Minisitry of Higher Education and Scientific Research
Sectoral Committee for Educational
Curricula of College of Education
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General biology

Animal part

1st STAGE

LEC. 1

by:

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Historical brief about biology evolution **Lec.1**

- **Definition of biology**
- **Importance of biology**
- **Branches of biology**

Manifestations and characteristics of life

- **Definition of life**
- **Manifestations of life**
- **Characteristics of life**

The word biology means, "the science of life", from the Greek "bios = life" and "logos = world or knowledge". Therefore, Biology is the science of Living Things. That is why Biology is sometimes known as Life Science. Biology is the science that studies living organisms. However, as a science it has multiple branches that intend to study issues such as evolution, nutrition, morphogenesis, reproduction etc. If you are interested in knowing a little more, we show you what the branches of biology are. The science has been divided into many sub disciplines, such as botany, bacteriology, anatomy, zoology, histology, mycology, embryology, parasitology, genetics, molecular biology, systematics, immunology, microbiology, physiology, cell biology, cytology, ecology, and virology. Other branches of science include or are comprised in part of biology studies, including paleontology, taxonomy, evolution, phycology, helimentology, protozoology, entomology, biochemistry, biophysics, biomathematics, bio engineering, bio climatology and anthropology. Biology examines the structure, function, growth, origin, evolution, and distribution of living things. It classifies and describes organisms, their functions, how species come into existence, and the interactions they have with each other and with the natural environment. Four unifying principles form the foundation of modern biology: cell theory, evolution, genetics and homeostasis.

Most biological sciences are specialized areas of study. Biochemistry is the study of the chemicals that make up life. Cell biology is the study of life at the level of the cell. Microbiology is the study of microscopic organisms. Immunology is the study of an organism's resistance to disease. Genetics is the study of how organisms pass traits to their offspring. The study of how the human body works is called physiology. Zoology is the study of animals. The study of how organisms interact with their environment and each other is called ecology. Evolutionary biology is the study of how populations and species change over time. Botany is the study of plants. The four unifying principles are important foundations for each and every field of biology. Applied fields of biology such as medicine and genetic research involve many specialized areas of study.

What Is Life?

There is not just one distinguishing feature that separates a living thing from a non-living thing. A chair, table, stone or a coin. We know that they are not alive. Similarly, we do know that we are alive and so are all the people of the world. We also see animals around us that are so full of life — dogs, cats, monkeys, squirrels, insects and many others. How do we know that something is living? Often, it is not so easy to decide. We are told that plants are living things, but they do not appear to move like a dog or a pigeon. On the other hand, a car or a bus can move, still we consider them as non-living. Plants and animals appear to grow in size with time. But then, at times, clouds in the sky also seem to grow in size. Does it mean that clouds are living? No! So, how does one distinguish between living and non- living things? Do living things have some common characteristics that make them very different from the non-living? all living things need food and it is essential to animals and to us. Plants makes their own food through the process of photosynthesis. Animals depend on plants and other animals for their food. Food gives organisms the energy needed for them to grow. Organisms also need this energy for other life processes that go on inside them.

Biologists define life by listing characteristics that living things share. Something that has all of the characteristics of life is considered to be alive.

1- Respond to their environment.

2- Grow and change.

3- Reproduce and have offspring.

4- Have a complex chemistry.

5- Maintain homeostasis.

6- Are built of structures called cells.

7- Pass their traits onto their offspring.

An individual living creature is called an organism. There are many characteristics that living organisms share. They all:

1. Are built of a complex chemistry (Organization).

A cell is the basic unit of structure and function of all living organisms. All living organisms are made of one or more cells: a simple bacterium will consist of just one cell, whereas you are made of trillions of cells. Organisms are organized in the microscopic level from atoms up to cells. The matter is structured in an ordered way. Atoms are arranged into molecules, then into macromolecules, which make up organelles, which work together to form cells. Beyond this, cells are organized in higher levels to form entire multicellular organisms. Cells together form tissues, which make up organs, which are part of organ systems, which work together to form an entire organism. Of course, beyond this, organisms form populations which make up parts of an ecosystem. All of Earth's ecosystems together form the diverse environment that is Earth.

2. Metabolism.

The sum of the processes in the buildup and destruction of protoplasm; specifically : the chemical changes in living cells by which energy is provided for vital processes and activities and new material is assimilated Biology, Physiology. the sum of the physical and chemical processes in an organism by which its material substance is produced, maintained, and destroyed, and by which energy is made available.

Compare anabolism, catabolism

- Anabolism

i. The process involving a sequence of chemical reactions that constructs or synthesizes molecules from smaller units, usually requiring input of energy (ATP) in the process.

ii. A constructive type of metabolism. Examples are bone growth and muscle mass build-up.

- Catabolism

i. The process involving a series of degradative chemical reactions that break down complex molecules into smaller units, usually releasing energy(???) in the process.

ii. A destructive type of metabolism. For instance, large molecules such as polysaccharides, nucleic acids and proteins are broken down into smaller units such as monosaccharides, nucleotides and amino acids, respectively.

3. Movement

Animals move. They move from one place to another and also show other body movements. That's action called locomotion. What about plants? Do they also move? Plants are generally anchored in soil so they do not move from one place to another. However, have you noticed any other kind of movement in plants? Opening or closing of flowers? Do you recall how some plants show movement in response to certain stimuli?

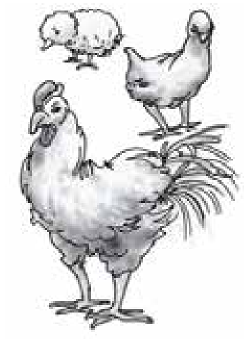
4. Respiration & Excretion.

Breathing is part of a process called respiration. In respiration, some of the oxygen of the air we breathe in is used by the living body. We breathe out the carbon dioxide produced in this process. The process of breathing in animals like cows, buffaloes, dogs or cats is similar to humans. Respiration is necessary for all living organisms. It is through respiration that the body finally obtains energy from the food it takes. Some animals may have different mechanisms for the exchange of gases, which is a part of the respiration process. For example, earthworms breathe through their skin. Fish, have gills for using oxygen dissolved in water. Do plants also respire? Exchange of gases in plants mainly takes place through their leaves. The leaves take in air through tiny pores in them and use the oxygen. They give out carbon dioxide to the air. We learnt that in sunlight, plants use carbon dioxide of air to produce their own food and give out oxygen. Plants produce their food only during the daytime whereas respiration in them takes place day and night. The amount of oxygen released in the process of food preparation by plants is much more than the oxygen they use in respiration.

Respond to their environment.

5. Growth & Change.

All living organisms have the ability to grow and change. A seed may be under the right conditions it will grow into a larger plant. Young ones of animals also grow into adults. You would surely have noticed pups of a dog grow into adults. A chicken hatched from an egg, grows into a hen or a cock. Even the smallest bacteria must grow. Growth seems to be common to all living things.



6. Reproduction.

All living organisms must have the ability to reproduce. Living things make more organisms like themselves. Animals reproduce their own kind. The mode of reproduction may be different, in different animals. Some animals produce their young ones through eggs. Some animals give birth to the young ones. Plants also reproduce. Like animals, plants also differ in their mode of reproduction. Many plants reproduce through seeds. Life will create more life. If a species cannot create the next generation, the species will go extinct. Reproduction is the process of making the next generation and may be a sexual or an asexual process. Sexual reproduction involves two parents and the fusion of gametes. Sexual reproduction produces offspring that are genetically unique and increases genetic variation within a species. Asexual reproduction involves only one parent. It produces offspring that are all genetically identical to the parent.

7. Respond to a stimuli.

All living organisms respond to changes in their environment. If you step on a rock, it will just lie there. Living things know what is going on around them, and respond to it. How do you feel when you see or think about your favourite food? You suddenly move from a dark place into bright sunlight. What happens? Your eyes shut themselves automatically for a moment till they adjust to the changed bright surroundings. The above situations are some examples of changes in your surroundings. All of us respond immediately to such changes. Changes in our surroundings that makes us respond to them, are called stimuli. Do other animals also respond to stimuli? Observe the behaviour of animals, when the food is served to them. Do you find them suddenly becoming active on seeing the food? When you move towards a bird, what does it do? Wild animals run away when bright light is flashed towards them. Do plants also respond to stimuli? Flowers of some plants bloom only at night. In some plants flowers close after sunset. In some plants like mimosa, commonly known as ‘touch-me-not’, leaves close or fold when someone touches them. These are some examples of responses of plants towards changes in their surroundings.

8. Homeostasis.

A human body has a temperature of 37 degrees Celsius, (about 98.6 degrees Fahrenheit). If you step outside on a cold morning, the temperature might be below freezing. Nevertheless, you do not become an ice cube. You shiver and the movement in your arms and legs allows you to stay warm. Eating food also gives your body the energy it needs to keep warm. Living organisms keep their internal environments within a certain range (they maintain a stable internal condition), despite changes in their external environment. This process is called homeostasis, and is an important characteristic of all living organisms.

9. Adaptation & Evolution.

An adaptation refers to the process of becoming adjusted to an environment. Adaptations may include structural, physiological, or behavioral traits that improve an organism's likelihood of survival, and thus, reproduction. any alteration in the structure or function of an organism or any of its parts that results from natural selection and by which the organism becomes better fitted to survive and multiply in its environment. Evolution is a change in the gene pool of a population over time. A gene is a hereditary unit that can be passed on unaltered for many generations. The gene pool is the set of all genes in a species or population.

Review

1. What are the four unifying principles that form the foundation of modern biology?
2. Identify three of the seven characteristics of living things.
3. What is adaptation?
4. Distinguish between metabolism and homeostasis.
5. What is a cell?

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The Reproductive Process in Animals

- Ø **Reproduction** is one of the ubiquitous properties of life.
- Ø **Evolution** is inextricably linked to reproduction.

Two modes of reproduction are recognized:

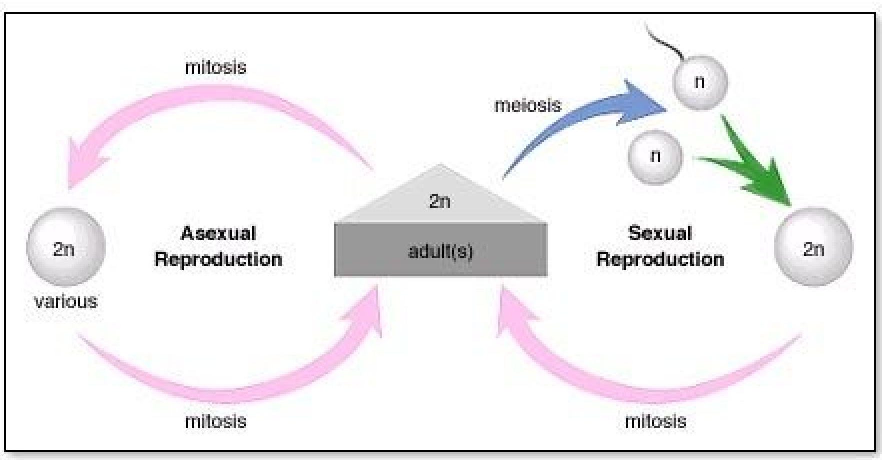
1– Asexual **2– Sexual**

Asexual reproduction: the production of offspring whose genes all come from one parent without the fusion of egg and sperm.

Usually diploid eggs are produced by mitosis which then develops directly.

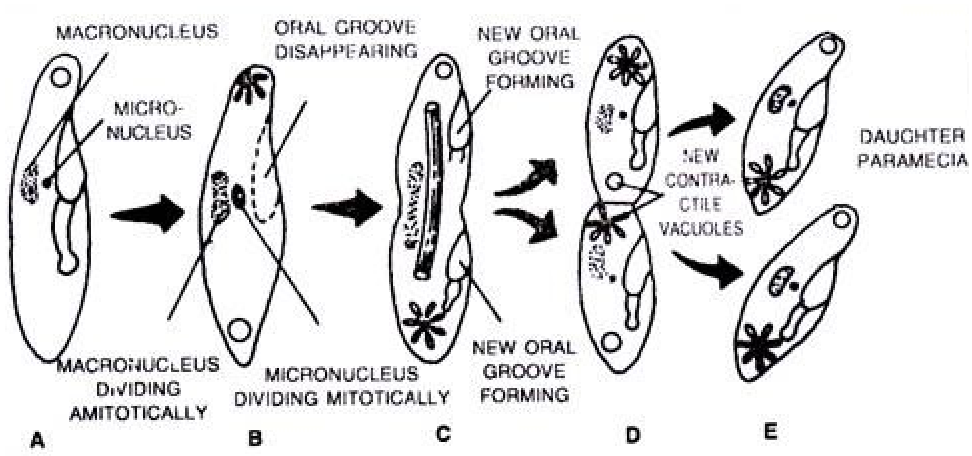
Sexual reproduction: the production of offspring by the fusion of haploid gametes (eggs & sperm) from two parents to form a diploid zygote (fertilized egg).

i. Dioecious
ii. Gametes arise by meiosis.
iii. Genetic variability is increased by the random combinations of genes from the parents.

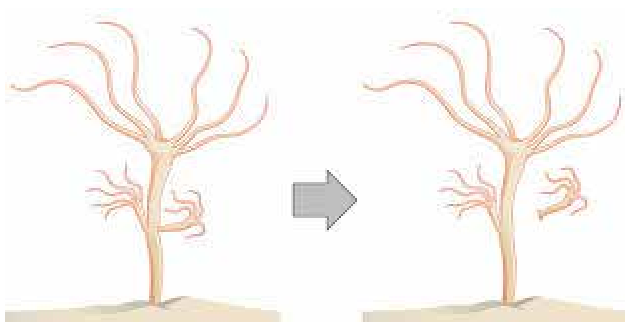


Methods of Asexual reproduction

1- **Binary Fission:** Bacteria and many protozoa can reproduce by **binary fission** – separating into two or more individuals approximately the same size.

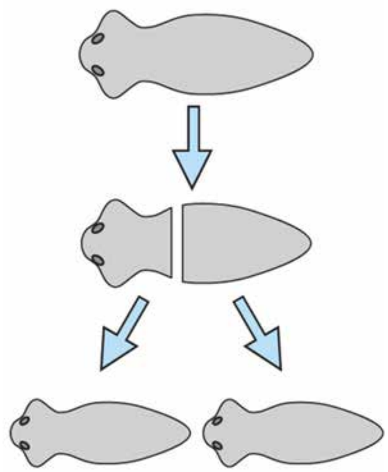


2- **Budding** is a form of asexual reproduction where new individuals form as offshoots of a parent. The offspring may separate or remain attached to form colonies.

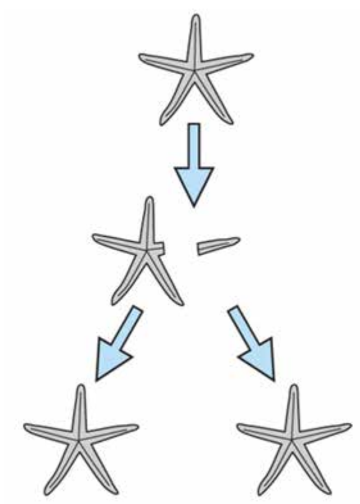


Freshwater sponges release specialized groups of cells called gemmules that can grow into new individual.

3- **Fragmentation:** results when an organism's body is broken into several pieces and each piece grows into a new organism. Fragmentation occurs in some sponges, cnidarians, polychaete annelids, tunicates.



4- **Regeneration** : the regrowth of lost body parts. Sea stars can regenerate lost limbs, but only species in the genus Linckia can form new individuals from broken arms.



