it promotes the secretion of the gonadotropins LH and FSH, both pituitary hormones critical for reproductive function and behavior, into the bloodstream.

Seasonal breeding readiness is strongly regulated by length of day (photoperiod) and thus season. Photoperiod likely affects the seasonal breeder through changes in melatonin secretion by the pineal gland that ultimately alter GnRH release by the hypothalamus. Seasonal breeders can be divided into groups based on fertility period. **"Long day"** breeders (horse, hamsters, and mink) cycle when days get longer (spring) and are in anestrus in fall and winter. **"Short day"** breeders (sheep, goat, and elk) cycle when the length of daylight shortens (fall) and are in anestrus in spring and summer.

4.3.1 Antlers

Antlers are extensions of an animal's skull found in members of the deer family. Antlers are shed and regrown each year (grown every spring and shed every winter) and function primarily as objects of sexual attraction and as weapons in fights between males.

The annual antler cycle is ultimately controlled by day length or photoperiod. Growth of antlers typically begins in April in response to increasing day length. In the spring, testicular and pituitary hormones get the growing process started. Antlers are covered with velvet (such as in the antlers of the deer in the photo above) which carries blood and nutrients to the antlers during development. By late summer, as day length decreases, testosterone levels begin to increase, the form is filled, and the antler begins to harden. Hard antlers remain on the deer through the peak of breeding until late fall or early winter. In winter, when

Figure 4.4: Antlers are shed and regrown each year.

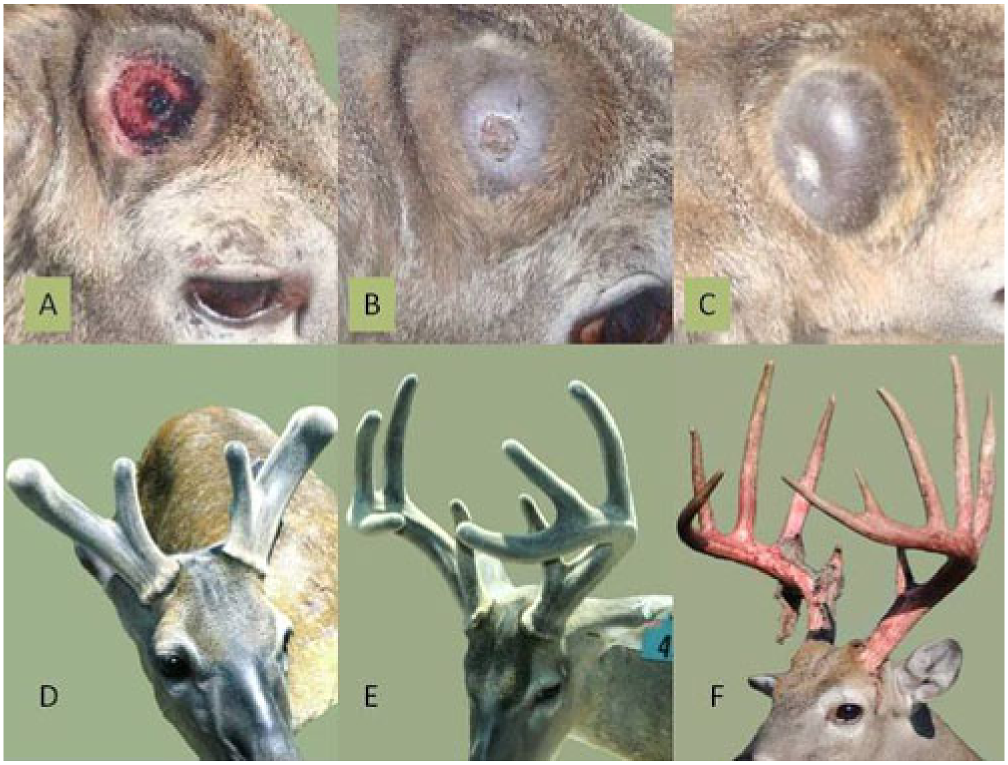


Figure 4.5: Stages of antler growth. A) one day after antler shed, B) 15 days after shed, scab still attached, C) 30 days after shed, scab is shed (A, B, C same animal), D) about three months after shed by different animal, E) about five months after shed antler growth is completed, with one additional month used to complete hardening and drying of velvet (D and E same animal), and F) hardened antler with shreds of dried velvet on a third animal. (Photo Credits A-E, Steve Demarais, F, Dave Hewitt)

the growth hormones quit pumping, the pedicel loses calcium which weakens the connection between the pedicel and the antler, and off come the antlers.

Horns, on the other hand, are found on members of the *Bovidae* family, which includes species as diverse as cows, sheep and goats to water buffalo, antelopes, and gazelles. Unlike antlers, horns are never branched, are never shed, and in many species horns never stop growing throughout an animal's life.

4.4 Effects on productivity

4.4.1 Light control in poultry production

Lighting is a key environmental factor in poultry production that is known to affect performance and behavior. The photoperiod is the duration of the light period and scotoperiod is the duration of the dark period perceived in a light:dark cycle, which is typically 24 h in length.

4.4.1.1 Broiler

Modern broiler stocks have been genetically selected for rapid growth, heavy BW, feed efficiency, and high breast meat yield. Lighting programs have been developed based on their effectiveness in the industry to optimize performance. The performance parameters of broilers in which producers are most interested are BW, feed efficiency, and livability. **Continuous lighting (24L:0D) leads to greater BW for meat-type**

Table 4.2: An example of broiler lighting program.

Days	Light (h)	Dark (h)	Intensity (lux)
0	23	1	20
1-2	20	4	20
3-4	18	6	20
5-14	6	18	5
15-21	10	14	5
22-28	14	10	5
29-35	18	6	5
36-42	24	0	5

chickens compared to those under 8L:16D or 12L:12D. Generally, longer dark period leads to greater feed efficiency.

4.4.1.2 Layers

Layer hens require a minimum amount of light intensity for optimal egg production, usually 5 to 10 lux. Both estrogen and progesterone are required to form eggs, and a short daylength will not stimulate the secretion of these hormones.

The color of light has been shown to affect the size and weight of the eggs. Blue-green light stimulates growth in chickens, whereas orange-red light stimulates reproduction. Red light, in the 630nm wavelength range, was found to be superior to any other wavelength in increasing egg production. However, blue light has a calming effect on birds whereas red may enhance feather pecking and cannibalism.

4.5 Appendix

Chapter 5

Sound

"One good thing about music, when it hits you, you feel no pain." — Bob Marley

Sound is a vibration that typically propagates as an audible wave of pressure, through a transmission medium such as a gas, liquid or solid. The sound waves are generated by a sound source, such as the vibrating diaphragm of a stereo speaker. The sound source creates vibrations in the surrounding medium. The speed of sound is the distance travelled per unit time by a sound wave as it propagates through an elastic medium. At 20 °C, the speed of sound in air is about 343 m/s.

The hertz (Hz) is the derived unit of frequency in the SI and is defined as one cycle per second. A decibel (dB) measures ratios of power or intensity. The decibel is not an SI unit.

5.1 Perception of sound

The physical reception of sound in any hearing organism is limited to a range of frequencies. Humans normally hear sound frequencies between approximately 20 Hz and 20,000 Hz (20 kHz). The upper limit of sound frequency decreases with age. Dogs can perceive vibrations higher than 20 kHz. Ultrasound is sound waves with frequencies higher than 20,000 Hz. Infrasound is sound waves with frequencies lower than 20 Hz. Although sounds of such low frequency are too low for humans to hear, whales, elephants and other animals can detect infrasound and use it to communicate.

Sound is used by many species for detecting danger, navigation, predation, and communication. Earth's atmosphere, water, and virtually any physical phenomenon, such as fire, rain, wind, surf, or earthquake, produces its unique sounds. Many species, such as frogs, birds, marine and terrestrial mammals, have also developed special organs to produce sound. In some species, these produce song and speech. Furthermore, humans have developed culture and technology (such as music, telephone and radio) that allows them to generate, record, transmit, and broadcast sound.

5.2 Vocalization

Animal vocalization refers to any sound an animal may make to communicate a message to others. All birds and mammals are able to vocalize. They use the voice as communication signals to indicate some types of "need".