5-Parthenogenesis: is a form of asexual reproduction in which females produce eggs that develop without fertilization. Parthenogenesis is seen to occur naturally in some invertebrates, along with several fish, amphibians, involves the development of an embryo from an unfertilized egg or one where sperm & egg nuclei did not fuse.

- **Ameiotic parthenogenesis** – no meiosis, egg is formed by mitosis (diploid)
- **Meiotic parthenogenesis** – haploid ovum formed by meiosis, it may be activated by a male (or not).

In some animals (aphids, rotifers, *Daphnia*) the females can produce two types of eggs. One must be fertilized. One type will develop directly into haploid adults – **parthenogenesis**.

Haploid females produce eggs by mitosis. *Daphnia* reproduce asexually (parthenogenesis) when conditions are favorable. In times of environmental stress, they utilize sexual reproduction. Increases variation!

In many social insects, like honeybees, males (drones) are haploid and are produced by parthenogenesis while females (workers & queens) develop from fertilized eggs. Parthenogenesis occurs in vertebrates in some fishes, amphibians, lizards, and has recently been discovered in snakes.

– After meiosis, the chromosomes are doubled, creating diploid "zygotes".

– Often mating behavior is required to stimulate development of offspring.

Asexual Reproduction - Advantages

i. Animals living far from members of their own species can reproduce without having to search for a mate.

ii. Numerous offspring quickly – ideal for colonizing a new area.
iii. Advantageous in a stable, favorabl.

Sexual reproduction

Generally involves two parents. Special germ cells unite to form a zygote. Sexual reproduction recombines parental characters. A richer, more diversified population results. In haploid asexual organisms mutations are expressed and selected quickly. In sexual reproduction a normal gene on the homologous chromosome may mask a gene mutation.

Why do so many animals reproduce sexually rather than asexually?

The costs of sexual reproduction are greater than asexual methods:

– More complicated.

– Requires more time.

– Uses more energy.

– The cost of meiosis to the female is passage of only half of her genes to offspring. Production of males reduces resources for females that could produce eggs.

However:

Sexual organisms produce more novel genotypes to survive in times of environmental change. In crowded habitats, selection is intense and diversity prevents extinction. On a geological time scale sexual lineages with less variation are prone to extinction. Many invertebrates with both sexual and asexual modes enjoy the advantages of both.

Fertilization: fusion of egg and sperm into a single diploid cell, the **zygote**.

Types of fertilization

1– External fertilization **2 – Internal fertilization**

External fertilization: fertilization takes place outside the female's body. A wet environment is required so gametes don't dry out and so sperm may swim to the eggs. Environmental cues (day length, temperature) or chemical cues may cause a whole population to release gametes at once. Increases likelihood of fertilization.

Internal Fertilization: Internal fertilization allows terrestrial animals to reproduce away from water. Cooperative behavior leading to copulation is required.

Pheromones: are chemical signals released into the environment by one organism that influence the physiology or behavior of members of the same species. Effective in very small amounts. Mate attractants. Ensuring Survival of Offspring. Species with external fertilization produce huge quantities of gametes that result in lots of zygotes. Predation on young is high. Few will survive to reproduce. Species with internal fertilization produce fewer zygotes, but protect them more from predation. Tough egg shells. Embryo may develop in reproductive tract.

Advantages of Sexual Reproduction

Sexual reproduction has costs including finding mates, greater energy cost, reduced proportion of genes passed on to offspring, and slower population growth. However, sexual reproduction increases variability in the population important during times of environmental change.

Gamete Production & Delivery

Gametes (eggs & sperm) are required for sexual reproduction. Usually, gametes are produced in gonads (ovaries & testes). Germ cells are set aside early in development. They will produce only gametes.

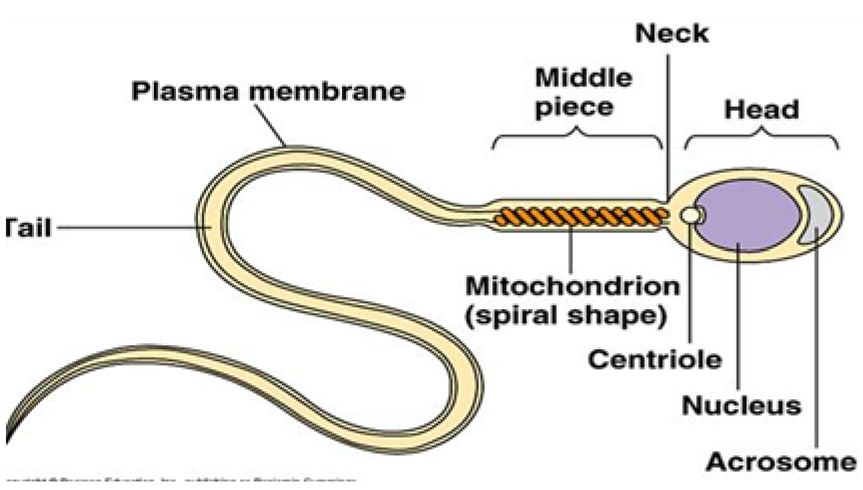
Migration of Germ Cells

Germ cells arise in the yolk-sac endoderm of vertebrates – not in the gonads. They migrate to the gonads using amoeboid movement.

Gametogenesis: the production of gametes.

Spermatogenesis: each primary spermatocyte divides to form 4 sperm.

Oogenesis – each primary oocyte divides to form 1 ovum and 2-3 polar bodies. In oogenesis, cytokinesis is unequal, most of the cytoplasm goes to one daughter cell which becomes the ovum. The other cells, **polar bodies**, degenerate. Outermost layer of the seminiferous tubules contain spermatogonia, diploid cells that grow to become primary spermatocytes. After the first meiotic division, they are called secondary spermatocytes. When meiosis is complete the haploid cells are spermatids. Spermatids mature into motile sperm with a tail for locomotion, and a head containing an acrosome as well as the nucleus.



Review:

Where does the spermatogenesis take place?

How sperm cells are formed?

How long does it take for spermatogenesis to take place?

Where does spermatogenesis begin?

Oogenesis

In the ovary, early germ cells called oogonia are diploid. Oogonia grow to become primary oocytes. After the first meiotic division, the cytoplasm divides unequally and only one secondary oocyte and one polar body result. Following the second meiotic division, one ootid and another polar body result. The ootid develops into a functional ovum. Meiosis is usually arrested at the beginning of meiosis and is not completed until ovulation or fertilization.

Review:

Where does Oogenesis take place?

What is the process of oogenesis in a human?

How many polar bodies are formed during oogenesis?

What is Gametogenesis and when does it occur?

Reproductive Patterns

Oviparous: animals that lay eggs. Most invertebrates, many vertebrates

Ovoviviparous: animals that retain the eggs within their bodies. Nourishment comes from the egg. Some annelids, insects, some fishes, reptiles.

Viviparous: eggs develop in oviduct or uterus, nourishment from mother. Mammals, some sharks, scorpions.

Female Reproductive System

Ovaries are where female gametes, egg cells, are produced. A follicle contains one egg cell as well as follicle cells that nurture the developing egg. Each month from puberty through menopause one follicle ruptures and releases its egg cell – ovulation. The corpus luteum forms from the ruptured follicle and secretes estrogen and progesterone to help maintain the uterine lining during pregnancy. If the egg is not fertilized the lining disintegrates. After ovulation, the egg leaves the ovary and enters the oviduct, which it follows to the uterus.

Review:

What are the main parts of the female reproductive system?

What is the role of the uterus in the female reproductive system?

How many eggs does a woman have?

What is the purpose of estrogen and progesterone?

Male Reproductive System

Testes are where male gametes, sperm cells, are produced. Testes contain the seminiferous tubules where sperm are formed. Leydig cells scattered between the tubules produce testosterone & other androgens. Sperm production can't occur at normal body temperature in mammals, so the testes are held outside the body abdominal cavity in the scrotum. After leaving the testes, sperm pass through the epididymis where they become motile and gain the ability to fertilize an egg. Sperm leave the body through the vas deferens and urethra.

Review

What is the male reproductive system?

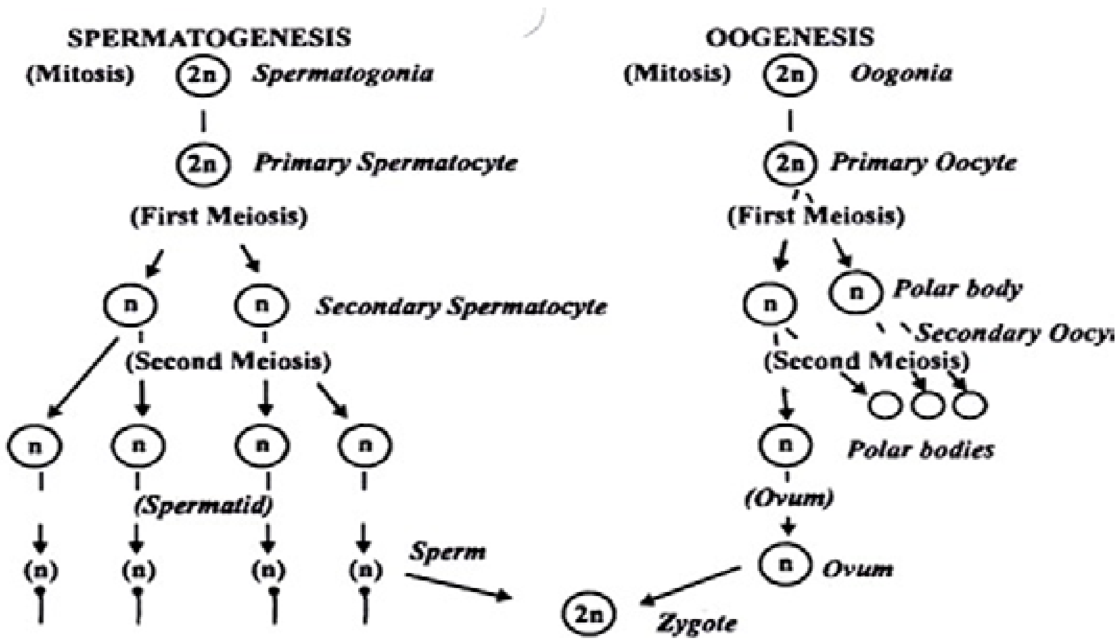
What is the purpose of your testicles?

Which male reproductive organ stores sperm until ejaculation?

What is the function of the male sperm duct?

Reproductive Cycles

Males produce sperm continuously, whereas females only release one or a few eggs at certain intervals.

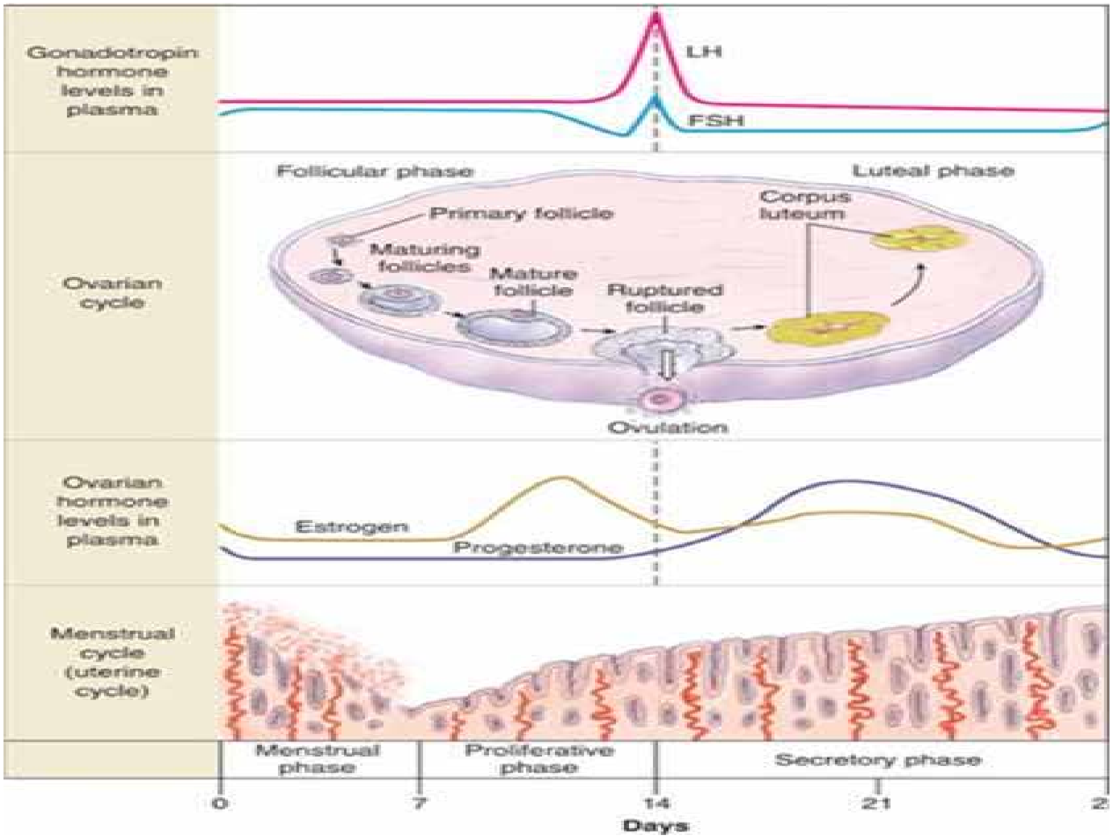


Reproductive Cycles in Female Mammals

Humans & some other primates have a menstrual cycle while other mammals have an estrous cycle. In both, ovulation occurs at a time when the endometrial lining of the uterus is ready for an embryo to implant. If no egg is fertilized, the lining is shed (menstruation) in humans & other primates and is reabsorbed in other mammals. Female mammals that have estrous cycles may have more behavioral changes. Estrous cycles may be more closely tied to season and climate. Females will usually only mate when in estrus – the time surrounding ovulation. The female reproductive cycle in humans contains two parts:

– Uterine (menstrual) cycle – Ovarian cycle

One integrated cycle involving the uterus & ovaries. The ovarian and uterine cycles are regulated by changing hormone levels in the blood.



GnRH (gonadotropin-releasing hormone) is released from the hypothalamus which stimulates the release of LH (luteinizing hormone) and FSH (follicle stimulating hormone) from the pituitary gland. FSH stimulates follicle growth, aided by LH. The follicle cells start producing estrogen. Rise in estrogen during the follicular phase. When the secretion of estrogen begins to rise steeply, the release of FSH and LH rise rapidly as well. Low levels of estrogen inhibit FSH & LH production. High levels of estrogen stimulate FSH & LH production. (Positive feedback). The maturing follicle develops an internal fluid filled cavity and grows very large. The follicular phase ends with ovulation. The follicle ruptures releasing the secondary oocyte. Following ovulation, during the luteal phase, LH stimulates transformation of the follicle into the corpus luteum. The corpus luteum secretes estrogen and progesterone. As the combination of these hormones rises, GnRH production in the hypothalamus is inhibited. (Negative feedback). At the end of the luteal phase, the corpus luteum disintegrates and production of estrogen and progesterone drops. Now, the hypothalamus will start producing GnRH and the cycle starts over. Estrogen and progesterone secreted in the ovary affect the uterus. Increasing amounts of estrogen released by the growing follicles causes the lining of the uterus (endometrium) to thicken. The follicular phase of the ovarian is coordinated with the proliferative phase of the uterine cycle. After ovulation, estrogen & progesterone stimulate the maintenance of the lining and growth of endometrial glands that secrete nutrient fluid to sustain an embryo before implantation. The luteal phase of the ovarian cycle and the secretory phase of the uterine cycle are coordinated. If the egg is not fertilized, the corpus luteum disintegrates, and production of estrogen and progesterone drops sharply. This triggers breakdown of the endometrium – menstruation.