With increasing interest in measures of welfare "from the animal's point of view" the study of vocalizations of the animal is still in the focus of interest. The vocalization of pigs has been a topic of research since nearly half a century. The vocalization in pigs is strongly related to their level of excitement. Low-pitched

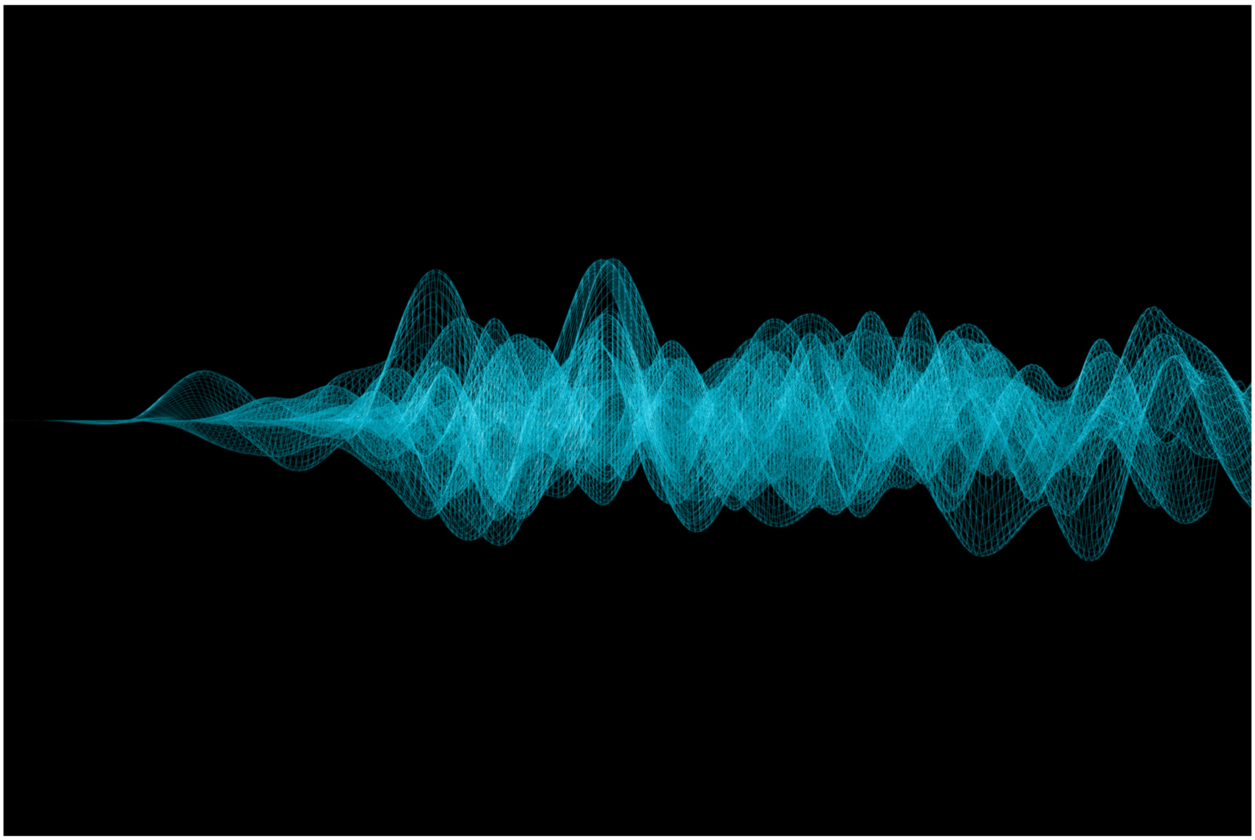
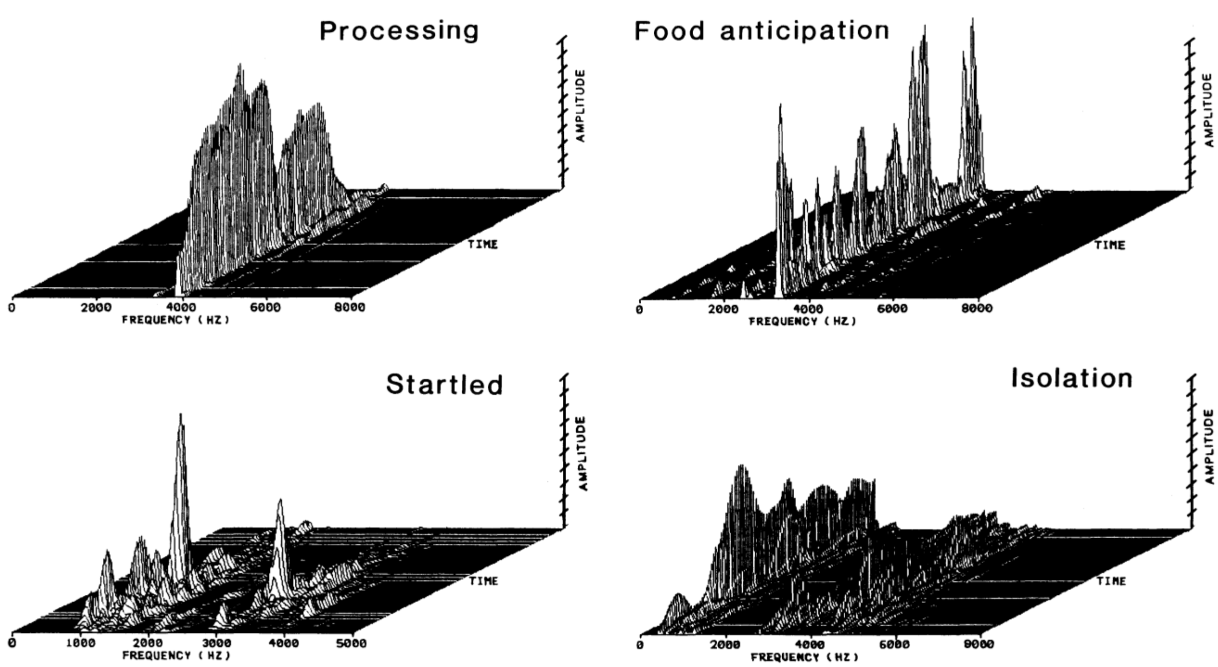


Figure 5.1: Sound is a vibration that typically propagates as an audible wave of pressure.

Table 5.1: Examples of different level of decibel.

Sound Level	Examples
171 dB	Next to a loud rifle being shot
150 dB	Right next to a jet engine
110-140 dB	Jet engine at 100 meters
130-140 dB	Where most people begin to feel pain
130 dB	Trumpet (a half meter in front of)
120 dB	Vuvuzela horn (1 meter in front of), risk of immediate hearing loss
110 dB	Gas chainsaw
100 dB	Jack hammer
80-90 dB	Traffic on a busy roadway
60-80 dB	Passenger car
40-60 dB	Normal conversation
20-30 dB	Very calm room
10 dB	Light leaf rustling, calm breathing
0 dB	Hearing threshold right next to ear

vocalizations with low tonality such as grunts are used to maintain social contact with group mates. Louder and longer but high-pitched calls such as screams are more related to the state of excitement. Xin et al. (1989) demonstrated that in a production environment several types of pig vocalizations can be distinguished.



A great number (roughly 30) of different vocalizations have been described for adult and juvenile chickens (Collias and Joos, 1953, Baumer, 1962, Guhl, 1968, Wood-Gush, 1971, Huber and Folsch, 1978, Wennrich, 1981).

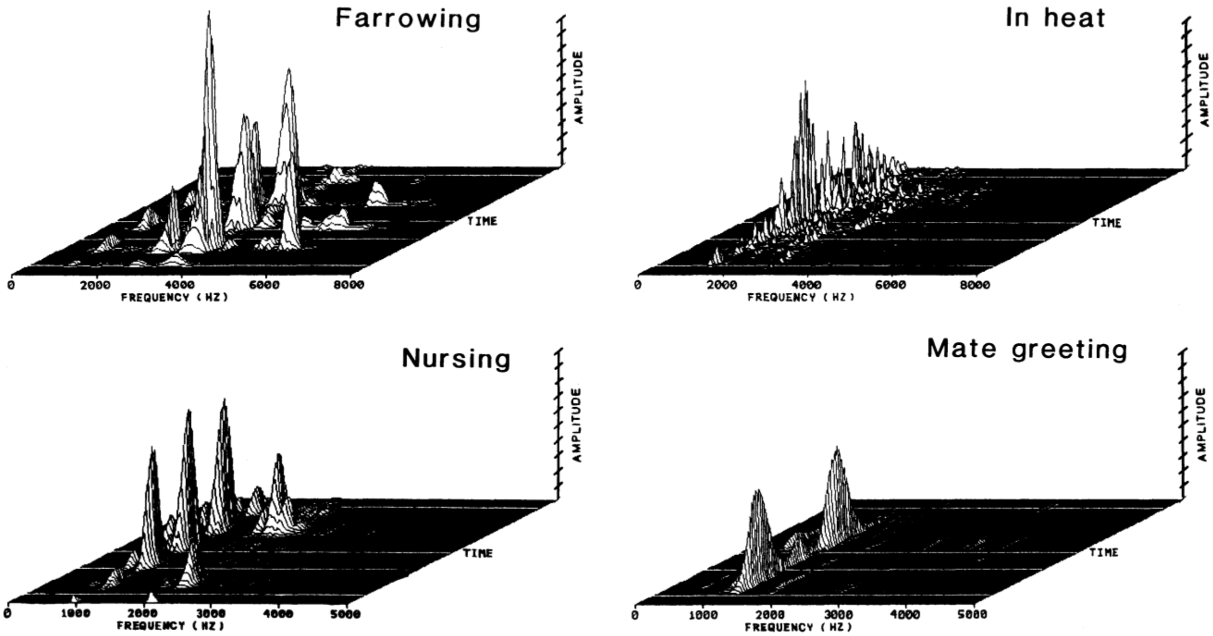


Figure 5.2: Sonographs of pig vocalizations (Xin et al., 1989).

5.3 Noise and animal stress

Noise is described as unwanted sound, either chronic or intermittent, and can be described in terms including its frequency, intensity, frequency spectrum, and shape of sound pressure through time (Burn, 2008). Decibel (dB) is the unit for measuring the intensity of sound.

Noise in farm animal environments is a detrimental factor to animal health. Noise directly affects reproductive physiology or energy consumption. Unexpected high intensity noise (above 110 dB), such as low altitude jet aircraft overflights at milking time could reduce the overall milk yield. However, a majority of the studies reviewed suggests that there is little or no effect of aircraft noise on cattle. Beyer (1983) found that helicopters caused worse reaction than other low-aircraft overflights.

Sounds produced by humans might also be stressful for farm animals. Loud cry causes stress responses in farm animals (Hemsworth et al., 2003). Shouting on dairy cows appears to be very aversive (Pajor et al., 2000). Noise made by humans shouting and slamming of metal gates increases heart rate and activity in cattle.

Although the majority of the literature suggests that farming animals and wildlife species exhibit adaptation after repeated exposure to noise, careful planning should be made before construction of the animal building, in order to avoid stressful environmental sounds both for the animal and personnel.

5.4 Music and animal welfare

Humans derive both psychological and physiological benefits from listening to music, including reduced anxiety, pain relief and decreases in measures of stress such as blood pressure and heart rate. Some nonhuman species may perceive music similarly to humans, but because of species differences in sensitivity to sound frequencies, music may be perceived differently by different species. For example, most studies examining the physiological effects of music to date used rats, but most of the common laboratory rat's social communication occurs in the ultrasonic range.

Figure 5.3: A band make the sound.

The type of music to which an animal is exposed is an important factor in determining whether the music will have any effect on the animal. Tempo, rhythm, pitch and tonality, may also influence the effects of music on the physiology of animals. ‘New age’ music has been reported to have a ‘calming’ effect on mice in comparison to classical or pop music or the absence of music. Raising chicks with music enrichment can decrease their stress levels. Music has been used to manipulate physiology in order to improve milk production in dairy cattle and growth of poultry, swine, and fish.

5.5 Appendix

Chapter 6

Air quality

Air quality is the degree of pollution of air. The air quality can be determined by measuring the concentration of pollutants in the air. Air quality has a direct influence on health, welfare and production performance of livestock. The high concentrations of noxious gases, dust, and airborne microorganisms can reduce the production efficiency and the general welfare of farm animals. Long term exposure to particulates in livestock buildings might also affect the respiratory health of farm workers. Dust in animal buildings contains many biologically active substances such as bacteria, fungi, and endotoxins that are suspected to be hazardous to human health.

Airborne emissions include ammonia, methane, nitrous oxide, particulates like dust and microorganisms. In addition, other potentially harmful substances such as heavy metals, antibiotic residues and components of disinfectants might be also emitted from livestock building that are potentially damaging to ecosystems.

6.1 Importance of air quality

Animals that continually exposed to bad air quality had reduced productivity and increased the stress. Maintaining good air quality is not only important for the productivity of the animals, but also for the welfare of the animals.

There are some benefits of improving the air quality:
1. Improves the health, welfare and production performance of the animals.
2. Improves the health and safety of producers and workers.
3. Reduces emissions of harmful pollutants to the outside environment which helps reduce nuisance complaints.
4. Results in significant energy and economic savings.
5. Prolongs the life of building structures.

Generally air quality is affected by weather, livestock facilities and management conditions. Air quality is getting worse during light wind conditions, as pollutants cannot be blown away.

6.2 Pollutants

6.2.1 Ammonia

Ammonia (NH3) is an important pollutant gas that accelerates fine particulate formation in the atmosphere and plays a crucial role in the acidification and the eutrophication of ecosystems (Krupa, 2003). Livestock wastes account for 39% of global emissions (Fig. 6.2). Among them, pig production is globally responsible

Figure 6.1: A white piglet chewing hay

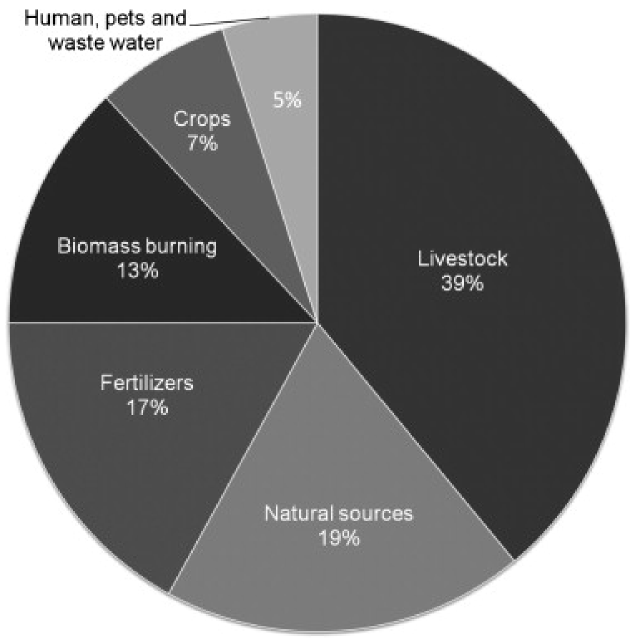


Figure 6.2: Repartition of sources of global ammonia emissions (Galloway et al., 2004).

Table 6.1: Summary of effects in humans following acute ammonia exposure.

Concentration (mg/m3)	Exposure time	Effects reported
3480	30 min	Death
350	30 min	Nasal and throat irritation
70	6 h	Transient irritation of eyes, nose, and throat
56	2 h	Coughing, eyes, nose, and throat irritation
35	2 h	No adverse effect
0.5-37(mean = 3.5)		Odour threshold
12-14		Odour complaint level

for about 15% of NH3 emissions associated to livestock, with a large variation by country (Olivier et al., 1998).

Ammonia is emitted from manure in livestock buildings, manure storage facilities and during manure application to soils. Ammonia in livestock facilities results primarily from the breakdown of urea (present in urine) by the enzyme urease (excreted in feces). Typical ammonia levels in well-ventilated buildings are 10 to 20 ppm. Ammonia can be easily removed from livestock buildings by proper ventilation because it is lighter than air.

6.2.1.1 Nitrogen transformations and ammonia production in manure

Nitrogen transformations occurring in livestock manure include mineralization of organic N into NH3, N assimilation into organic matter, nitrification into nitrite (NO2−) and then into nitrate (NO3−), and finally denitrification into dinitrogen (N2) with nitrous oxide (N2O) as a potential by-product (Fig. 6.3).

6.2.1.2 Suppression methods

1. Decreasing of the length of the time manure remained.

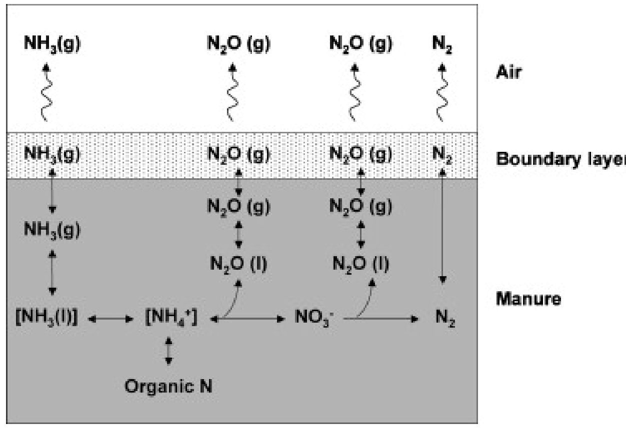


Figure 6.3: Nitrogen (N) transformation in livestock manure and releases to the atmosphere (NH3, ammonia; NH4+, ammonium; NO3−, nitrate; N2O, nitrous oxide; N2, dinitrogen; g, gaseous form; l, liquid form) (adapted from Philippe et al., 2011).

2. Keeping buildings and the animals clean and dry.
3. Separation manure from urine.
4. Using acidifying agents to suppress ammonia emissions from manure.
5. Filtration.

6. Landscaping: Trees, shrubs and other vegetative barriers planted around livestock buildings have the potential of reducing ammonia emissions.

6.2.1.3 Dietary strategies

1. Reduced crude protein (CP) diets containing synthetic amino acids have been shown to reduce N excretion, which leads to reduce NH3 emissions.
2. Reducing NH3 emissions from the slurry can also be achieved by the addition of fibrous feedstuffs in the diet.
3. Feed additives: Non-starch polysaccharides enzymes, yucca extract, zeolites, probiotics, and so on.

6.2.2 Hydrogen sulphide

Hydrogen sulfide (H2S) is a toxic gas and has potential to cause health problems if the concentration becomes too high. Hydrogen sulphide is heavier than air, soluble in water, and can accumulate in the livestock buildings. It has a rotten-egg odour and it can be easily detected at low concentrations.

6.2.2.1 Suppression methods

- Modifying diets to balance rations reduce hydrogen sulphide emissions.
- Frequent removal of manure from static pits significantly reduces hydrogen sulphide.
- Physical, chemical and biological treatment of stored manure such as manure additives and oil sprinkling.
- Biofiltration is an effective method for reducing the emissions of hydrogen sulphide.