Reproductive Cycles in Male Mammals

In males, the principle sex hormones are androgens, including testosterone.

–Produced mainly by Leydig cells in the testes.

– Responsible for secondary sexual characteristics.

– Important determinants of behavior in vertebrates.

• Sex drive • Aggression • Calling in birds & frogs

As in females, GnRH from the hypothalamus stimulates release of FSH and LH from the pituitary.

– FSH promotes spermatogenesis.

– LH stimulates Leydig cells to make testosterone.

Review

Who has more hormones male or female?

What is the difference between estrogen and testosterone?

Where are the target cells for follicle stimulating hormone?

What are the names of the female hormones?

What is the role of estrogen and progesterone?

What is female reproductive system?

What hormones are produced by the ovaries?

How are LH and FSH involved in male reproduction?

What hormones are in the male reproductive system?

What is the purpose of Leydig cells?

What does the male reproductive system consist

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Coordination and Control in Animals

Systems of Coordination Irritability is a characteristic of living organisms. Ability to respond to a stimulus. The stimulus is received by a receptor. It is transmitted by nerves or hormones, and an effector brings about the response. Animals have two systems of coordination, the nervous system and the endocrine system. The nervous system coordinates rapid responses to external stimuli. The endocrine system controls slower, longer lasting responses to internal stimuli. Activity of both systems is integrated. The Nervous System has Three basic functions are performed by the nervous systems:

1. Receive sensory input from internal and external environments

2. Integrate the input 3. Respond to stimuli

Functions of Nervous System Sensory input can be in many forms, including pressure, taste, sound, light, blood pH, or hormone levels, that are converted to a signal and sent to the brain or spinal cord. In the sensory centers of the brain or in the spinal cord, the barrage of input is integrated and a response is generated. The response, a motor output, is a signal transmitted to organs than can convert the signal into some form of action, such as movement, changes in heart rate, release of hormones. The human nervous system is made up of two parts:

- **Central nervous system (CNS)** - brain and spinal cord: role of coordination.
- **Peripheral nervous system (PNS) -** nerves: connect all parts of the body to the CNS.

Together, they coordinate and regulate body functions.

Sense organs are linked to the peripheral nervous system. They are groups of receptor cells responding to specific stimuli: light, sound, touch, temperature and chemicals.When exposed to a stimulus they generate an electrical impulse which passes along peripheral nerves to the CNS, triggering a response.

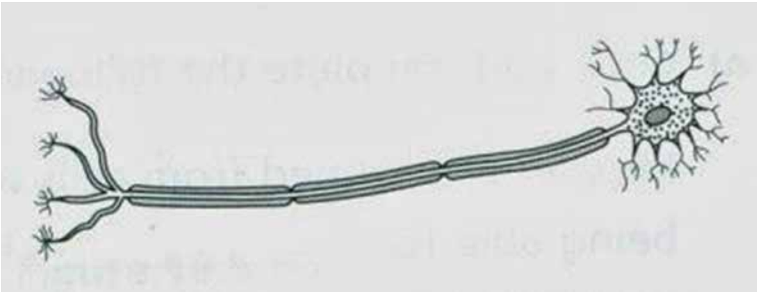
Divisions of the Nervous System The nervous system monitors and controls almost every organ system through a series of positive and negative feedback loops. The Central Nervous System (CNS) includes the brain and spinal cord.

The Peripheral Nervous System (PNS) connects the CNS to other parts of the body, and is composed of nerves (bundles of neurons).

Neuron The cell has a nucleus contained in the cell body. Dendrites carry impulses toward the cell body. Axon transmits nerve impulse away from the cell body. The axon breaks up into many some branches with swollen endings called synaptic knobs. Nervous Tissue Forms a Communication Network. Three types of neurons occur.

I- Sensory neurons typically have a long dendrite and short axon, and carry messages from sensory receptors to the central nervous system.

II- Motor neurons have a long axon and short dendrites and transmit messages from the central nervous system to the muscles (or to glands).

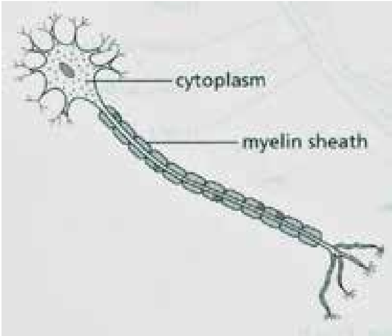


III- Interneurons are found only in the central nervous system where they connect neuron to neuron.

Motor and sensory neurones are covered with a myelin sheath, which insulates the neurone to make transmission of the impulse more efficient. The cytoplasm (mainly axon and dendron) is elongated to transmit the impulse for long distances.

Structure	**Sensory neurone**	**Motor neurone**
Cell body	Near end of neurone, in a ganglion (swelling) just	At start of neurone, indise the grey matter
Dendrites	Present at end of neurone	Attached to cell body
Axon	Very short	Very long
Dendron	Very long	None

Fun fact: The human nervous system runs on electrical impulses that travel close to the speed of light. The space between two cells is known as the synaptic cleft. To cross the synaptic cleft requires the actions of neurotransmitters. Neurotransmitters are stored in small synaptic vessicles clustered at the tip of the axon.



The Peripheral Nervous System (PNS) contains only nerves and connects the brain and spinal cord (CNS) to the rest of the body. Peripheral Nervous System Cranial nerves in the PNS take impulses to and from the brain (CNS).brain Spinal nerves take impulses to and away from the spinal cord.

Components of the PNS: Two main components of the PNS Sensory (afferent) pathways that provide input from the body into the CNS. Motor (efferent) pathways that carry signals to muscles and glands (effectors). There are two major subdivisions of the PNS motor pathways: the somatic and the autonomic. Most sensory input carried in the PNS remains below the level of conscious awareness. Input that does reach the conscious level contributes to perception of our external environment.

The Central Nervous System (CNS): is composed of the brain and spinal cord. Central Nervous System The brain is composed of three parts: the cerebrum (seat of consciousness), the cerebellum, and the medulla oblongata (these latter two are "part of the unconscious brain").

Vertebrate Evolutionary Trends :

1. Increase in brain size relative to body size.

2. Subdivision and increasing specialization of the forebrain, midbrain, and hindbrain.

3. Growth in relative size of the forebrain, especially the cerebrum, which is associated with increasingly complex behaviour in mammals.

A **reflex action** is an automatic response to a stimulus. A **reflex arc** describes the pathway of an electrical impulse in response to a stimulus. All organisms are able to sense changes in their environment, called stimuli, and respond to them. The part of the body that senses the stimulus is a receptor, and the part that responds is an effector. The human nervous system contains specialized cells called neurons. The brain and spinal cord make up the central nervous system (CNS), which coordinates responses to stimuli.

Reflex actions are fast, automatic responses to a stimulus. They involve a series of neurons making up a reflex arc. A sensory neurone takes the impulse to the CNS and a motor neurone takes it from the CNS to an effector.

Effectors are muscles or glands which respond when they receive impulses from motor neurones. Examples of effectors are the biceps and triceps muscles in the arm. When stimulated, muscles contract get shorter). The biceps and triceps are antagonistic muscles - they have opposite effects when they contract.

Part of sequence	Part in pupil reflex
Coordinator	Brain
Effector	Iris (muscle)
Receptor	Retina or rods or cones
Response	Pupil changes diameter or iris muscles contract
Stimulus	Bright light or change in light intensity

Endocrine System: The endocrine system is composed of several endocrine glands. A ductless gland is called endocrine gland. Endocrine gland secretes its product directly into the bloodstream. Hormones are produced in the endocrine glands. Hormone is mainly composed of protein. Hormones assist the nervous system in control and coordination. Nerves do not reach to every nook and corner of the body and hence hormones are needed to affect control and coordination in those parts. Moreover, unlike nervous control; hormonal control is somewhat slower.

Hormones: are a chemical substances, secreted by endocrine gland, carried by the blood, which alters the activity of one or more specific target organs and is then destroyed by the liver.

1. Chemical control of metabolic activity by adrenalin. Adrenaline is a hormone secreted by adrenal glands. When you are frightened, excited, your brain sends impulses along a verve to your adrenal glands. This makes them secrete adrenaline into the blood.

Endocrine gland	Location	Hormones Produced	Funcations
Pituitary gland (Also known as the master gland)	At the base of brain	Growth hormone (GH), thyroid stimulating hormone (TSH), Follicle stimulating hormone (FSH)	GH stimulates growth, TSH stimulates functioning of thyroid gland, FSH stimulates the follicles during ovulation.
Thyroid Gland	Neck	Thyroxine	Controls general metabolism and growth in the body.
Adrenal gland	Above kidneys	Adrenalin	Prepares the body for emergency situations and hence is also called 'Fight and flight' hormone.
Pancreas	Near stomach	Insulin	Controls blood sugar level
Testis (male)	In scrotum	Testosterone	Sperm production, development of secondary sexual characters during puberty.
Ovary (female)	Near uterus	Oestrogen	Egg production, development of secondary sexual characters during puberty.

Review:

1. What kind of factors would an animal need to coordinate and control?
2. Look at the list you have made in question one and say what the consequences of not being able to control each of these factors would be.
3. What do we mean when we say someone has quick reflexes or that something was a reflex response?

4. What about when we say that certain behavior is due to stress? Or due to hormones? What is most commonly meant?
5. Draw a flow diagram that explains the steps between a stimulus and a response.
6. What are the 2 main types of coordination and control in animals?
7. What are the components of a neurone? What is the role of each component?
8. What are the 3 types of neurones? What does each one do?
9. What change occurs when a neurone is activated? What mechanism is involved?
10. What is a synapse? How does a nerve impulse cross the synaptic gap?
11. Explain a reflex arc.
12. What are the 2 main parts of the nervous system?
13. What does the autonomic system control? What does the somatic system control?
14. What is the definition of a hormone
15. Why is a hormonal response slower than a nervous system one
16. What is the purpose of feedback control? What are the 2 ways mentioned that this can work? What is the word used by Biologists to describe this maintenance of certain important variables within narrow limits?
17. Why is the functioning of the adrenal cortices vital to life?
18. Explain how each hormone produced by the adrenal medulla is involved in the fight or flight response .
19. What are the endocrine hormones produced by the pancreas? What does insulin do? What does glucagon do ?
20. What hormones are produced by the anterior pituitary to control the female reproductive cycle? What is the effect of each one?

21. What hormones are produced by the anterior pituitary to control the male reproductive system? What is the effect of each one?
22. Summarize the differences between the coordination effected by the nervous system and the endocrine system. Use a table for your findings

and consider method and speed of transmission, how long the message lasts, and the target of the message.

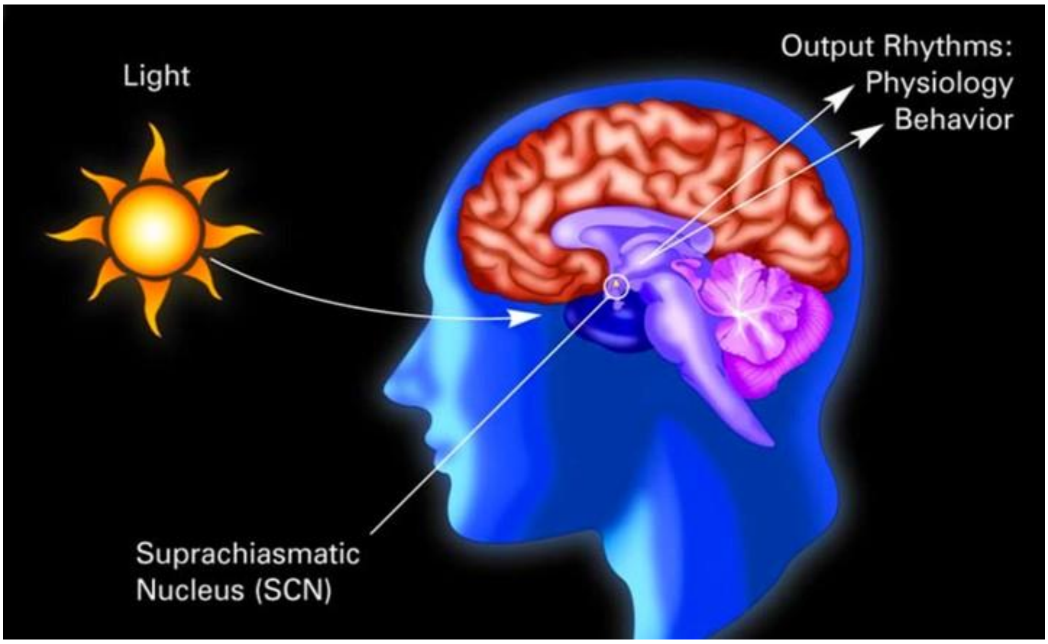
23Make a list of hormones mentioned in the program that have opposing effects. Say what the effect of each one is. Do some research to find some more pairs of hormones.

24.Complete the following table:

Gland	**Hormones produced**	**The Effect of Hormones**
Thyroid		
Parathyroids		
Adrenal Cortex Medulla		
Female gonads		
Male gonads		

LEC:4 Circadian Rhythms - Biological Clock

A circadian rhythm is any biological process that displays an endogenous, entrainable oscillation of about 24 hours. These rhythms are driven by a circadian clock, and rhythms have been widely observed in plants, animals, fungi and cyanobacteria. A **"master clock"** in the brain coordinates all the body clocks so that they are in synch. This master cock controls circadian rhythms consists of a group of nerve cells in the brain called the **suprachiasmatic nucleus**, or **SCN**. The SCN contains about 20,000 nerve cells and is located in the hypothalamus, an area of the brain just above where the optic nerves from the eyes cross.



- Circadian rhythms are produced by natural factors within the body, but they are also affected by signals from the environment. Light is the main cue influencing circadian rhythms, turning on or turning off genes that control an organism's internal clocks.
- Circadian rhythms can influence sleep-wake cycles, hormone release, body temperature and other important bodily functions. They have been linked to various sleep disorders, such as insomnia. Abnormal circadian rhythms have also been associated with obesity, diabetes, depression, bipolar disorder and seasonal affective disorder.
- Circadian rhythms are important in determining human sleep patterns. The body's master clock, or SCN, controls the production of melatonin, a hormone that makes you sleepy. Since it is located just above the optic nerves, which relay information from the eyes to the brain, the SCN receives information about incoming light. When there is less light - like at night - the SCN tells the brain to make more melatonin so you get drowsy.

Disruption to rhythms usually has a negative effect in the short term. Many travelers have experienced the condition known as jet lag, with its associated symptoms of fatigue, disorientation and insomnia. Jet lag occurs when travelers suffer from disrupted circadian rhythms. When you pass through different time zones, your body's clock will be different from your wristwatch.

The term "circadian" comes from the Latin circa, "around", and dies, "day", meaning literally "about a day." The formal study of biological temporal rhythms such as daily, weekly, seasonal, and annual rhythms, is called chronobiology. Although circadian rhythms are endogenous ("built-in", self-sustained), they are adjusted (entrained) to the environment by external cues called zeitgebers, the primary one of which is daylight. In a strict sense, circadian rhythms are endogenously generated, although they can be modulated by external cues such as sunlight and temperature.

Criteria: To be called circadian, a biological rhythm must meet these four general criteria:

1. The rhythms repeat once a day (they have a 24-hour period). In order to keep track of the time of day, a clock must be at the same point at the same time each day, i.e. repeat every 24 hours.