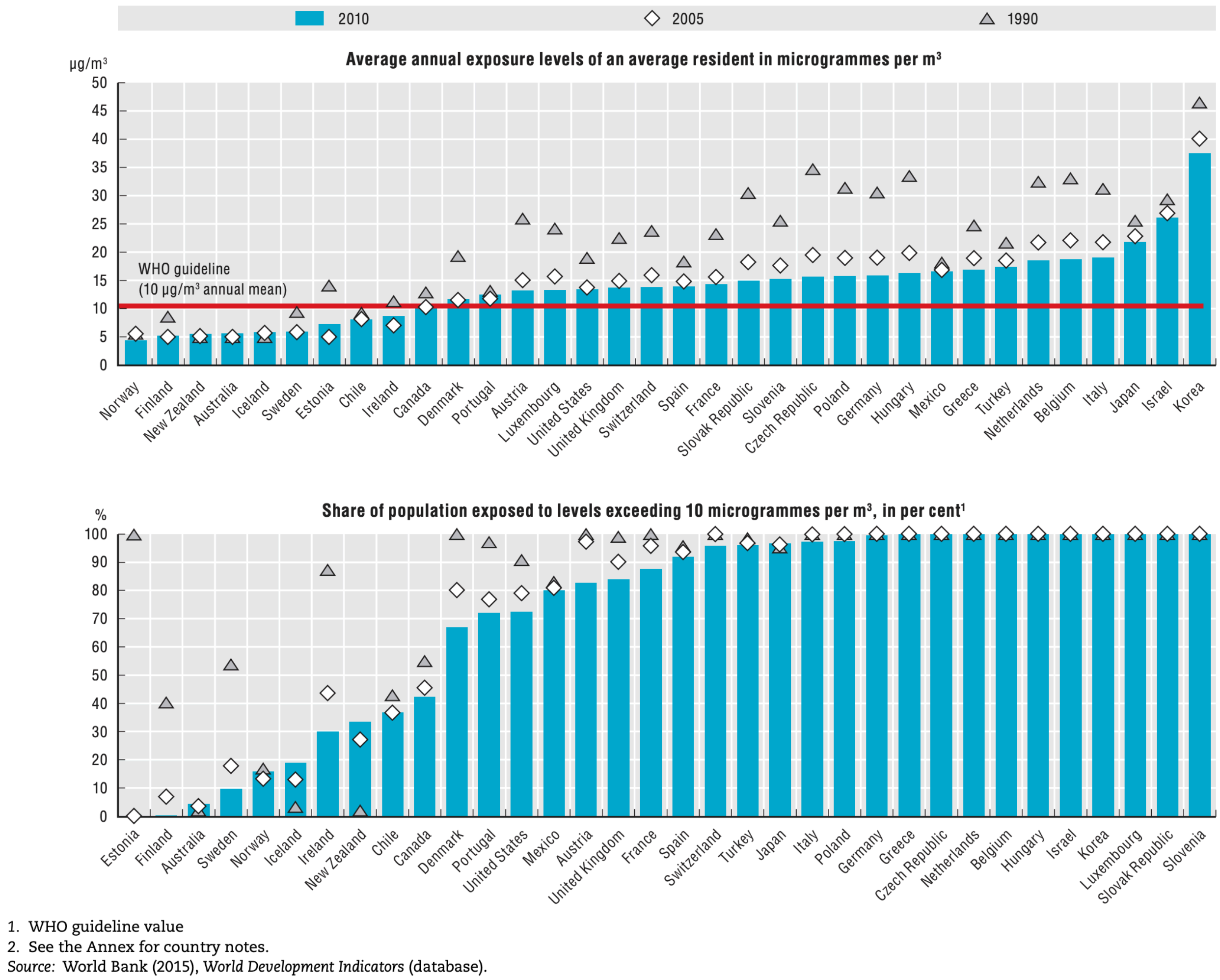


Figure 6.4: Population exposure to fine particulates (PM2.5).

6.2.3 Particulate matters (Dust)

Particulate Matter (PM) is an unusual air pollutant in that it is defined by its physical morphology rather than chemical identity. The most common classifications are PM10 (coarse PM), which includes particles smaller than 10 m in aerodynamic diameter, and PM2.5 (fine or respirable PM), which includes particles smaller than 2.5 m in diameter.

- **PM10**: inhalable particles, with diameters that are generally 10 micrometers and smaller
- **PM2.5**: fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.

Dust from swine/pourtly barns originates from feed, bedding material, manure and the animals themselves. Many of the respirable dust particles are odorous because of their fecal origin. The factors determining the amount of dust in confinement includes animal activity, temperature, relative humidity, and ventilation rate, stocking density and feeding methods.

Dust is related to the odor. Removal of dust in animal production facilities can reduce the odour in the air by 65-75% (Hammond and Smith 1981; Hartung 1985.Hartung, 1986; Hoff et al., 1997). Filtering the dust from the exhaust air reduced VOC–odor emissions from swine buildings by up to 65%.

6.2.3.1 Factors affecting dust emissions

1. **Temperature**: There is the negative correlation between outside temperature and the dust concentration.
2. **Relative humidity**: The humid air also increases the moister content of the dry manure or and settle dust, so that less dust become airborne.
3. **Animal Activity**

6.2.3.2 Suppression methods

1. **Ventilation**: The major method of controlling dust and air contamination in enclosed livestock facilities is by mechanical ventilation.
2. **Air Misting**: The oil/water spraying is a promising technique for dust control in livestock buildings.
3. **Fibrous Filter**
4. **Wet Collectors**: Wet scrubber using water to capture dust particle are very efficient in removing dust particles from air, however its use is not recommended in livestock building due to the needs for handling large amount of air in livestock buildings.

6.3 Appendix

Chapter 7

Water quality

Water is a critical nutrient for animal. An adequate and safe water supply is essential to the production of healthy animals. From transportation to lubrication to temperature regulation, water keeps animal life functioning. All chemical reactions in the bodies of animals use water as a medium.

Water has the functions in the animal's body as:
1. Temperature regulation: Water acts as a buffer against overheating due to water's high specific heat.
2. pH regulation: When the water introduced into an animal's system, it brings the pH closer to a neutral value.
3. Hydrolysis and energy production
4. Digestion
5. Joint lubrication

Measurements of water quality and quantity are required for effective planning and monitoring of water supplies for livestock. **If water quality is poor, livestock may drink less than they need or, rarely, may stop drinking.** When animals drink less, they will eat less and lose condition and if they are lactating, their milk production will reduce. Failure to provide proper and sufficient water for livestock not only affects production, it may be an animal welfare offence. Mangers must provide enough good quality water to meet the needs of the animal.

7.1 Water salinity

Excessive salinity in livestock drinking water can reduce production. High levels of specific ions in water can cause animal health problems and death. The National Academy of Sciences offers upper limits for toxic substances in water (Table. 7.1). Unsafe levels of salts and ions depend on the amount of water consumed each day and the weight of the animal. The general guidelines presented in Table. 7.1 include an appropriate margin of safety.

7.2 Microbiological contaminants

7.2.1 Cyanobacteria

Natural toxins originating from cyanobacteria (blue-green algae) are a primary concern in drinking water for livestock. Cyanobacteria is a phylum of bacteria that obtain their energy through photosynthesis. Cyanobacteria are known to produce acute hepatotoxins, cytotoxins, neurotoxins, and toxins causing the gastrointestinal diseases. However, heavy cyanobacteria growth does not necessarily mean high levels of toxin.

Figure 7.1: All living things, from tiny bacteria to giant blue whales, need water to survive.

Figure 7.2: Natural toxins originating from cyanobacteria are a primary concern in drinking water for livestock.

Table 7.1: Recommendations for levels of toxic substances in drinking water for lilvestock.

Constituent	Upper limit	Constituent	Upper limit
Aluminum (Al)	5.0 mg/L	Lead (Pb)	0.1 mg/L
Arsenic (As)	0.2 mg/L	Manganese (Mn)	no data
Beryllium (Be)	no data	Mercury (Hg)	0.01 mg/L
Boron (B)	5.0 mg/L	Molybdenum (Mo)	no data
Cadmium (Cd)	0.05 mg/L	Nitrate + nitrite (NO3-N + NO2-N)	100 mg/L
Chromium (Cr)	1.0 mg/L	Nitrite (NO2-N)	10 mg/L
Cobalt (Co)	1.0 mg/L	Selenium (Se)	0.05 mg/L
Copper (Cu)	0.5 mg/L	Vanadium (V)	0.10 mg/L
Fluorine (F)	2.0 mg/L	Zinc (Zn)	24 mg/L
Iron (Fe)	no data	Total dissolved solids (TDS)	10,000 mg/L

The trigger for cyanobacteria to produce toxins is not completely understood. If the cyanobacteria growth is not of the *Microcystis* species, there is a low probability of having high toxin levels. It is recommended that water contaminated with cyanobacteria should be avoided until the level of toxins is determined or until the water is treated.

7.2.2 Pathogens

A variety of microbial pathogens can be transmitted to livestock from drinking water sources contaminated. The pathogens of greatest concern in water supplies for farm animals include enteric bacteria such as *E. coli*, *Salmonella* and *Campylobacter jejuni*. Other bacterial diseases known to affect livestock that may be transmitted through water supplies include *Leptospira, Burkholderia (Pseudomonas) pseudomallei*, and *Clostridium botulinum*. **Notably, the cause of biological contamination of water sources is associated with the animal industry itself**. For instance, in the situation of intensive livestock operation, the risk of water source contamination with animal waste may be very high.

7.3 Water treatment technologies

Water contaminants can be decreased considerably or even completely eliminated by a variety of treatment methods. Some methods are more effective than others, but for treating water for livestock consumption, economics are an important issue.

7.3.1 Activated carbon filters

This method is based on passing water through a filter containing activated carbon granules. Contaminants attach to the granules and are removed. Chlorine, some organic compounds associated with coloration, odour and offtaste of water, mercury, some pesticides and volatile organic compounds can be removed by this method. The filters must be inspected and replaced frequently. Poor filter maintenance will decrease effectiveness, and may result in bacterial growth on the filter, causing potential contamination of the water with pathogens.

7.3.2 Air stripping

Air stripping is the transferring of volatile components of a liquid into an air stream. It is an environmental engineering technology used for the purification of groundwaters and wastewaters containing volatile com-

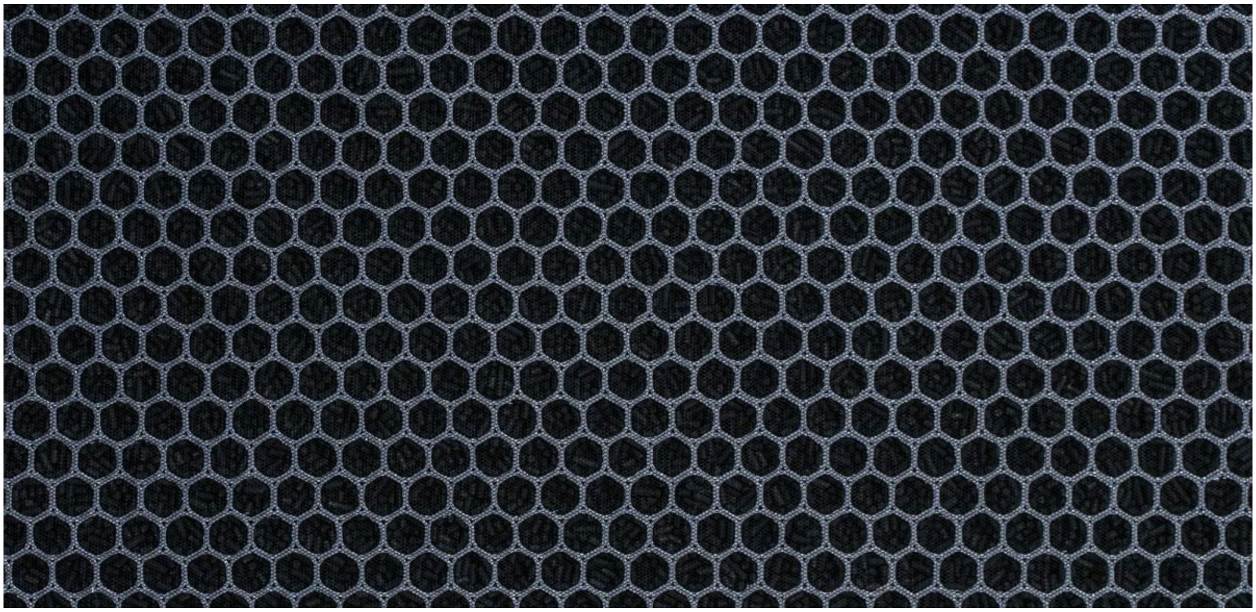


Figure 7.3: Activated carbon filters.

pounds. Contaminants are transferred from water to air and vented off. This method may be effective in removing hydrogen sulphide, some odours and tastes, and some volatile organic chemicals.

7.3.3 Biological filters

Biological filtration is a natural process that takes place in rivers, streams, and oceans. Bacteria eat certain compounds, like ammonia, which is broken down into byproducts that are not toxic. This method is effective at removing iron, arsenic, and organics. A microbiological layer is used to filter and consume contaminants.

7.3.4 Chlorination

This is one of the most common methods in water treatment for pathogen reduction in drinking water for livestock. Chlorination is much more effective if it follows a filtration system to remove large particles that can house bacteria. In particular, this is an effective and widely used method to kill many kinds of microorganisms in water. Chlorine content of the treated water should be monitored because the high concentrations of chlorine released to the animal water system may affect water intake and productivity.

7.3.5 Ozonation

This method of water treatment is based on application of ozone gas. Ozone is a very potent oxidizing agent, and destroys pathogenic microorganisms. It can reduce color, improves taste, odor, kills bacteria, viruses, oxidize iron, manganese, cyanide, phenol, benzene, chlorophenol, atrazine, nitrobenzene and other pollutants. The equipment typically is quite expensive.

7.4 Importance of clean water to mankind

Safe and readily available water is important for public health, whether it is used for drinking, domestic use, food production or recreational purposes. Improved water supply and sanitation, and better management

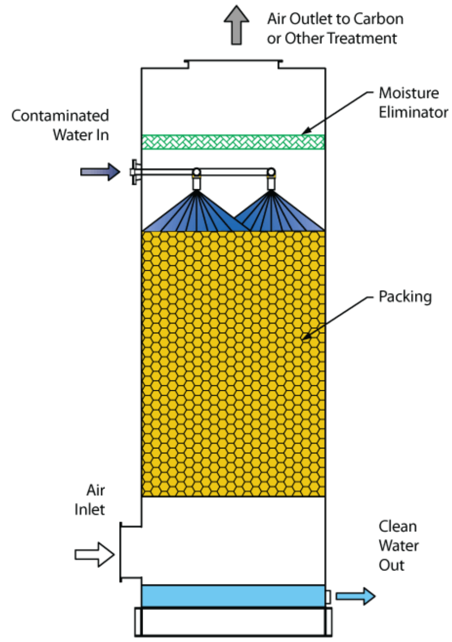


Figure 7.4: Air-Stripper diagram (Monroe Environmental Corp., 2019).

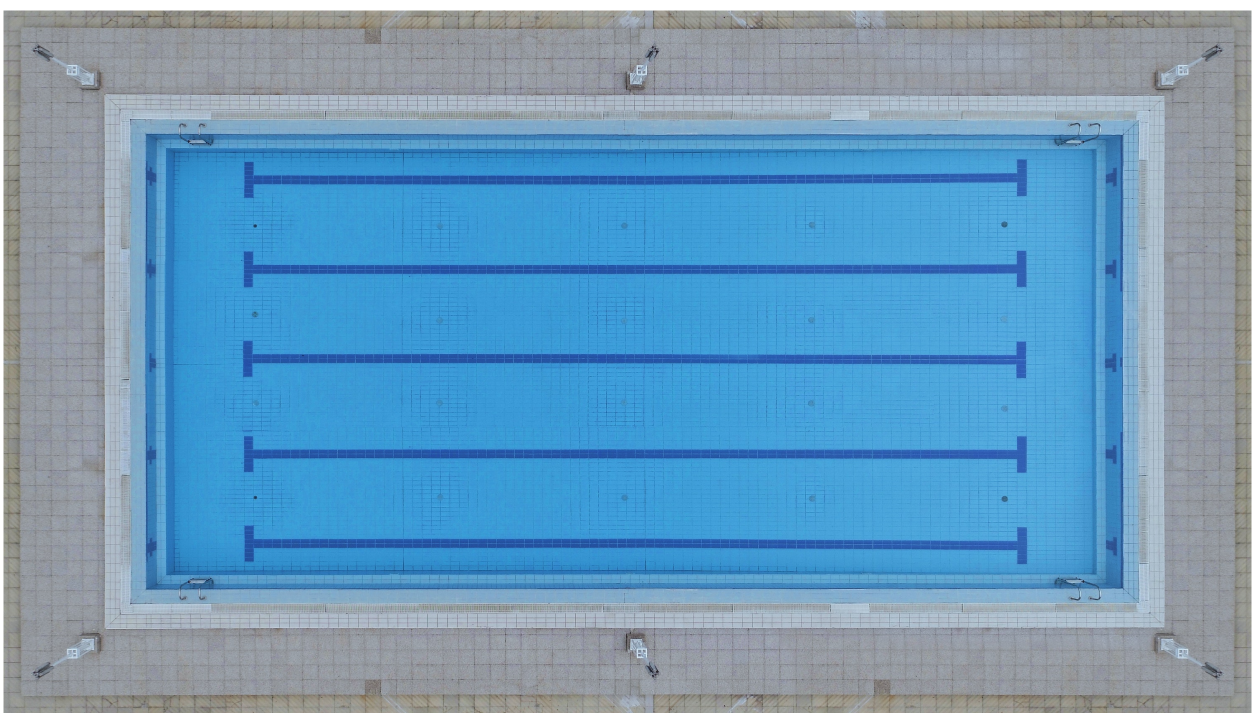


Figure 7.5: A swimming pool which treated chloride.