2. The rhythms persist in the absence of external cues (endogenous). The rhythm persists in constant conditions with a period of about 24 hours. The rationale for this criterion is to distinguish circadian rhythms from simple responses to daily external cues. A rhythm cannot be said to be endogenous unless it has been tested in conditions without external periodic input.

3. The rhythms can be adjusted to match the local time (entrainable). The rhythm can be reset by exposure to external stimuli (such as light and heat), a process called entrainment. The rationale for this criterion is to distinguish circadian rhythms from other imaginable endogenous 24-hour rhythms that are immune to resetting by external cues, and hence do not serve the purpose of estimating the local time. Travel across time zones illustrates the ability of the human biological clock to adjust to the local time; a person will usually experience jet lag before entrainment of their circadian clock has brought it into sync with local time.

4. The rhythms maintain circadian periodicity over a range of physiological temperatures; they exhibit temperature compensation. Some organisms live at a broad range of temperatures, and differences in thermal energy will affect the kinetics of all molecular processes in their cell(s). In order to keep track of time, the organism's circadian clock must maintain a roughly 24-hour periodicity despite the changing kinetics, a property known as temperature compensation.

Origins of Circadian Rhythms

Circadian rhythms are believed to have originated in the earliest cells to provide protection for replicating DNA, from high ultraviolet radiation during day-time. As a result, replication was relegated to the dark. The fungus Neurospora, which exists today, retains this clock-regulated mechanism. The simplest known circadian clock is that of the prokaryotic cyanobacteria. Recent research has demonstrated that the circadian clock of Synecohococcus elongatus can be reconstituted in vitro with just the three proteins of their central oscillator. This clock has been shown to sustain a 22 hour rhythm over several days upon the addition of ATP. Previous explanations of the prokaryotic circadian timekeeper were dependent upon a DNA transcription / translation feedback mechanism, and although this has not been shown to be the case, it is still believed to hold true for eukaryotic organisms. Indeed, although the circadian systems of eukaryotes and prokaryotes have the same basic architecture: input - central oscillator - output, they do not share any homology. This implies probable independent origins.

Circadian rhythms allow organisms to anticipate and prepare for precise and regular environmental changes; they have great value in relation to the outside world. The rhythmicity appears to be as important in regulating and coordinating internal metabolic processes, as in coordinating with the environment. This is suggested by the maintenance (heritability) of circadian rhythms in fruit flies after several hundred generations in constant laboratory conditions, as well as in creatures in constant darkness in the wild, and by the experimental elimination of behavioral but not physiological circadian rhythms in quail.

It is now known that the molecular circadian clock can function within a single cell; i.e., it is cell-autonomous. At the same time, different cells may communicate with each other resulting in a synchronized output of electrical signaling. These may interface with endocrine glands of the brain to result in periodic release of hormones. The receptors for these hormones may be located far across the body and synchronize the peripheral clocks of various organs. Thus, the information of the time of the day as relayed by the eyes travels to the clock in the brain, and, through that, clocks in the rest of the body may be synchronized. This is how the timing of, for example, sleep/wake, body temperature, thirst, and appetite are coordinately controlled by the biological clock. Circadian rhythmicity is present in the sleeping and feeding patterns of animals, including human beings. There are also clear patterns of core body temperature, brain wave activity, hormone production, cell regeneration and other biological activities. In addition, photoperiodism, the physiological reaction of organisms to the length of day or night, is vital to both plants and animals, and the circadian system plays a role in the measurement and interpretation of day length.

The rhythm is linked to the light-dark cycle. Animals, including humans, kept in total darkness for extended periods eventually function with a free-running rhythm. Their sleep cycle is pushed back or forward each "day", depending on whether their "day", their endogenous period, is shorter or longer than 24 hours. The environmental cues that reset the rhythms each day are called zeitgebers (from the German, "time-givers"). It is interesting to note that totally-blind subterranean mammals (e.g., blind mole rat Spalax sp.) are able to maintain their endogenous clocks in the apparent absence of external stimuli. Although they lack image-forming eyes, their photoreceptors (which detect light) are still functional; they do surface periodically as well.

Free-running organisms that normally have one or two consolidated sleep episodes will still have them when in an environment shielded from external cues, but the rhythm is, of course, not entrained to the 24-hour light-dark cycle in nature. The sleep-wake rhythm may, in these circumstances, become out of phase with other circadian or ultradian rhythms such as metabolic, hormonal, CNS electrical, or neurotransmitter rhythms.

Recent research has influenced the design of spacecraft environments, as systems that mimic the light-dark cycle have been found to be highly beneficial to astronauts. Norwegian researchers at the University of Tromso have shown that some Arctic animals (ptarmigan, reindeer) show circadian rhythms only in the parts of the year that have daily sunrises and sunsets. In one study of reindeer, animals at 70 degrees North showed circadian rhythms in the autumn, winter, and spring, but not in the summer. Reindeer at 78 degrees North showed such rhythms only in autumn and spring. The researchers suspect that other Arctic animals as well may not show circadian rhythms in the constant light of summer and the constant dark of winter.

However, another study in northern Alaska found that ground squirrels and porcupines strictly maintained their circadian rhythms through 82 days and nights of sunshine. The researchers speculate that these two small mammals see that the apparent distance between the sun and the horizon is shortest once a day, and, thus, a sufficient signal to adjust by. The navigation of the fall migration of the Eastern North American monarch butterfly (Danaus plexippus) to their overwintering grounds in central Mexico uses a time-compensated sun compass that depends upon a circadian clock in their antennae

History

The earliest known account of a circadian process dates from the 4th century BC, when Androsthenes, a ship captain serving under Alexander the Great, described diurnal leaf movements of the tamarind tree. The observation of a circadian or diurnal process in humans is mentioned in Chinese medical texts dated to around the 13th century, including the Noon and Midnight Manual and the Mnemonic Rhyme to Aid in the Selection of Acu-points According to the Diurnal Cycle, the Day of the Month and the Season of the Year.

The first recorded observation of an endogenous circadian oscillation was by the French scientist Jean-Jacques d'Ortous de Mairan in 1729. He noted that 24-hour patterns in the movement of the leaves of the plant Mimosa pudica continued even when the plants were kept in constant darkness, in the first experiment to attempt to distinguish an endogenous clock from responses to daily stimuli.

In 1896, Patrick and Gilbert observed that during a prolonged period of sleep deprivation, sleepiness increases and decreases with a period of approximately 24 hours.

In 1918, J.S. Szymanski showed that animals are capable of maintaining 24-hour activity patterns in the absence of external cues such as light and changes in temperature. Ron Konopka and Seymour Benzer isolated the first clock mutant in Drosophila in the early 1970s and mapped the "period" gene, the first discovered genetic component of a circadian clock. Joseph Takahashi discovered the first mammalian 'clock gene' (CLOCK) using mice in 1994. The term "circadian" was coined by Franz Halberg in the late 1950s.

Biological Clock in Mammals

The primary circadian "clock" in mammals is located in the suprachiasmatic nucleus (or nuclei) (SCN), a pair of distinct groups of cells located in the hypothalamus. Destruction of the SCN results in the complete absence of a regular sleep-wake rhythm. The SCN receives information about illumination through the eyes. The retina of the eye contains "classical" photoreceptors ("rods" and "cones"), which are used for conventional vision. But the retina also contains specialized ganglion cells which are directly photosensitive, and project directly to the SCN where they help in the entrainment of this master circadian clock.

These cells contain the photopigment melanopsin and their signals follow a pathway called the retinohypothalamic tract, leading to the SCN. If cells from the SCN are removed and cultured, they maintain their own rhythm in the absence of external cues.

The SCN takes the information on the lengths of the day and night from the retina, interprets it, and passes it on to the pineal gland, a tiny structure shaped like a pine cone and located on the epithalamus. In response, the pineal secretes the hormone melatonin. Secretion of melatonin peaks at night and ebbs during the day and its presence provides information about night-length.

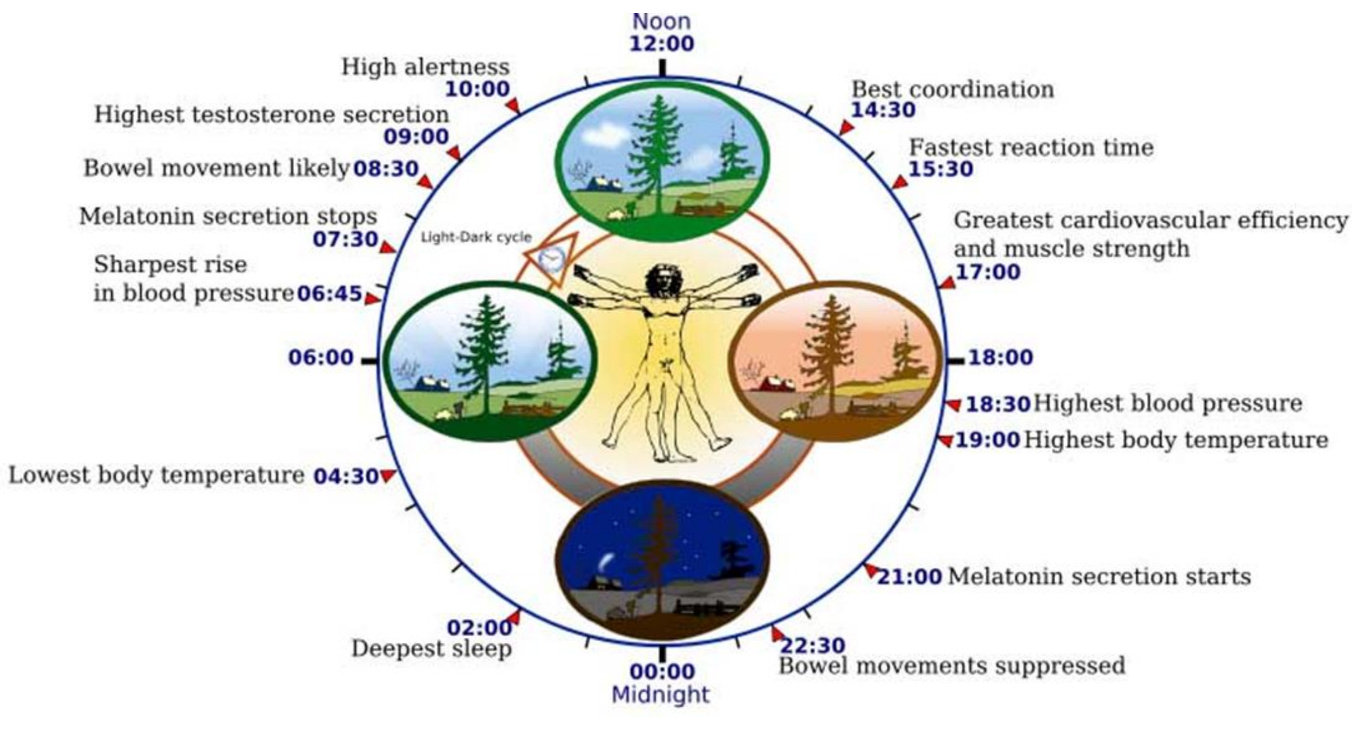
Several studies have indicated that pineal melatonin feeds back on SCN rhythmicity to modulate circadian patterns of activity and other processes. However, the nature and system-level significance of this feedback are unknown.

The circadian rhythms of humans can be entrained to slightly shorter and longer periods than the Earth's 24 hours. Researchers at Harvard have recently shown that human subjects can at least be entrained to a 23.5-hour cycle and a 24.65-hour cycle (the latter being the natural solar day-night cycle on the planet Mars).

Humans

Early research into circadian rhythms suggested that most people preferred a day closer to 25 hours when isolated from external stimuli like daylight and timekeeping. However, this research was faulty because it failed to shield the participants from artificial light. Although subjects were shielded from time cues (like clocks) and daylight, the researchers were not aware of the phase-delaying effects of indoor electric lights. The subjects were allowed to turn on light when they were awake and to turn it off when they wanted to sleep. Electric light in the evening delayed their circadian phase. These results became well-known.

More recent research has shown that: adults have a built-in day, which averages about 24 hours; indoor lighting does affect circadian rhythms; and most people attain their best-quality sleep during their chronotype-determined sleep periods. A study by Czeisler et al. at Harvard found the range for normal, healthy adults of all ages to be quite narrow: 24 hours and 11 minutes plus or minus 16 minutes. The "clock" resets itself daily to the 24-hour cycle of the Earth's rotation.



Biological Markers

The classic phase markers for measuring the timing of a mammal's circadian rhythm are:

- ❖ melatonin secretion by the pineal gland
- ❖ core body temperature
- ❖ plasma level of cortisol.

For temperature studies, subjects must remain awake but calm and semi-reclined in near darkness while their rectal temperatures are taken continuously. The average human adult's temperature reaches its minimum at about 05:00 (5 a.m.), about two hours before habitual wake time, though variation is great among normal chronotypes.

Melatonin is absent from the system or undetectably low during daytime. Its onset in dim light, dim-light melatonin onset (DLMO), at about 21:00 (9 p.m.) can be measured in the blood or the saliva. Its major metabolite can also be measured in morning urine. Both DLMO and the midpoint (in time) of the presence of the hormone in the blood or saliva have been used as circadian markers.

However, newer research indicates that the melatonin offset may be the more reliable marker. Benloucif et al. in Chicago in 2005 found that melatonin phase markers were more stable and more highly correlated with the timing of sleep than the core temperature minimum. They found that both sleep offset and melatonin offset were more strongly correlated with the various phase markers than sleep onset. In addition, the declining phase of the melatonin levels was more reliable and stable than the termination of melatonin synthesis.

One method used for measuring melatonin offset is to analyses a sequence of urine samples throughout the morning for the presence of the melatonin metabolite 6-sulphatoxymelatonin (aMT6s). Laberge et al. in Quebec in 1997 used this method in a study that confirmed the frequently found delayed circadian phase in healthy adolescents.

A third marker of the human pacemaker is the timing of the maximum plasma cortisol level. Klerman et al. in 2002 compared cortisol and temperature data to eight different analysis methods of plasma melatonin data, and found that "methods using plasma melatonin data may be considered more reliable than methods using CBT or cortisol data as an indicator of circadian phase in humans."

Other physiological changes which occur according to a circadian rhythm include heart rate and production of red blood cells.

Outside the "Master clock"

More-or-less independent circadian rhythms are found in many organs and cells in the body outside the suprachiasmatic nuclei (SCN), the "master clock". These clocks, called peripheral oscillators, are found in the oesophagus, lungs, liver, pancreas, spleen, thymus, and the skin.

Though oscillators in the skin respond to light, a systemic influence has not been proven so far. There is also some evidence that the olfactory bulb and prostate may experience oscillations when cultured, suggesting that these structures may also be weak oscillators.

Furthermore, liver cells, for example, appear to respond to feeding rather than to light. Cells from many parts of the body appear to have freerunning rhythms.

Light and the Biological Clock

Light resets the biological clock in accordance with the phase response curve (PRC). Depending on the timing, light can advance or delay the circadian rhythm. Both the PRC and the required illuminance vary from species to species and lower light levels are required to reset the clocks in nocturnal rodents than in humans.

Lighting levels that affect the circadian rhythm in humans are higher than the levels usually used in artificial lighting in homes. According to some researchers the illumination intensity that excites the circadian system has to reach up to 1000 lux striking the retina.