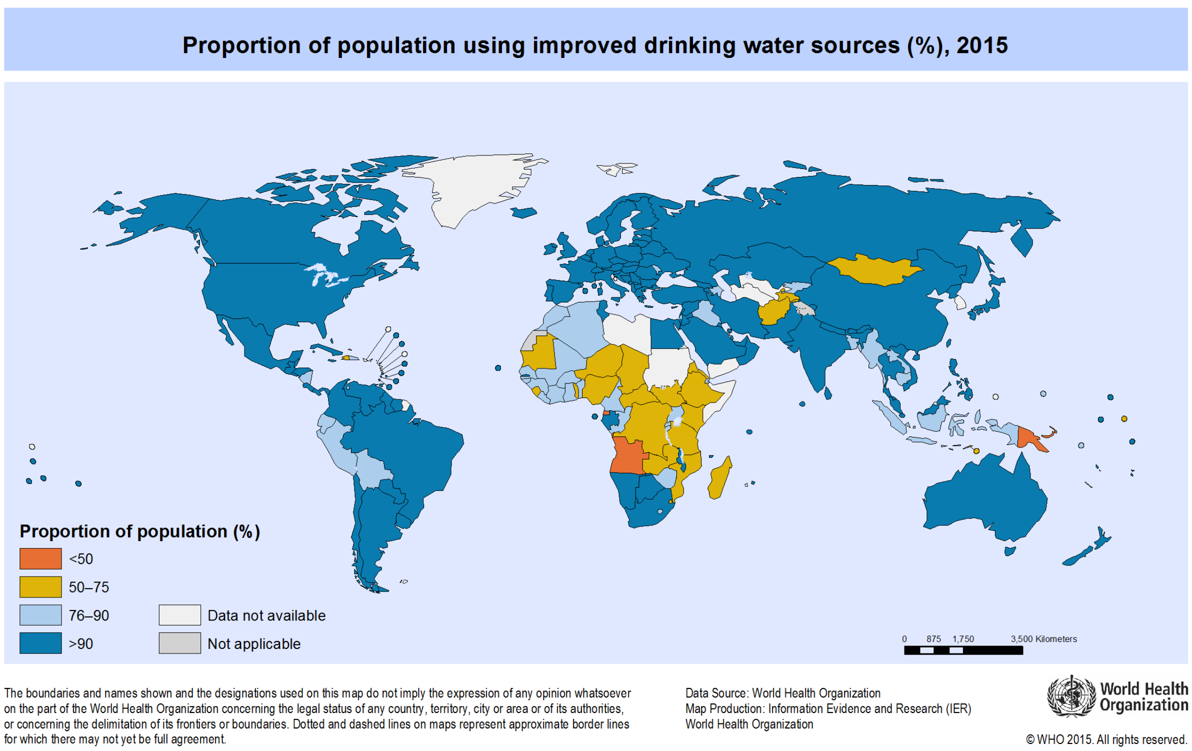


Figure 7.6: Proportion of population using improved drinking water sources (WHO, 2015).

of water resources, can boost countries' economic growth and can contribute greatly to poverty reduction.

Billions of people have gained access to water, but huge inequalities remain. In 2015, 71% of the global population (5.2 billion people) used a safely managed drinking-water service – that is, one located on premises, available when needed, and free from contamination. 89% of the global population (6.5 billion people) used at least a basic service. A basic service is an improved drinking-water source within a round trip of 30 minutes to collect water. 844 million people lack even a basic drinking-water service, including 159 million people who are dependent on surface water. Globally, at least 2 billion people use a drinking water source contaminated with faeces.

Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid, and polio. Inappropriately managed water and sanitation services expose individuals to preventable health risks. Some 842,000 people are estimated to die each year from diarrhoea as a result of unsafe drinking-water, sanitation, and hand hygiene. Yet diarrhoea is largely preventable, and the deaths of 361,000 children aged under 5 years could be avoided each year if these risk factors were addressed.

In most countries, the majority of people spend less than 30 minutes collecting water, or have a piped supply within their home. But in some regions, especially sub-Saharan Africa, many people spend more than 30 minutes – and some more than an hour – on each trip to collect water. This burden still falls mainly on women and girls.

7.5 Livestock and sustainable management of water

Agriculture uses approximately 70% of the available freshwater supply, and roughly 30% of global agricultural water goes on livestock production (Ran et al., 2016), with one third of that supporting beef cattle (Mekonnen and Hoekstra, 2012). However, the largest proportion is associated with the production of feed. Besides water scarcity, one of the central water-related challenges facing the livestock sector is waste management and disposal given that feces and urine can be hazardous to the environment.

The water footprint has been used as an indicator of water consumption for both direct and indirect water usage at consumer and producer level. It aims to measure the total volume of freshwater used to produce the goods and services consumed or utilized by individuals, communities and businesses.

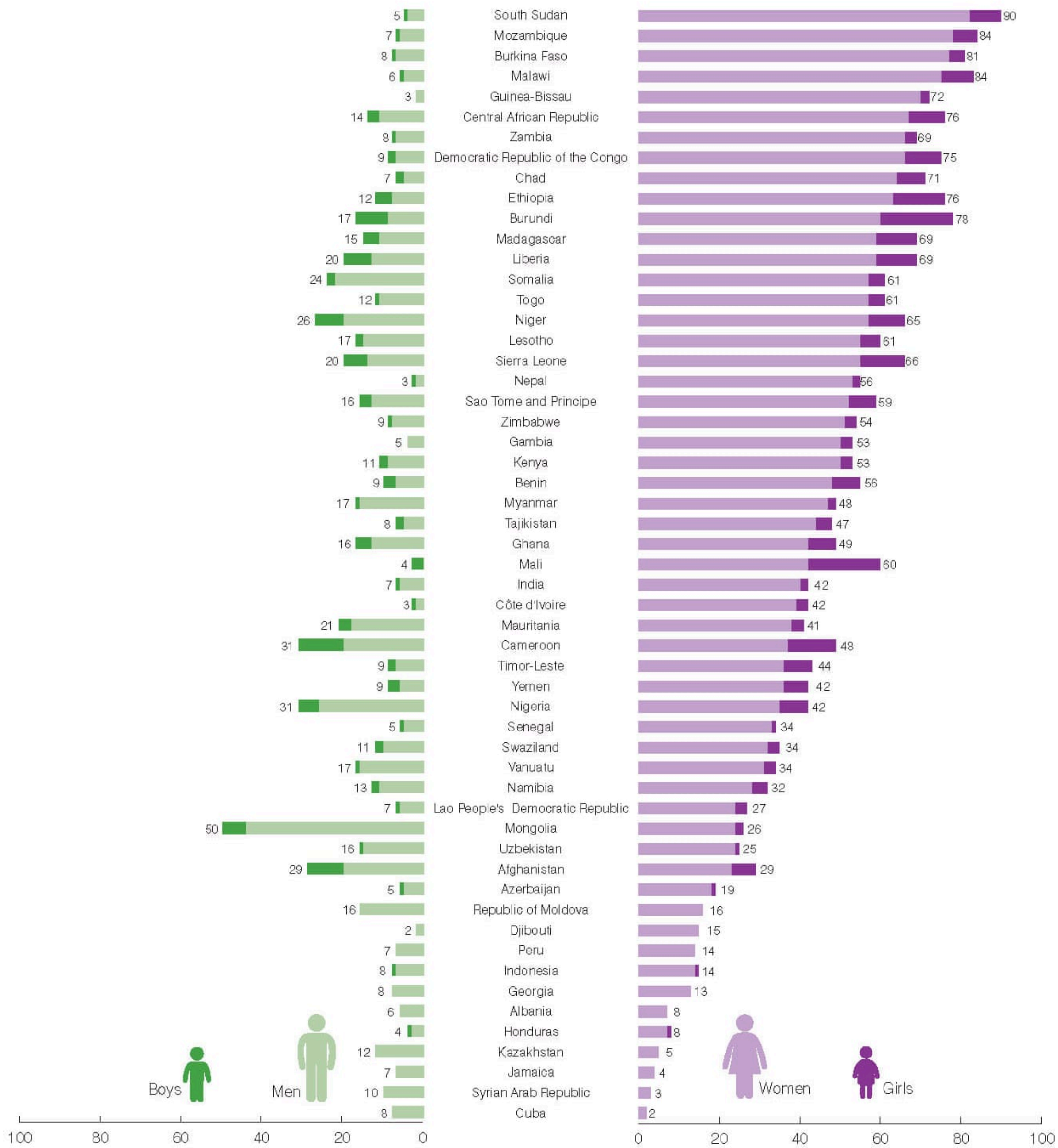


Figure 7.7: Who has primary responsibility for collecting water in rural areas? (WHO/Unicef joint monitoring program).