In addition to light intensity, wavelength (or color) of light is a factor in the entrainment of the body clock. Melanopsin is most efficiently excited by light from the blue part of the spectrum (420-440 nm according to some researchers while others have reported 470 -485 nm). These blue wavelengths are present in virtually all light sources, therefore their elimination requires special lights or filters which appear amber.

It is thought that the direction of the light may have an effect on entraining the circadian rhythm; light coming from above, resembling an image of a bright sky, has greater effect than light entering our eyes from below.

According to a 2010 study completed by the Lighting Research Center, daylight has a direct effect on circadian rhythms and, consequently, on performance and well-being. The research showed that students who experience disruption in lighting schemes in the morning consequently experience disruption in sleeping patterns. The change in sleeping patterns may lead to negatively impacted student performance and alertness. Removing circadian light in the morning delays the dim light melatonin onset by 6 minutes a day, for a total of 30 minutes for five days.

Eiko Ojala

Human Health

Timing of medical treatment in coordination with the body clock may significantly increase efficacy and reduce drug toxicity or adverse reactions. For example, appropriately timed treatment with angiotensin converting enzyme inhibitors (ACEi) may reduce nocturnal blood pressure and also benefit left ventricular (reverse) remodeling.

A number of studies have concluded that a short period of sleep during the day, a power-nap, does not have any measurable effect on normal circadian rhythms, but can decrease stress and improve productivity.

There are many health problems associated with disturbances of the human circadian rhythm, such as seasonal affective disorder (SAD), delayed sleep phase syndrome (DSPS) and other circadian rhythm disorders. Circadian rhythms also play a part in the reticular activating system, which is crucial for maintaining a state of consciousness. In addition, a reversal in the sleep-wake cycle may be a sign or complication of uremia, azotemia or acute renal failure.

Studies have also shown that light has a direct effect on human health because of the way it influences the circadian rhythms.

Effect of drugs

Circadian rhythms and clock genes expressed in brain regions outside the suprachiasmatic nucleus may significantly influence the effects produced by drugs such as cocaine. Moreover, genetic manipulations of clock genes profoundly affect cocaine's actions.

Scientists pinpoint link between light signal and circadian rhythms PhysOrg - December29,2010 Scientists who work in this field, known as chronobiology, have identified the genes that direct circadian rhythms in people, mice, fruit flies, fungi and several other organisms. However, the mechanisms by which those genes interact with light in the organism's environment have not been well understood.

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by:
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Department of Biology
2018 – 2019

Blood Function and Composition Lec:7

Blood facts:

- Approximately 8% of an adult's body weight is made up of blood.
- Females have around 4-5 litres, while males have around 5-6 litres. This difference is mainly due to the differences in body size between men and women.
- Its mean temperature is 38 degrees Celcius.
- It has a pH of 7.35-7.45, making it slightly basic (less than 7 is considered acidic).
- Whole blood is about 4.5-5.5 times as viscous as water, indicating that it is more resistant to flow than water. This viscosity is vital to the function of blood because if blood flows too easily or with too much resistance, it can strain the heart and lead to severe cardiovascular problems.
- Blood in the arteries is a brighter red than blood in the veins because of the higher levels of oxygen found in the arteries.
- An artificial substitute for human blood has not been found.

Blood plasma

1. Proteins 2. Amino acids 3. Nitrogenous waste 4. Nutrients 5. Gases 6. Electrolytes

- Red blood cells - White blood cells

i.Granulocytes ii. Agranulocytes

Platelets

- Vascular spasm - Platelet plug formation - Coagulation

Production of blood

- Haemopoiesis - Erythropoesis - Leukopoiesis - Thrombopoiesis

Functions of blood

Blood has three main functions: transport, protection and regulation.

Transport

Blood transports the following substances:

- Gases, namely oxygen (O_2) and carbon dioxide (CO_2), between the lungs and rest of the body

- Nutrients from the digestive tract and storage sites to the rest of the
- body Waste products to be detoxified or removed by the liver and
- kidneys Hormones from the glands in which they are produced to
- their target cells Heat to the skin so as to help regulate body
- temperature

Protection : Blood has several roles in inflammation:

- Leukocytes, or white blood cells, destroy invading microorganisms and cancer cells
- Antibodies and other proteins destroy pathogenic substances
- Platelet factors initiate blood clotting and help minimise blood loss

Regulation : Blood helps regulate:

- pH by interacting with acids and bases
- Water balance by transferring water to and from tissues.

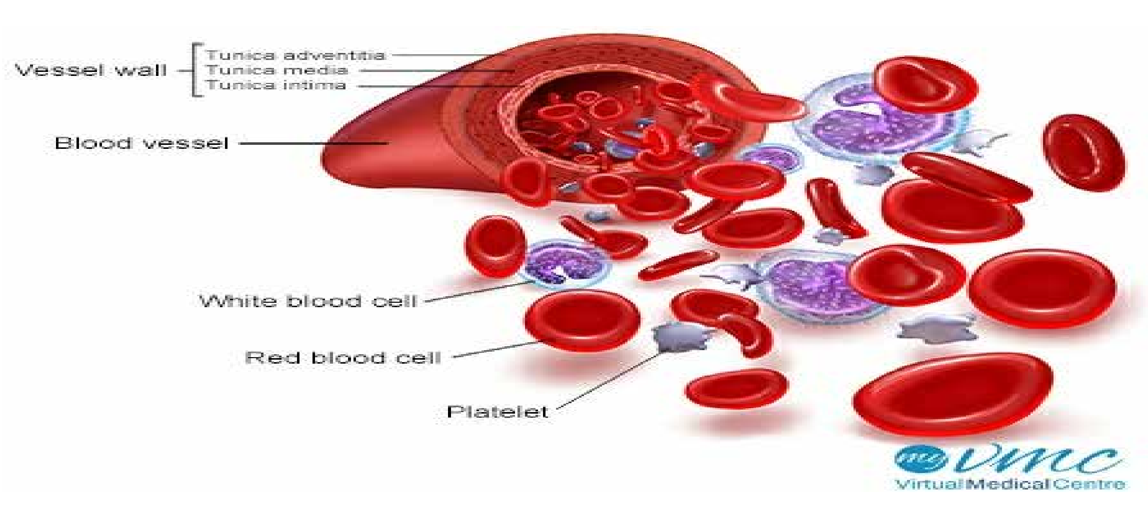
Composition of blood : Blood is classified as a connective tissue and consists of two main components:

1. Plasma, which is a clear extracellular fluid
2. Formed elements, which are made up of the blood cells and platelets

The formed elements are so named because they are enclosed in a plasma membrane and have a definite structure and shape. All formed elements are cells except for the platelets, which are tiny fragments of bone marrow cells.

Formed elements are:

- Erythrocytes, also known as red blood cells (RBCs)
- Leukocytes, also known as white blood cells (WBCs)
- Platelets



Leukocytes are further classified into two subcategories called granulocytes which consist of neutrophils, eosinophils and basophils; and agranulocytes which consist of lymphocytes and monocytes.

The formed elements can be separated from plasma by centrifuge, where a blood sample is spun for a few minutes in a tube to separate its components according to their densities. RBCs are denser than plasma, and so become packed into the bottom of the tube to make up 45% of total volume. This volume is known as the haematocrit. WBCs and platelets form a narrow cream-coloured coat known as the buffy coat immediately above the RBCs. Finally, the plasma makes up the top of the tube, which is a pale yellow colour and contains just under 55% of the total volume.

Blood plasma

Blood plasma is a mixture of proteins, enzymes, nutrients, wastes, hormones and gases. The specific composition and function of its components are as follows:

Proteins

These are the most abundant substance in plasma by weight and play a part in a variety of roles including clotting, defence and transport. Collectively, they serve several functions. There are three major categories of plasma proteins, and each individual type of proteins has its own specific properties and functions in addition to their overall collective role:

1. **Albumins**, which are the smallest and most abundant plasma proteins..
2. **Globulins**, which can be subdivided into three classes from smallest to largest in molecular weight into alpha, beta and gamma globulins.
3. **Fibrinogen**, which is a soluble precursor of a sticky protein called fibrin, which forms the framework of blood clot. Fibrin plays a key role in coagulation of blood, which is discussed later in this article under Platelets.

Amino acids : These are formed from the break down of tissue proteins or from the digestion of digested proteins.

Nitrogenous waste : Being toxic end products of the break down of substances in the body, these are usually cleared from the bloodstream and are excreted by the kidneys at a rate that balances their production.

Nutrients : Those absorbed by the digestive tract are transported in the blood plasma. These include glucose, amino acids, fats, cholesterol, phospholipids, vitamins and minerals.

Gases : Some oxygen and carbon dioxide are transported by plasma. Plasma also contains a substantial amount of dissolved nitrogen.

Electrolytes : The most abundant of these are sodium ions, which account for more of the blood's osmolarity than any other solute.

Red blood cells : Red blood cells (RBCs), also known as erythrocytes, have two main functions:

1. To pick up oxygen from the lungs and deliver it to tissues elsewhere
2. To pick up carbon dioxide from other tissues and unload it in the lungs.

White blood cells : White blood cells (WBCs) are also known as leukocytes. They can be divided into granulocytes and agranulocytes. The former have cytoplasms that contain organelles that appear as coloured granules through light microscopy, hence their name. Granulocytes consist of neutrophils, eosinophils and basophils. In contrast, agranulocytes do not contain granules. They consist of lymphocytes and monocytes.

Granulocytes

1. **Neutrophils:** These contain very fine cytoplasmic granules that can be seen under a light microscope.
   Neutrophils are also called polymorphonuclear (PMN) because they have a variety of nuclear shapes. They
   play roles in the destruction of bacteria and the release of chemicals that kill or inhibit the growth of bacteria.
2. **Eosinophils:** These have large granules and a prominent nucleus that is divided into two lobes. They function in the destruction of allergens and inflammatory chemicals, and release enzymes that disable parasites.
3. **Basophils:** They have a pale nucleus that is usually hidden by granules. They secrete histamine which increases tissue blood flow via dilating the blood vessels, and also secrete heparin which is an anticoagulant that promotes mobility of other WBCs by preventing clotting.

Agranulocytes

1. **Lymphocytes:** These are usually classified as small, medium or large. Medium and large lymphocytes are generally seen mainly in fibrous connective tissue and only occasionally in the circulation bloodstream. Lymphocytes function in destroying cancer cells, cells infected by viruses, and foreign invading cells. In addition, they present antigens to activate other cells of the immune system. They also coordinate the actions of other immune cells, secrete antibodies and serve in immune memory.
2. **Monocytes:** They are the largest of the formed elements. Their cytoplasm tends to be abundant and

relatively clear. They function in differentiating into macrophages, which are large phagocytic cells, and digest pathogens, dead neutrophils, and the debris of dead cells. Like lymphocytes, they also present antigens to
activate other immune cells.

Platelets : Platelets are small fragments of bone marrow cells and are therefore not really classified as cells themselves. Platelets have the following functions:

1. Secrete vasoconstrictors which constrict blood vessels, causing vascular spasms in broken blood vessels
2. Form temporary platelet plugs to stop bleeding
3. Secrete procoagulants (clotting factors) to promote blood clotting
4. Dissolve blood clots when they are no longer needed
5. Digest and destroy bacteria.
6. Secrete chemicals that attract neutrophils and monocytes to sites of inflammation
7. Secrete growth factors to maintain the linings of blood vessels

The first three functions listed above refer to important haemostatic mechanisms in which platelets play a role in during bleeding: vascular spasms, platelet plug formation and blood clotting (coagulation).

Vascular spasm : This is a prompt constriction of the broken blood vessel and is the most immediate protection against blood loss. Injury stimulates pain receptors. Some of these receptors directly innervate nearby blood vessels and cause them to constrict. After a few minutes, other mechanisms take over. Injury to the smooth muscle of the blood vessel itself causes a longer-lasting vasoconstriction where platelets release a chemical vasoconstrictor called serotonin. This maintains vascular spasm long enough for the other haemostatic mechanisms to come into play.

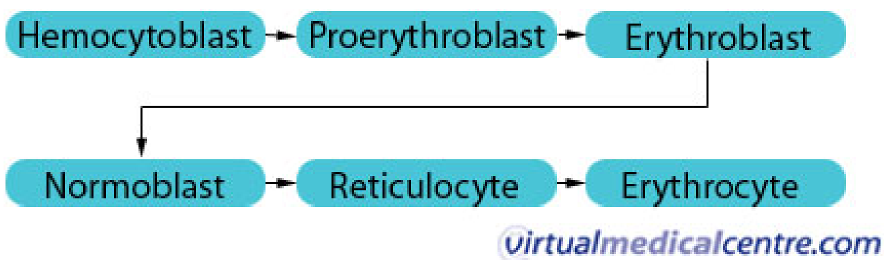
Platelet plug formation : Under normal conditions, platelets do not usually adhere to the wall of undamaged blood vessels, since the vessel lining tends to be smooth and coated with a platelet repellent. When a vessel is broken, platelets put out long spiny extensions to adhere to the vessel wall as well as to other platelets. These extensions then contract and draw the walls of the vessel together. The mass of platelets formed is known as a platelet plug, and can reduce or stop minor bleeding.

Coagulation : This is the last and most effective defence against bleeding. During bleeding, it is important for the blood to clot quickly to minimise blood loss, but it is equally important for blood not to clot in undamaged vessels. Coagulation is a very complex process aimed at clotting the blood at appropriate amounts. The objective of coagulation is to convert plasma protein fibrinogen into fibrin, which is a sticky protein that adheres to the walls of a vessel. Blood cells and platelets become stuck to fibrin, and the resulting mass helps to seal the break in the blood vessel. The forming of fibrin is what makes coagulation so complicated, as it involved numerous chemicals reactions and many coagulation factors.

Production of blood
Haemopoiesis

Haemopoiesis is the production of the formed elements of blood. Haemopoietic tissues refer to the tissues that produce blood. The earliest haemopoietic tissue to develop is the yolk sac, which also functions in the transfer of yolk nutrients of the embryo. In the foetus, blood cells are produced by the bone marrow, liver, spleen and thymus. This changes during and after birth. The liver stops producing blood cells around the time of birth, while the spleen stops producing them soon after birth but continues to produce lymphocytes for life. From infancy onwards, all formed elements are produced in the red bone marrow. Lymphocytes are additionally produced in lymphoid tissues and organs widely distributed in the body, including the thymus, tonsils, lymph nodes, spleen and patches of lymphoid tissues in the intestine.

Erythropoesis : Refers specifically to the production of erythrocytes or red blood cells (RBCs). These are formed through the following sequence of cell transformations:



Leukopoiesis : Refers to the production of leukocytes (WBCs). It begins when some types of haemocytoblasts differentiate into three types of committed cells:

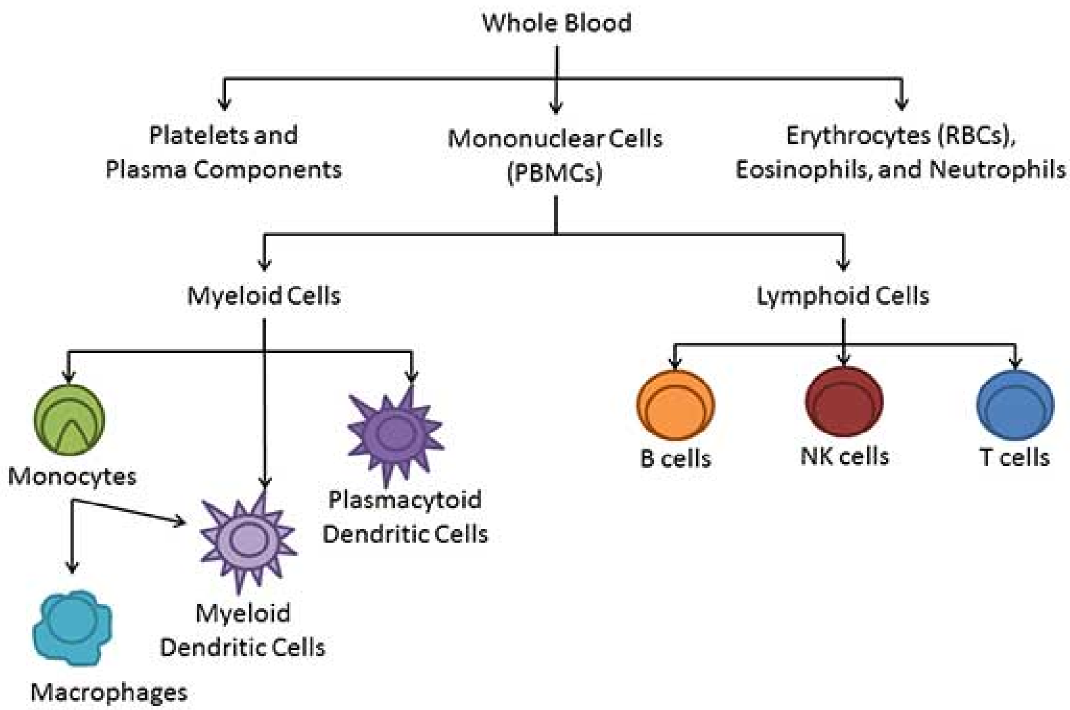
1. B progenitors, which are destined to become B lymphocytes
2. T progenitors, which become T lymphocytes
3. Granulocyte-macrophage colony-forming units, which become granulocytes and monocytes

Thrombopoiesis : Refers to the production of platelets in the blood, because platelets used to be called thrombocytes. This starts when a haemocytoblast develops receptors for the hormone thrombopoietin which is produced by the liver and kidneys. When these receptors are in place, the haemocytoblast becomes a committed cell called a megakaryoblast. This replicates its DNA, producing a large cell called a megakaryocyte, which breaks up into tiny fragments that enter the bloodstream. About 25-40% of the platelets are stored in the spleen and released as needed. The remainder circulate freely in the blood are live for about 10 days.

Ageing changes in the blood : The properties of blood change as we grow older. It is thought that these changes might contribute to the increased incident of clot formation and atherosclerosis in older people. Some of the most prominent findings on these changes include:

1. Rise in fibrinogen
2. Rise in blood viscosity
3. Rise in plasma viscosity
4. Increased red blood cell rigidity
5. Increased formation of fibrin degradation products
6. Earlier activation of the coagulation system

The increased level of plasma fibrinogen is thought to be due to either its rapid production or slower degradation. As age progresses, fibrinogen and plasma viscosity tend to be positively correlated, with the rise in plasma viscosity bing largely attributed to the rise in fibrinogen.



LEC. 7

The Evolutionary Theory

Evolution: refers to change through time as species become modified and diverge to produce multiple descendant species.

Evolution and natural selection are often conflated, but evolution is the historical occurrence of change, and natural selection is one mechanism in most cases the most important that can cause it. Recent years have seen a flowering in the field of evolutionary biology, and much has been learned about the causes and consequences of evolution. The two main pillars of our knowledge of evolution come from knowledge of the historical record of evolutionary change, deduced directly from the fossil record and inferred from examination of phylogeny, and from study of the process of evolutionary change, particularly the effect of natural selection. It is now apparent that when selection is strong, evolution can proceed considerably more rapidly than was generally envisioned by Darwin. As a result, scientists are realizing that it is possible to conduct evolutionary experiments in real time. Recent developments in many areas, including molecular and developmental biology, have greatly expanded our knowledge and reaffirmed evolution's central place in the understanding of biological diversity. Evolution Descent with modification; transformation of species through time, including both changes that occur within species, as well as the origin of new species.

Natural Selection: The process in which individuals with a particular trait tend to leave more offspring in the next generation than do individuals with a different trait.

Jean Baptiste de Lamarck (1744-1829): However, around 1800, some scientists began to wonder if species could change their form or 'transmute'. One of the early proponents of this idea was French scientist, Jean Baptiste de

Lamarck (1744-1829). If species were able to change their form over time, then how did it happen? Lamarck thought that if an animal acquired a characteristic during its lifetime, it could pass it onto its offspring. One of his favorite examples was the giraffe. In his view, the giraffe got its long neck through straining to reach the leaves on high branches, and this characteristic got passed down the generations. Most scientists of his day thought that Lamarck was wrong. At that time, only a few radical thinkers like Charles Darwin's grandfather, Erasmus, agreed that species could change over time.

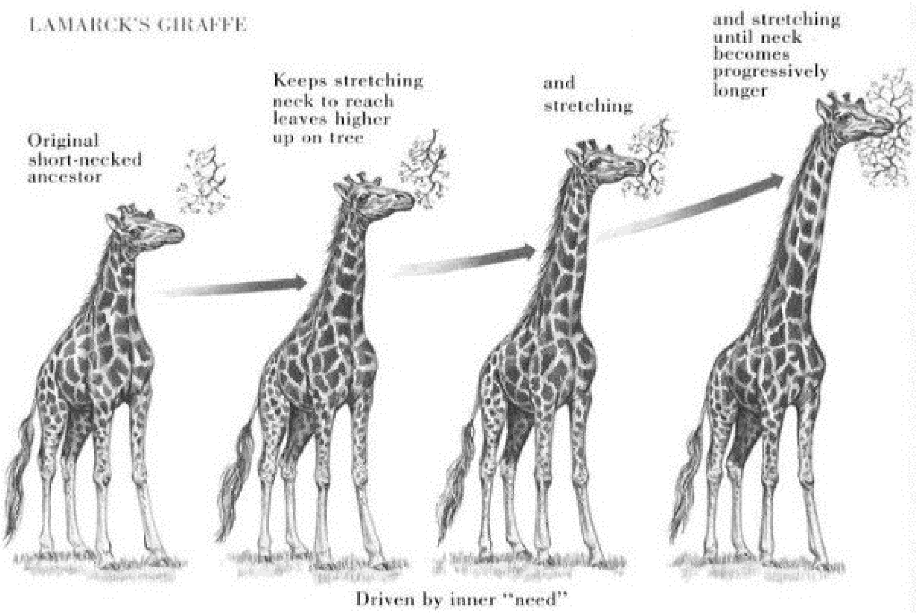


Figure 1: lamarckism

Darwin and the Theory of Evolution (1831-1836): The Linnean system was highly successful. So much so in fact, that in his publications, Linnaeus provided a survey of all the world Plants and animals as then known—about 7,700 species of plants and 4,400 species of animals. Linnaeus believed that God was the ordering principle behind this classification system, and that its structure somehow reflected the divine master plan. It was not until after the 1859 publication of Charles Darwin's "On the Origin of Species" that an alternative explanation was widely accepted. According to Darwin (and others), the ordering principle behind the Linnean system was instead a history of "common descent with modification": all life was believed to have evolved from one or a few common ancestors, and taxonomic groupings were simply manifestations of the tree-shaped evolutionary history connecting all present-day species. The theory of common descent did not in itself address the issue of *how* evolutionary change takes place, but it was able to explain a great deal of puzzling observations. For instance, similar species are often found in adjacent or overlapping geographical regions, and fossils often resemble (but are different from) present-day species living in the same location. These phenomena are easily explained as the result of divergence from a common ancestor, but have no clear cause if one assumes that each species has been created individually.

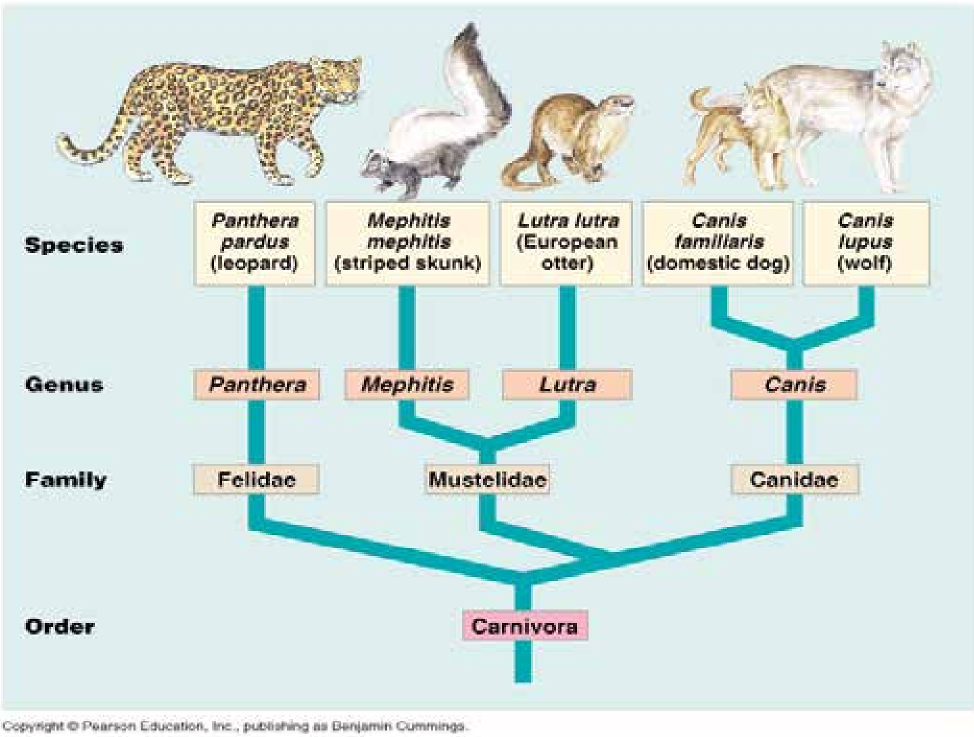


Figure 2.1: Linnean classification depicted in the form of a tree.

Natural Selection

The mechanism that Darwin proposed for evolutionary change is called natural selection. This is related to artificial selection the process of intentional (or unintentional) modification of a species through human actions which encourage the breeding of certain traits over others. Examples include crop plants, such as rice and wheat, which have been artificially selected for proteinrich seeds, and dairy cows which have been artificially selected for high milk yields. The wide variety of dog breeds is also a result of artificial selection (for hunting, herding, protection, companionship, and looks) and illustrates that rather significant changes can be obtained in a limited amount of time (a couple of thousand years in the case of dogs.) You should note that for artificial selection to be possible in the first place, there needs to be naturally occurring and heritable variation in traits of interest: it is only possible to breed high-protein grass sorts, if there are some grass plants that produce more seed protein than others, *and* if that trait is inherited by their descendants.

Darwin suggested that a similar process occurs naturally: individuals in the wild who possess characteristics that enhance their prospects for having offspring would undergo a similar process of change over time. Specifically, Darwin postulated that there are four properties of populations that together result in natural selection. These are:

1. Each generation more offspring is born than the environment can support - a fraction of offspring therefore dies before reaching reproductive age.
2. Individuals in a population vary in their characteristics.
3. Some of this variation is based on genetic differences.
4. Individuals with favorable characteristics have higher rates of survival and reproduction compared to individuals with less favorable characteristics. If all four postulates are true (and this is generally the case) then advantageous traits will automatically tend to spread in the population, which thereby changes gradually through time. This is natural selection. Let us consider, for instance, a population of butterflies that are preyed upon by birds. Now imagine that at some point a butterfly is born with a mutation that makes the butterfly more difficult to detect. This butterfly will obviously have a smaller risk of being eaten, and will consequently have an increased chance of surviving to produce offspring. A fraction of the fortunate butterfly’s offspring will inherit the advantageous

mutation, and in the next generation there will therefore be *several* butterflies with an improved chance of surviving to produce offspring. After a number of generations it is possible that all butterflies will have the mutation, which is then said to be “fixed”.

The Modern Synthesis

One problem with the theory described in “Origin of Species”, was that its genetic basis the nature of heritability was entirely unknown. In later editions of the book, Darwin proposed a model of inheritance where “hereditary substances” from the two parents merge physically in the offspring, so that the hereditary substance in the offspring will be intermediate in form (much like blending red and white paint results in pink paint). Such “blending inheritance” is in fact incompatible with evolution by natural selection, since the constant blending will quickly result in a completely homogeneous population from which the original, advantageous trait cannot be recovered (in the same way it is impossible to extract red paint from pink paint). Moreover, due to the much higher frequency of the original trait, the resulting homogeneous mixture will be very close to the original trait, and very far from the advantageous one. (In the paint analogy, if one single red butterfly is born at some point, then it will have to mate with a white butterfly resulting in pink offspring. The offspring will most probably mate with white butterflies and their offspring will be a *lighter* shade of pink, *etc.* , *etc.* In the long run, the population will end up being a very, very light shade of pink, instead of all red).

However, as shown by the Austrian monk Gregor Mendel, inheritance is in fact particulate in nature: parental genes do not merge physically; instead they are retained in their original form within the offspring, making it possible for the pure, advantageous trait to be recovered and, eventually, to be fixed by natural selection. Although Mendel published his work in 1866 it was not widely noticed until around 1900, and not until the 1930’s was Mendelian genetics fully integrated into evolutionary theory (the so-called “Modern Synthesis”). This led to the creation of the new science of population genetics which now forms the theoretical basis for all evolutionary biology.

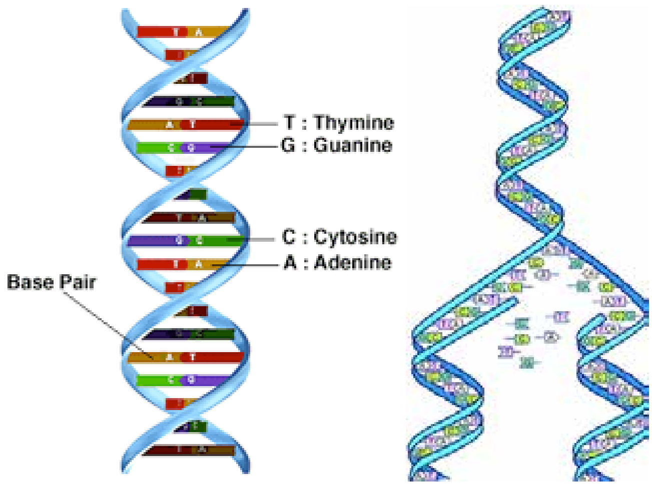
Mendelian Genetics

An organism can be either haploid or diploid. Haploid organisms have one complete set of genetic material (and therefore one copy of each gene), while diploid organisms have two complete sets of genetic material located on two complete sets of chromosomes (and therefore two copies of each gene). A particular gene in a haploid or diploid organism is said to occupy a particular locus (plural: loci). If different versions of a gene are present at a particular locus (*e.g.*, in different individuals of a population) then these are referred to as alleles of that gene. A diploid organism may have different alleles present on the two individual copies of a chromosome. If a diploid organism has the same allele on both chromosomal copies, then it is said to be homozygous for that allele (it is a homozygote). If it has two different alleles present at a locus, then it is said to be heterozygous for that allele (and is then referred to as a heterozygote). The total complement of alleles present in an organism is its genotype. Depending on the molecular nature of the different alleles present at a locus in a diploid organism, one allele may not make an impact on the organisms appearance (its phenotype). It is then said to be a recessive allele. An allele that is fully expressed in the organism’s phenotype is called dominant. In diploid organisms, one allele comes from the mother, one from the father. When diploid organisms reproduce sexually, it occurs via an intermediate, haploid sex cell called a gamete (the gamete is an egg cell if it is produced by a female, and a sperm cell if it is produced by a male). During gamete formation, genetic material from the two parents is mixed by the process of recombination.