ANIMAL PRODUCTS	FARMING SYSTEM	WEIGHTED GLOBAL AVERAGE (LITRES/KILOGRAM)			
		GREEN	BLUE	GREY	TOTAL
Beef	Grazing	21 121	465	243	21 829
	Mixed	14 803	508	401	15 712
	Industrial	8 849	683	712	10 244
	Weighted average	14 414	550	451	15 415
Sheep meat	Grazing	15 870	421	20	16 311
	Mixed Industrial	7 784	484	67	8 335
	Industrial	4 607	800	216	5 623
	Weighted average	9 813	522	76	10 411
Goat meat	Grazing	9 277	285	-	9 562
	Mixed	4 691	313	4	5 008
	Industrial	2 431	413	18	2 862
	Weighted average	5 185	330	6	5 521
Pig meat	Grazing	7 660	431	632	8 723
	Mixed Industrial	5 210	435	582	6 227
	Industrial	4 050	487	687	5 224
	Weighted average	4 907	459	622	5 988
Chicken meat	Grazing	7 919	734	718	9 371
	Mixed	4 065	348	574	4 987
	Industrial	2 337	210	325	2 872
	Weighted average	3 545	313	467	4 325
Eggs	Grazing	6 781	418	446	7 645
	Mixed Industrial	3 006	312	545	3 863
	Industrial	2 298	205	369	2 872
	Weighted average	2 592	244	429	3 265
Milk	Grazing	1 087	56	49	1 192
	Mixed	790	90	76	956
	Industrial	1 027	98	82	1 207
	Weighted average	863	86	72	1 021

Figure 7.8: Water footprint values reported for selected food products (Mekonnen and Hoekstra, 2012).

Chapter 8

Feed

Feeding has a direct impact on the growth rate, production capacity and health status of the animal. Proper feeding is key for a profitable and sustainable farming.

The classification of feed materials is summarized in Fig. 8.2. It is based first on whether the product from which they are derived is edible by humans (i.e. cerealgrains, soybeans, pulses, banana and cassava) or not (roughages suchas grass, crop residues and fodder beets, cotton and rape seeds). Second, only part ofthe product is used as feed. In that case, the Economic Fraction Allocation (EFA) is used to identify which co-product is the main driver of the land use. If the EFA of the part used as feed material is $> 66\%$, then the feed material is considered as the main driver of land-use and therefore in competition with food production.

8.1 By-products as animal feed

In modern livestock industry, high amount of grains and pulses are necessary to meet the requirement of high producing animal, however, these ingredients are in competition with humans (Knaus, 2013). **An agricultural by-product is a secondary product generated during harvest or processing of grains, vegetables, and fruits.** Although most by-products are human-inedible, they contain adequate organic materials which can be used by domestic animals. For hundreds of years, the livestock industry has been typically used these agricultural by-products as a practical alternative feed ingredient (Grasser et al., 1995). Hence, **using human-inedible by-products as feed ingredient could diminish the dependence on grains and pulses in livestock industry** (Bocquier and González-García, 2010). In addition, if agricultural by-products are not disposed properly, it can cause the substantial environmental problems (Grasser et al., 1995).

There are some examples of by-products:

- Beer brewing waste is a by-product of the beer brewing industry, which ferments barley grains. This is a foodstuff high in protein and cell wall, all of which has high digestibility.
- Beet pulp before drying contains high levels of soluble carbohydrates and as calculated dry weight, it has an energetic value the same as or a little higher than cereals. Dry pulp, after heat and drying treatments, has for many years been a fully paid up member in the concentrates club for the dairy farm.
- Beet molasses or sugar cane molasses – the by-products after extraction of sugars from the plants. It contains high concentrations of minerals and proteins, mostly soluble proteins. CMS (Condensed Molasses Soluble) are also high in soluble protein and today, either with or without molasses they are standard additives in the ration.

Figure 8.1: Proper feeding is key for a sustainable livestock industry.

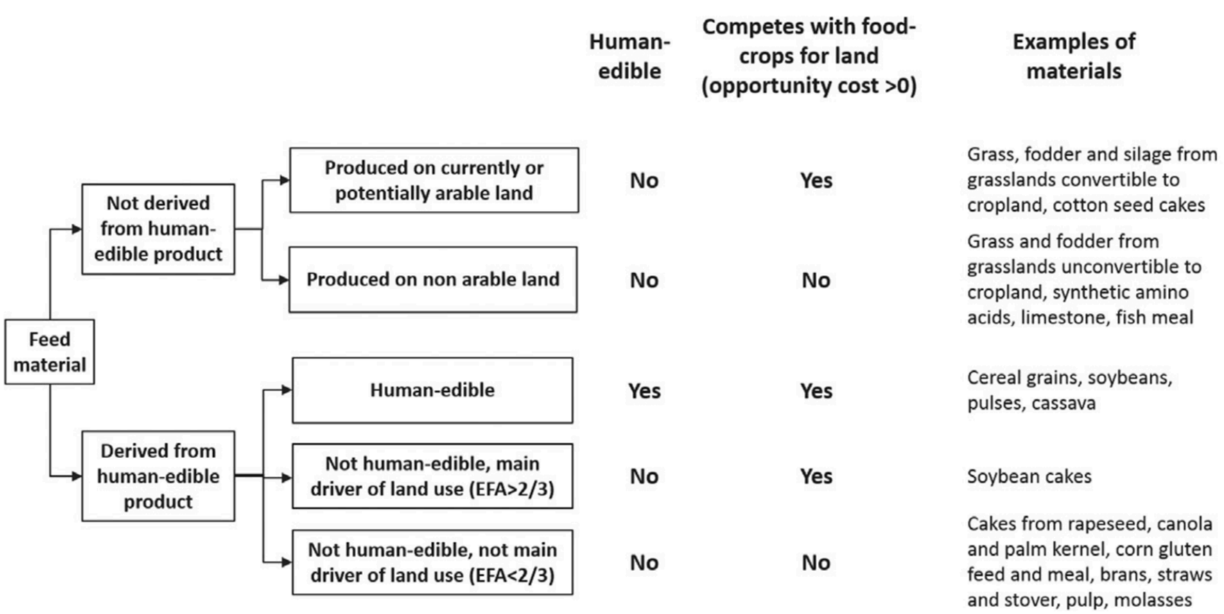


Figure 8.2: Feed classification methodology (Mottet et al., 2017).

Figure 8.3: Soybean oil, meal and beans.

- Citrus peels – a high energy food with a specific advantage because it contains high levels of pectin and non-structured carbohydrates. When fresh, citrus peels can be used on a daily basis and after fermentation and preservation, they can be used for long periods. As is true for dried pulp, dried citrus peels are also a good quality, standard component in the ration.
- In tropical regions, wastes from the banana growing industry are in widespread use, usually to feed mothers of meat calves and the calves themselves. In some tropical regions, the cattle are also fed sugar cane waste after extraction of the sugar, which is a high fiber food with very low value.
- Whey and other milk processing wastes are usually fed to pigs. Whey has a high energy value and other milk processing wastes contain considerable levels of both fat and protein. Whey is transported as a liquid, which requires a fleet of tankers and it is therefore difficult to exploit this resource to the full.
- Poultry manure from broiler chicken is a good source of protein for beef cattle and calves. In order to turn poultry manure into cattle feed, it must undergo a sterilization process to destroy pathogens. Foreign bodies and lumps must be removed. In Israel, where this source of food is forbidden for milking cows and fattening calves one month before marketing.
- Potatoes, carrots and other vegetables are good sources of available energy in the rumen, on condition that they are supplied fresh and without soil.
- Grape processing waste is a low value material, high in digestion depressant lignin and tannins. It can be used to cover silage pits, but it is not recommended as feed.
- Olive processing wastes, despite their lignin content, can be an efficient food because of their oil and protein content and as such they can be suitable as support for the straw fed to cattle living at maintenance level.

The exploitation of high moisture by-products is problematic because of their short storage life and the high moisture content, which can often lead to negative effects, such as overheating, low digestibility and

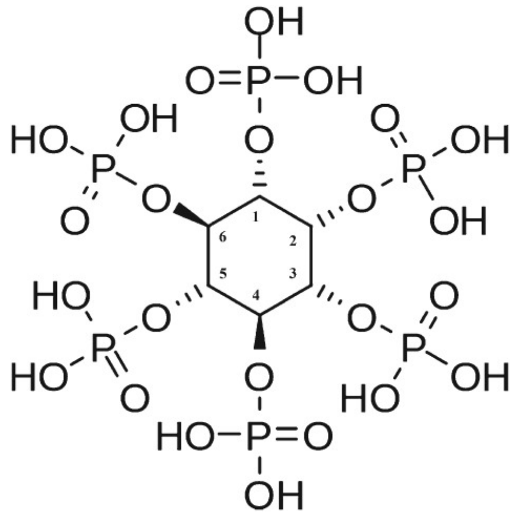


Figure 8.4: Structure of phytate (myo-inositol, 1,2,3,4,5,6-hexakisphosphate (IP6, IUPAC).

low feed consumption. Although there are the high risk when using the by-products as the animal feed, using of the by-product is a very good chance that of improved profit margins along with a contribution to environmental.