Recombination is one stage of the special type of cell division termed meiosis which ultimately results in formation of the haploid gamete. At any one locus, there will (by necessity) be only one allele present in the gamete. The diploid cell formed by fusion of two gametes is called a zygote. Sexually reproducing organisms have life cycles that alter between a haploid stage and a diploid stage. In some organisms most of the life cycle is diploid (*e.g.*, humans, where only the sex cells are haploid), while the situation is reversed for other organisms (including some algae where the diploid zygote quickly undergoes meiosis to form new haploid cells). There are also organisms (*e.g.*, ferns) where the life cycle alternates between a haploid, multicellular generation and a diploid, multicellular generation. Asexual reproduction is seen in both haploid organisms (*e.g.*, bacteria) and diploid organisms (*e.g.*, yeast and some plants).

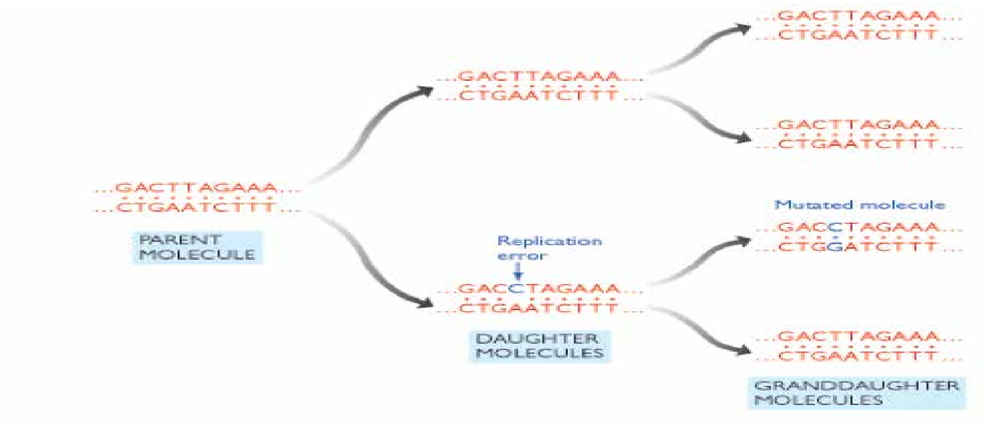
Mutation

As mentioned above, Darwin had no knowledge of the molecular basis for heredity. Consequently he did not understand the source of inherited variation, which forms the basis for all evolution by natural selection. Today, we know that hereditary information is stored in DNA molecules .



Hereditary information is stored in DNA molecules and replicated by copying each of the complementary strands

The structure of DNA (two complementary strands kept together by hydrogen bonded A-T and C-G basepairs) directly explains how this information is propagated from one generation to the next. Encoded within the string of nucleotides that make up the DNA of a cell is the information necessary for the production of catalytic and structural proteins and RNAs. However, the cellular machinery that copies DNA sometimes makes mistakes (Fig. 2).



Errors during DNA replication is a source of genetic variation

These mistakes alter the sequence of a gene. This is called a mutation. There are many kinds of mutations. **A point mutation** is a mutation in which one nucleotide is changed to another. Lengths of DNA can also be **deleted** or **inserted** in a gene; these are also **mutations**. Finally, genes or parts of genes can become inverted or duplicated. Typical rates of mutation are between 10−10 and 10−12 mutations per base pair of DNA per generation. Most mutations are thought to be neutral with regards to fitness. The majority of these are lost soon after they appear, and only a small percentage reach fixation (*i.e.*, increase to a frequency at or near one). Most mutations within coding sequences are probably deleterious. Mutations that result in amino acid substitutions can change the shape of a protein, potentially changing or eliminating its function. This can lead to inadequacies in biochemical pathways or interfere with the process of development.

Deleterious mutants are selected against but remain at low frequency in the gene pool. In diploids, a deleterious recessive mutant may increase in frequency due to drift. Selection cannot see it when it is masked by a dominant allele. Many disease causing alleles remain at low frequency for this reason. People who are carriers do not suffer the negative effect of the allele. Unless they mate with another carrier, the allele may simply continue to be passed on. Deleterious alleles also remain in populations at a low frequency due to a balance between recurrent mutation and selection. This is called the **mutation load**. Only a very small percentage of mutations are beneficial. The ratio of neutral to deleterious to beneficial mutations is unknown and probably varies with respect to details of the locus in question and environment. One example of a beneficial mutation comes from the mosquito Culex pipiens. In this organism, a gene that was involved with breaking down organophosphates "common insecticide ingredients" became duplicated. Progeny of the organism with this mutation quickly swept across the worldwide mosquito population. There are numerous examples of insects developing resistance to chemicals, especially DDT. And, most importantly, even though beneficial mutations occur much less frequently than detrimental ones, organisms with beneficial mutations thrive while organisms with ”bad” ones die out.

Speciation

Biologists recognize two types of speciation: allopatric and sympatric speciation. The two differ in geographical distribution of the populations in question.

Allopatric speciation is thought to be the most common form of speciation. It occurs when a population is split into two (or more) geographically isolated subdivisions that organisms cannot bridge.

Eventually, the two populations’ gene pools change independently until they could not interbreed even if they were brought back together. In other words, they have speciated.

Sympatric speciation occurs when two subpopulations become reproductively isolated without first becoming geographically isolated. Insects that live on a single host plant provide a model for sympatric speciation. If a group of insects switched host plants they would not breed with other members of their species still living on their former host plant. The two subpopulations could then diverge and speciate.

Biologists know little about the genetic mechanisms of speciation. Some think a series of small changes in each subdivision gradually lead to speciation. The founder effect could set the stage for relatively rapid speciation. **Alan Templeton** hypothesized that a few key genes could change and confer reproductive isolation. He called this a genetic transilience. **Lynn Margulis** thinks most speciation events are caused by changes in internal symbionts. Populations of organisms are very complicated. It is likely that there are many ways speciation can occur. Thus, all of the above ideas may be correct, each in different circumstances. Darwin’s book was titled ”The Origin of Species” despite the fact that he did not really address this question; over one hundred and fifty years later, how species originate is still largely a mystery.

LEC: 7

The Evolution of Animal Behavior: The Impact of the Darwinian Revolution

Animal behavior refers to the activities animals perform during their lifetime, including locomotion, feeding, breeding, capture of prey, avoidance of predators, and social behavior. Animals send signals, respond to signals or stimuli, carry out maintenance behavior, make choices, and interact with one another. This chapter examines some of these aspects of animal behavior.

FOUR APPROACHES TO ANIMAL BEHAVIOR

Naturalists and philosophers have observed animal behavior for centuries. Only in the last century, however, has there been significant progress in understanding this behavior. One approach to the study of animal behavior is **comparative psychology.**

Comparative psychologists emphasize studies of the genetic, neural, and hormonal bases of animal behavior. Psychologists conduct experimental studies, in both laboratory and field settings, that relate to animal learning and to the development of behavior. They explore how animals receive information, and the processes and nature of the behavior patterns constituting the animals' responses to their surroundings.

Ethology (Gr. *ethologica*, depicting character) is the study of animal behavior that focuses on evolution and the natural environment. The leaders of this approach have been **Konrad Lorenz**, **Niko Tinbergen, and Karl von Frisch**, who were awarded the Nobel Prize in Physiology or Medicine in 1973. Ethologists observe the behavior of a variety of animals in their natural environments and study the behavior of closely related species to consider the evolution and origin of certain behavior patterns. Ethologists rarely deal with learning and are interested instead in animal communication, mating behavior, and social behavior.

Behavioral ecology emphasizes the ecological aspects of animal behavior. Predator-prey interactions, foraging strategies, reproductive strategies, habitat selection, intraspecific and interspecific competition, and social behavior are topics of interest to behavioral ecologists.

Sociobiology is the study of the evolution of social behavior. It combines many aspects of ethology and behavioral ecology. Sociobiologists emphasize the importance of natural selection on individuals living in groups.

PROXIMATE AND ULTIMATE CAUSES

Behavioral scientists frequently ask, “Why do animals do what they do?” More immediate ecological and physiological causes of behavior, such as eating to satisfy hunger, are called proximate causes. **A**nother level of causation in behavior occurs on the evolutionary time scale and is that of ultimate causes. For example, a display not only attracts a mate, but also increases the likelihood of passing genetic information to the next generation.

ANTHROPOMORPHISM

Anthropomorphism (Gr. *anthropos,* man **_** *morphe,* form) is the application of human characteristics to anything not human. In observations of animals, assigning human feelings to animal behavior is not likely to be accurate, especially with invertebrate animals. Consider the example of placing an earthworm on a fishhook. Does the fishhook hurt the earthworm, causing it to writhe in pain? Both of the descriptive words, hurt and pain, are based on human experience and conscious awareness. A better explanation that reduces the anthropomorphic interpretation is that placing the earthworm on the hook stimulates certain receptors which generate nerve impulses that travel along reflex neural circuits. The impulses stimulate muscles that allow the worm to wriggle in an attempt to escape from the hook. This explanation more closely describes what has been observed and does not attempt to suggest what the earthworm “feels.”

DEVELOPMENT OF BEHAVIOR

Development of a normal behavior pattern requires the genes that code for the formation of the structures and organs involved in the behavior. For example, in vertebrates, normal locomotion movements will not occur without proper development and growth of the limbs. This process requires some interaction with the animal’s environment because proper nourishment, water balance, and other factors must be maintained for normal development.

MATURATION

Some behavior patterns appear only after a specific developmental stage or time. During **maturation,** performance of the behavior pattern improves as parts of the nervous system and other structures complete development. A classic example is tail movement in frog embryos that are near hatching. While still in the egg membranes, they start moving their tails as they would if they were swimming, and movement coordination improves with time. These improved movements are due to maturation, not practice or experience.

INSTINCT/LEARNING INTERACTIONS

In recent years, many behavioral scientists have concluded that both instinct and learning are important in animal behavior. Interaction of inherited (i.e., instinctive) and learned components shapes a number of behavior patterns. For example, the nut-cracking behavior of squirrels. Squirrels gnaw and pry to open a nut. Inexperienced squirrels are not efficient; they gnaw and pry at random on the nut. Experienced squirrels, however, gnaw a furrow on the broad side, then wedge their lower incisors into the furrow and crack the nut open.

IMPRINTING

During **imprinting,** a young animal develops an attachment toward another animal or object. The attachment usually forms only during a specific critical period soon after hatching or birth and is not reversible. Imprinting is a rapid learning process that apparently occurs without reinforcement. **Konrad Lorenz** (1903–1989) conducted experiments with geese in which he allowed the geese to imprint on him. The goslings followed him as though he was their mother. In nature, many species of birds in which the young follow the parent soon after birth use imprinting so that the young can identify with or recognize their parent(s). They can then be led successfully to the nest or to water. Both visual and auditory cues are important in imprinting systems.

LEARNING

Learning produces changes in the behavior of an individual that are due to experience. Learning is adaptive because it allows an animal to respond quickly to changes in its environment. Once an animal learns something, its behavioral choices increase. An animal's ability to learn may correlate with the predictability of certain characteristics of its environment. Where certain changes in the habitat occur regularly and are predictable, the animal may rapidly respond to a stimulus with an unmodified instinctive behavior. An animal would not necessarily benefit from learning in this situation. However, where certain environmental changes are unpredictable and cannot be anticipated, an animal may modify its behavioral responses through learning or experience. This modification is adaptive because it allows an animal to not only change its response to fit a given situation, but also to improve its response to subsequent, similar environmental changes. Several different categories of learning have been identified, ranging from habituation (the simplest form of learning) to insight learning (the most complex form) that involves cognitive processes.

HABITUATION

Habituation is the simplest and perhaps most common type of behavior in many different animals. Habituation involves a waning or decrease in response to repeated or continuous stimulation. Simply, an animal learns not to respond to stimuli in its environment that are constant and probably relatively unimportant. By habituating to unimportant stimuli, an animal conserves energy and time that are better spent on other important functions. For example, after time, birds learn to ignore scarecrows that previously caused them to flee. Squirrels in a city park adjust to the movements of humans and automobiles. If the stimulus is withheld, then the response returns rapidly. Habituation does not involve any conditioning. Habituation is believed to be controlled through the central nervous system and should be distinguished from sensory adaptation. Sensory adaptation involves repeated stimulation of receptors until they stop responding. For example, if you enter a room with an unusual odor, your olfactory sense organs soon stop responding to these odors.

CLASSICAL CONDITIONING

Classical conditioning is a type of learning documented by Russian physiologist, Ivan Pavlov (1849–1936). In his classic experiment on the salivary reflex in dogs, Pavlov presented food right after the sound of a bell (figure 34.2). After a number of such presentations, the dogs were conditioned—they associated the sound of the bell with food. It was then possible to elicit the dog's usual response to food—salivation—with just the sound of the bell. The food was a positive reinforcement for salivating behavior, but responses could also be conditioned using negative reinforcement. Classical conditioning is very common in the animal kingdom. For example, birds learn to avoid certain brightly colored caterpillars that have a noxious taste. Because birds associate the color pattern with the bad taste, they may also avoid animals with a similar color pattern.

INSTRUMENTAL CONDITIONING

In **instrumental conditioning** (also known as trial-and-error learning), the animal learns while carrying out certain searching actions, such as walking and moving about. For example, if the animal finds food during these activities, the food reinforces the behavior, and the animal associates the reward with the behavior. Ifthis association is repeated several times, the animal learns that the behavior leads to reinforcement. A classic example of instrumental conditioning is that of a rat in a "Skinner box," developed by B. F. Skinner (1904–1990), a prominent psychologist. When placed in the box, the rat begins to explore. It moves all about the box and, by accident, eventually presses a lever and is rewarded with a food pellet. Because food rewards are provided each time the rat presses the lever, the rat associates the reward with the behavior. Through repetition, the rat learns to press the lever right away to receive the reward. In this type of learning, the animal is instrumental in providing its own reinforcement. In instrumental conditioning, providing the reinforcement (food) whenever the animal comes close to the lever and continuing to supply reinforcement when the animal touches the lever "shapes" the behavior. Finally, the animal learns to press the lever to obtain food. Young animals' attempts to learn new motor patterns often involve instrumental conditioning. A young bird learning to fly or a young mammal at play may improve coordination of certain movements or behavior patterns by practice during these activities.

LATENT LEARNING

Latent learning, sometimes called exploratory learning, involves making associations without immediate reinforcement or reward. The reward is not obvious. An animal is apparently motivated, however, to learn about its surroundings. For example, if a rat is placed in a maze that has no food or reward, it explores the maze, although rather slowly. If food or another reward is provided, the rat quickly runs the maze. Apparently, previous learning of the maze had occurred but remained latent, or hidden, until an obvious reinforcement was provided. Latent learning allows an animal to learn about its surroundings as it explores. Knowledge about an animal's home area may be important for its survival, perhaps enabling it to escape from a predator or capture prey.

INSIGHT LEARNING

In **insight learning,** the animal uses cognitive or mental processes to associate experiences and solve problems. The classic example is the work of Wolfgang Kohler (1887–1967) on chimpanzees that were trained to use tools to obtain food rewards (figure 34.3*a*). One chimpanzee was given some bamboo poles that could be joined to make a longer pole, and some bananas were hung from the ceiling. Once the chimp formed the longer pole, it used the pole to knock the bananas to the cage floor. Kohler believed that the animal used insight learning to get the bananas. In addition, Jane van Lawick-Goodall (1934–) has observed chimpanzees in the wild using tools to accomplish various tasks. For example, they use crumpled leaves as a sponge for drinking water (figure 34.3*b*).