8.2 Exogenous enzyme

8.2.1 Phytase

Phosphorous is normally present in surface water at a rate of only 0.02 parts per million.Introducing additional phosphorous in water results in a massive growth of algae, which are aquatic plants including many single-celled, free-floating plants. Excessive amounts of algae cloud the water in an effect called an algal bloom, which reduces the sunlight available to other plants and sometimes kills them.

Phosphorus is an essential nutrient for animals. It is required for bone growth, cell structure, and enzymatic processes. However, meeting phosphorus requirements for growing pigs is difficult because approximately 60 % to 70 % of phosphorus in plant-based swine feed ingredients occurs as phytate phosphorus. Phytates are complex molecules that bind phosphorus and other nutrients for storage in seeds and grains. Phytate is considered an antinutritional factor for swine because it reduces digestibility of phosphorus, energy, and other nutrients in pigs. Therefore, the degradation of phytate in the upper part of the digestive tract is essential to improve phosphorus availability and eliminate the antinutritional effects of phytate.

Monogastric animals lack sufficient intestinal phytase, which is the enzyme required to break down phytate molecules and release bound phosphorus. Several studies have shown that supplementing swine diets with the phytase from various sources improves phytate phosphorus utilization. **Adding phytase can reduce the antinutritional effect of phytate and improve the digestibility of phosphorous (P), calcium, amino acids and energy, as well as reduce the negative impact of inorganic P excretion to the environment.**

8.3 Appendix

World mapping of animal feeding systems in the dairy sector

Chapter 9

Cycles of materials

Materials are recycled while energy flows through ecosystems. The atoms that make up animal's body already existed when the dinosaurs existed, and if you die they will be returned to the atmosphere and the soil to be taken up by other organisms.

9.1 Trophic level

The trophic level of an organism is the position it occupies in a food chain. A food chain is a succession of organisms that eat other organisms and may, in turn, be eaten themselves. A food chain starts at trophic level 1 with primary producers such as plants, can move to herbivores at level 2, carnivores at level 3 or higher.

The three basic ways in which organisms get food are as producers, consumers and decomposers.

1. **Producers** (autotrophs) are typically plants or algae. Plants and algae do not usually eat other organisms, but pull nutrients from the soil or the ocean and manufacture their own food using photosynthesis. For this reason, they are called primary producers. In this way, it is energy from the sun that usually powers the base of the food chain.
2. **Consumers** (heterotrophs) are species that cannot manufacture their own food and need to consume other organisms. Animals that eat primary producers (like plants) are called herbivores. Animals that eat other animals are called carnivores, and animals that eat both plant and other animals are called omnivores.
3. **Decomposers** (detritivores) break down dead plant and animal material and wastes and release it again as energy and nutrients into the ecosystem for recycling. Decomposers, such as bacteria and fungi (mushrooms), feed on waste and dead matter, converting it into inorganic chemicals that can be recycled as mineral nutrients for plants to use again.

9.2 Water cycle

The water cycle describes the continuous movement of water on, above and below the surface of the Earth. The water cycle involves the exchange of energy, which leads to temperature changes. When water evaporates, it takes up energy from its surroundings and cools the environment. When it condenses, it releases energy and warms the environment. These heat exchanges influence climate.

Figure 9.1: All living things will return to Mother Nature.

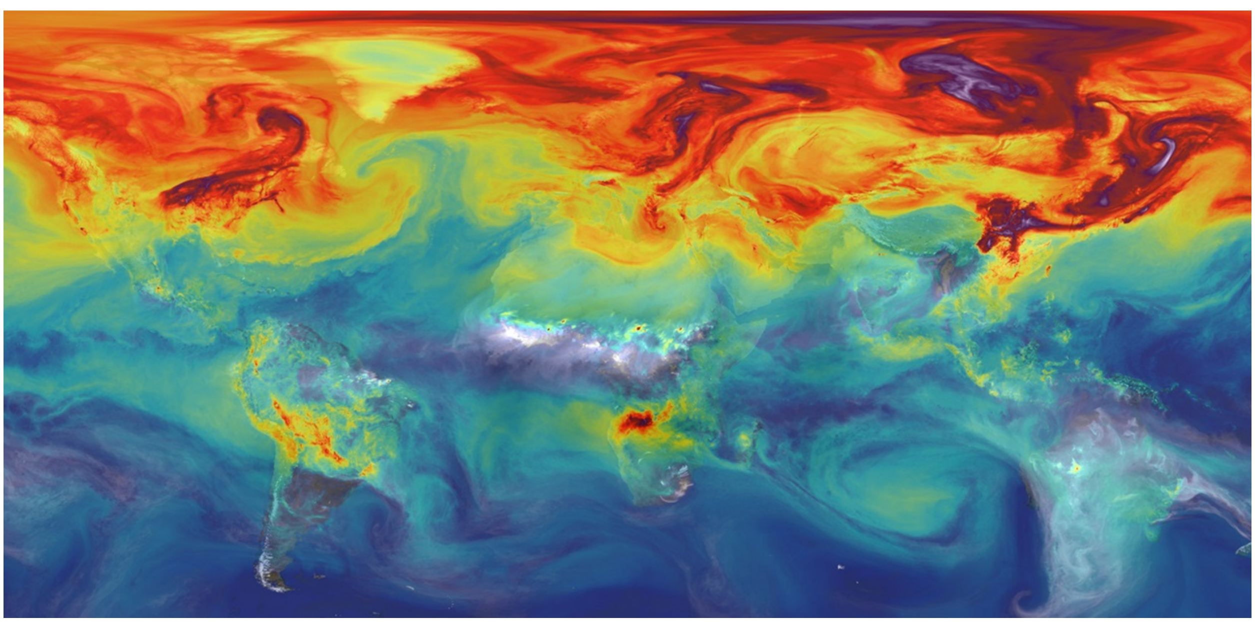


Figure 9.2: Carbon dioxide in Earth's atmosphere if half of global-warming emissions are not absorbed (NASA).

9.3 Carbon cycle

Carbon is the basis of all organic molecules. It makes up our genetic material (DNA and RNA) and proteins, which are essential for life. Carbon is so special because of its ability to bond to almost any other molecule. The major element within our bodies is carbon.

The carbon cycle is the process through which carbon is cycled through the air, ground, plants, animals, and fossil fuels. Large amounts of carbon exist in the atmosphere as carbon dioxide (CO2). Carbon dioxide is cycled by green plants during the process known as photosynthesis to make organic molecules (glucose, which is food).

Animals release carbon dioxide back into the air as a waste product from respiration. Decomposers, when they break down dead organic matter, release carbon dioxide into the air also. Decomposers are essential because without them, all of the carbon on the planet would eventually become locked up in dead carcasses and other trash.

Carbon is also stored in fossil fuels, such as coal, petroleum, and natural gas. When these are burned, carbon dioxide is also released back into the air. Volcanoes and fires also release large amounts of CO2 into the atmosphere. Carbon dioxide can dissolve in water, where some of it is later returned back into the atmosphere. The rest can be taken to form calcium carbonate, which builds up shells, rocks, and skeletons of protozoans and coral.

9.4 Nitrogen cycle

Another important nutrient cycle is that of nitrogen. Nitrogen is a critically important element for all life. Proteins, which are constituents of all living cells, contain an average of 16% nitrogen by weight. Other complex nitrogenous substances important to life are nucleic acids and amino sugars. Without a continuous supply of nitrogen, life on earth would cease.

Even though 79% of the earth atmosphere is composed of elemental nitrogen (N2), this inert gas is entirely unavailable for uptake by most plants and animals. A relatively few microbes are capable of fixing atmospheric nitrogen from the inorganic to the organic form. A number of bacteria, fungi, and blue-green algae are known to be able to fix nitrogen. Nitrogen fixation involves the direct incorporation of atmospheric nitrogen into the organic body of the fixing organisms.

Nitrogen fixing organisms can be divided into:

1. Symbiotic nitrogen fixers, which are largely bacteria, and which are associated with roots of legumes.
2. Free living (nonsymbiotic) nitrogen fixers which includes the *Cyanobacteria*, *Anabaena*, and *Nostoc* and genera such as *Azotobacter, Beijerinckia,* and *Clostridium.*

Since bacterial cells die very rapidly, this nitrogen becomes available to the higher plants. Crops of clover and beans actually add nitrogen to the soils in which they grown and eliminate the need for expensive fertilizers. The symbiotic nitrogen fixers seem to be confined to terrestrial ecosystems and have not been found in aquatic habitats.

Figure 9.3: Rhizobia which symbiotically related with legumes is capable of fixing atmospheric nitrogen from the inorganic to the organic form.

Chapter 10

Manure

10.1 Charateristics of animal manure

10.2 Manure treatment

10.2.1 Solid fertilizer (Composting)

10.2.2 Liquid fertilizer

10.2.3 Purification

10.2.4 Energy generation

10.2.5 Animal feed

Chapter 11

Greenhouse gases

Chapter 12

Animal welfare

Chapter 13

ICT technology

Chapter 14

Sustainable livestock industry

> “In essence, the conflict between livestock and the environment is a conflict between different human needs and expectations.” — Henning Steinfeld (FAO)

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