CONTROL OF BEHAVIOR

Internal mechanisms (proximate causes) that include the nervous system and the endocrine system regulate animal behavior. These systems receive information from the external environment via the sensory organs, process that information involving the brain and the endocrine glands, and initiate responses in terms of motor patterns or changes in the operations of internal organs. In general, the nervous system mediates more specific and rapid responses, while the endocrine system monitors slower, more general responses.

NERVOUS SYSTEM

See lecture 5 provides details of the structure of the nervous systems found in animals, and how the various parts function. The manner in which blowflies feed illustrates how the nervous system mediates behavior. The blowfly has special sensory receptors on its feet. As the fly moves around and encounters different substrates, the receptors can detect the presence of certain sugars. The information from the feet is processed in the fly's nervous system and results in the extension of the proboscis, which, in turn, stimulates the oral taste receptors, and the fly begins to feed. How does the fly know when to stop feeding? Without some feedback mechanism, the fly could continue to consume the sugar solution until it burst! Receptors in the blowfly's foregut (the first stop for the incoming food in the fly's digestive system), send a message to the fly's brain when the foregut swells sufficiently. The message is relayed to the nerves that control the feeding response, halting further intake of the sugar solution. Another example of how the nervous system regulates behavior concerns the control of aggressive behavior in rhesus monkeys. In one study, researchers identified the dominant male monkey in a group of four to six animals and then surgically implanted electrodes into the monkey's brain regions involved in either eliciting or inhibiting aggressive behavior. Mild electrical stimulation to the monkey's brain produced either aggressive or passive behaviors, depending on which electrode sent the message. The other monkeys in the group also could be trained to press a lever whenever the dominant monkey became aggressive. Pressing the lever sent a message to the brain of the dominant male that inhibited his aggression.

ENDOCRINE SYSTEM

In animals, the endocrine system is closely interrelated with the nervous system. (see lecture 5).

Organizational effects of hormones occur during development and are particularly important for sex differentiation. These effects involve the presence of hormones and critical time periods during which the developmental pathways for specific brain regions and developing gonadal tissues are influenced to become either female- or malelike. The major effect is such that at about the middle of gestation in most male mammalian embryos (e.g., guinea pigs, monkeys), the testes produce a surge of male hormone (testosterone). This organizes both other developing tissues and certain regions of the brain. In the absence of a testosterone surge, female embryos develop more femalelike characteristics in terms of external anatomy and brain regions important for sex differences. Genes normally turn on the production and release of testosterone in the tissues of the developing animal, but sometimes, the testosterone comes from an external source. In cattle, a female embryo is masculinized if her twin is a male fetus. When his system turns on and releases testosterone during gestation, some of that hormone crosses over to affect the developing female. The result is a freemartin, a sterile heifer that exhibits a number of malelike behavior patterns. In humans, some hormone treatments that used to be given to pregnant women who were in danger of losing their fetus resulted in masculinization of female embryos because the hormones injected as a medical treatment were converted to and acted like testosterone within the embryo.

Activational effects of hormones occur when an external stimulus triggers a hormonally mediated response by the organism. Many male fishes change color patterns when their territory boundary is threatened; the color change is a prelude to potentially aggressive behavior to defend the territory. Many animals, including domestic cats, roosters, and mice, lose their aggressive fighting ability after castration (removal of the gonads). The gonads are the source of testosterone, which stimulates particular brain receptors to produce aggression.

COMMUNICATION

Communication is the transfer of information from one animal to another. It requires a sender and receiver that are mutually adapted to each other. The animal acting as the sender must send a clear signal to the receiver. Communication can occur within species (intraspecific) or between species (interspecific). Intraspecific communication in animals is especially important for reproductive success. Examples of interspecific communication include warning signals, such as the rattle of a rattlesnake’s tail and the skunk’s presentation of its hindquarters and tail. Animals use a variety of modalities for communication, including visual, auditory, tactile, and chemical signals. Natural selection has influenced the characteristics of a signal system. Animals have evolved combinations of signals that may be more effective than any single signal.

VISUAL COMMUNICATION

Visual communication is important to many animals because a large amount of information can be conveyed in a short time. Most animals (e.g., cephalopod molluscs, arthropods, and most vertebrates other than mammals) with well-developed eyes have color vision. Many fishes, reptiles, and birds exhibit brilliant color patterns that usually have a signaling function. **M**ost mammals have plain, darker colors and lack color vision because they are nocturnal, as were their probable ancestors–nocturnal insectivores. Primates are a notable exception in that they have both color vision and colorful displays. A visual signal may be present at all times, as are the bright facial markings of a male mandrill. The signal may be hidden or located on a less exposed part of an animal's body, and then suddenly presented. Some lizards, such as green anoles, can actually change their color through activities of pigment cells in the skin. Visual signals have some disadvantages in that various objects in the environment may block the line of sight, and/or the signals may be difficult to see over a long distance. Also, the signals are usually not effective at night and may be detected by predators.

ACOUSTIC COMMUNICATION

Arthropods and vertebrates commonly use acoustic or sound communication. These animals must expend energy to produce sounds, but sounds can be used during night or day. Sound waves also have the advantage of traveling around objects, and may be produced or received while an animal is in the open or concealed. Sounds can carry a large amount of information because of the many possible variations in frequency, duration, volume, and tone. Acoustic communication systems are closely adapted to the environmental conditions in which they are used and the function of the signal. For example, tropical forest birds produce low frequency calls that pass easily through dense vegetation. Many primates in tropical forests produce sounds that travel over long distances. Other examples include the calls of territorial birds that sit on a high perch to deliver the signal more effectively and the alarm calls of many small species of birds. Some of the more complex acoustic signals that have been studied are birdsong and human speech.

TACTILE COMMUNICATION

Tactile communication refers to the communication between animals in physical contact with each other. The antennae of many invertebrates and the touch receptors in the skin of vertebrates function in tactile communication. Some examples of tactile communication are birds preening the feathers of other birds and primates grooming each other.

CHEMICAL COMMUNICATION

Chemical communication is another common mode of communication. Unicellular organisms with chemoreceptors can recognize members of their own species. Chemical signals are welldeveloped in insects, fishes, salamanders, and mammals. Advantages of chemical signals are that they (1) usually provide a simple message that can last for hours or days; (2) are effective night or day; (3) can pass around objects; (4) may be transported over long distances; and (5) take relatively little energy to produce. Disadvantages of chemical signals are that they cannot be changed quickly and are slow to act. Chemicals that are synthesized by one organism and that affect the behavior of another member of the same species are called **pheromones.** Olfactory receptors in the receiving animal usually detect chemical signals. Many animals mark their territories by depositing odors that act as chemical signals to other animals of the same species. For example, many male mammals mark specific points in their territories with pheromones that warn other males of their presence in the area. The same pheromones may also attract females that are in breeding condition.

Differences in the chemical structure of pheromones may be directly related to their function. Pheromones used for marking territories and attracting mates usually last longer because of their higher molecular weights. Airborne signals have lower molecular weights and disperse easily. For example, the sex attractant pheromones of female moths who are ready to mate are airborne, and males several kilometers away can detect them.

BEHAVIORAL ECOLOGY

Behavioral ecologists investigate how animals find their way about (orientation and navigation), how they find a place to live (habitat selection), what foods they select to eat (foraging behavior), and the ways in which behavior can influence population biology.

HABITAT SELECTION

Habitat selection refers to the animal’s choice of a place to live. Two types of factors affect where animals of a particular species live. **F**irst are the animal’s physiological tolerance limits, which are determined by the species evolutionary history and may involve temperature, humidity, water salinity, and other environmental parameters. Within those constraints, a second set of psychological factors are important: Animals make choices about where to reside based on available food resources, nest sites, lack of predators, and past experience. For example, woodland deer mice may be constrained to live in forests rather than fields because they cannot tolerate the high temperatures in the field environment. Within the forest, they may prefer (choose to live in) areas with larger trees (e.g., oak or beech) because these trees provide more food in the form of acorns and beechnuts, in addition to better shelter and more nest sites.

FORAGING BEHAVIOR

All animals must consume food to survive. For most organisms, a large portion of their daily routine involves finding and consuming food. The process of locating food resources is called **foraging behavior.** Animals face the following choices:

1. What items should be included in the diet?

2. Given that food is not often distributed evenly in the environment, but occurs in patches or clumps, what path should an animal take between patches, and how should it locate new patches of food?

3. As the food in a patch is depleted, when should the animal depart from that location and seek another patch of food? Hummingbirds and various species of bees that visit clumps of flowers to obtain nectar must make each of these decisions. Owls that forage for small rodents in different habitats, including fields and forests, must make similar decisions. Although animals do not calculate their personal energy budgets as they forage, there are energy costs and gains in finding and consuming food. These considerations include energy needed to search for food, energy used to pursue or handle the food, and energy required to digest the food. If the animal is to survive, then the energy gain from digesting a particular set of food items must exceed the costs. Thus, a praying mantis must expend energy to locate a moth, to strike the moth, to remove the moth's wings, to consume the moth's body, and finally, to digest the meal. The mantis will survive if the energy derived from digesting the moth is greater than these costs. This is particularly true if extra energy is needed for searching for a mate or laying eggs.

Specialists and Generalists

Some animals are **specialists** with respect to diet and habitat selection. Evolution has resulted in these animals being very efficient at utilizing a particular resource. The koala, an Australian marsupial, eats the leaves of only certain species of eucalyptus trees. Its digestive system is adapted to derive energy from the leaves of these trees more efficiently than are the digestive systems of other animals. Although being a specialist means successfully exploiting a particular resource, it is also risky. If a plant disease invades and kills trees of the eucalyptus species that form the koalas' diet, koalas may not be able to survive. At the other end of the continuum are **generalists,** animals capable of eating a variety of foods or living in a variety of habitats. These animals can survive under a wide range of conditions. Humans are a good example of a generalist species. So, tooUnited States a century ago and now living in almost every available type of habitat. The disadvantage for generalists is that almost everywhere they eat and live, they face competition from other organisms, something that specialists often avoid.

SOCIAL BEHAVIOR

Social behavior typically refers to any interactions among members of the same species, but it also applies to animals of different species, excluding predator-prey interactions.

LIVING IN GROUPS

Animal populations are often organized into groups. A group of animals may form an aggregation for some simple purpose, such as feeding, drinking, or mating. Several *Drosophila* flies on a piece of rotting fruit is an example of an aggregation. A true animal **society** is a stable group of individuals of the same species that maintains a cooperative social relationship. This association typically extends beyond the level of mating and taking care of young. **S**ocial behavior has evolved independently in many species of animals; invertebrates as well as vertebrates have complex social organizations. One major benefit of belonging to a group may be that it offers protection against predators (figure 34.4). There is safety in numbers, and predator detection may be enhanced by having several group members on alert to warn against an intruder. Also, cooperative hunting and capture of prey increase the feeding efficiency of predators. Living in social groups is also advantageous in some instances due to the ability to gain protection from the elements (e.g., huddling together in cold weather) and during the processes of mate finding and rearing of young. In many species, most notably the social insects, living in groups has resulted in the evolutionary division of labor, with specific individuals performing specialized tasks (e.g., defense, food procurement, feeding of young). A disadvantage of group living may be competition for resources. Other disadvantages include the diseases and parasites that may spread more rapidly in group-living animals, and interference between individuals with regard to reproduction and rearing of young. The value of group living depends on the species and behaviors involved.

AGONISTIC BEHAVIOR, TERRITORIES, AND DOMINANCE HIERARCHIES

A society of animals usually has some maintenance of social structure and spacing of group members. Agonistic behavior, in which one animal is aggressive or attacks another animal, which responds by either returning the aggression or submitting, is often responsible for these patterns. In rare cases, agonistic behavior is lethal, but usually, animals are not killed or even severely injured. In many species, males vent much of their aggression in the form of threat displays. Displays typically involve signals that warn other males of an intention to defend an area or territory. Although agonistic behavior may seem antisocial, it maintains the social order. It is especially important in the maintenance of territories and dominance hierarchies. A territorial animal uses agonistic behavior to defend a site or area against certain other individuals. The site is known as the animal's **territory,** and competing individuals are excluded from it. Many male birds and mammals occupy a breeding territory for part of the year. A male actively defends his area against other males, so that he can attract a female and court her without interference from other males. In addition to being a location for attracting a mate and rearing young, territories may contain a food supply or provide shelter to avoid predators and unfavorable climate. In **dominance hierarchies,** a group of animals is organized so that some members of the group have greater access to resources, such as food or mates, than do others. Those near the top of the order have first choice of resources, whereas those near the bottom go last and may do without if resources are in short supply. An example of a dominance hierarchy is the "pecking order" of chickens in a pen. When chickens are placed together, they fight among themselves until a linear hierarchy of dominance is established. Higher-ranked chickens are among the first to eat and may peck lower-ranked chickens. Once the hierarchy is set, peaceful coexistence is possible. Occasional fights will occur if a bird tries to move up in the order. Dominance hierarchies exist in many vertebrate groups, the most common being in the form of linear relationships, although triangular relationships may form. In baboons, the strongest male is usually highest in the rank order. But sometimes, older males may form coalitions to subdue a stronger male and lead the troop.

ALTRUISM

In **altruism,** an individual gives up or sacrifices some of its own reproductive potential to benefit another individual. For example, one individual of a group of crows gives an alarm call to warn other individuals of the group of an approaching predator, even though the call may attract the predator to the sender of the signal. How did such behavior evolve? Are normal natural selection processes at work here? To be successful in a biological sense, an animal must produce as many young as possible, thereby passing its genes to succeeding generations. However, genes can be passed on by aiding a relative and its young because they probably share some genes. In terms of reproductive potential or output, an individual may theoretically pass more genes to the next generation by aiding the survival of relatives than it would rearing its own young. A well-known example of altruism occurs in societies of hymenopteran insects, such as honeybees. The male drones are haploid, and the female workers and queen are diploid, resulting in a genetic asymmetry. Diploid workers share, on the average, threefourths of their genes with their full sisters. If they reproduced, they would share only half of their genes with hypothetical offspring. Thus, female honeybees may have more genes in common with their sisters than they would with their own offspring. The workers may pass more genes to the next generation by helping their mother produce more full sisters, some of whom may become reproductive queens, than if they produce their own young.

William Hamilton (1936–) proposed the idea of **kin selection** to explain how selection acting on related animals can affect the fitness of an individual. In this way, a gene that a particular individual carries may pass to the next generation through a related animal. An individual's fitness is therefore based on the genes it passes on, as well as those common genes its relatives pass on. A genetically based tendency to be altruistic could therefore be passed on by the individual carrying it or by a relative who also carries it. Obviously, for kin selection to work, individuals of a group must be able to identify relatives, as can small groups of primates and social insects.

LEC.8

Brief History of Life

Biologists studying evolution do a variety of things: population geneticists study the process as it is occurring; systematists seek to determine relationships between species and paleontologists seek to uncover details of the unfolding of life in the past. Discerning these details is often difficult, but hypotheses can be made and tested as new evidence comes to light. This section should be viewed as the best hypothesis scientists have as to the history of the planet. The material here ranges from some issues that are fairly certain to some topics that are nothing more than informed speculation. For some points there are opposing hypotheses – I have tried to compile a consensus picture. In general, the more remote the time, the more likely the story is incomplete or in error. The first replicating molecules were most likely RNA. In laboratory studies it has been shown that some RNA sequences have catalytic capabilities.

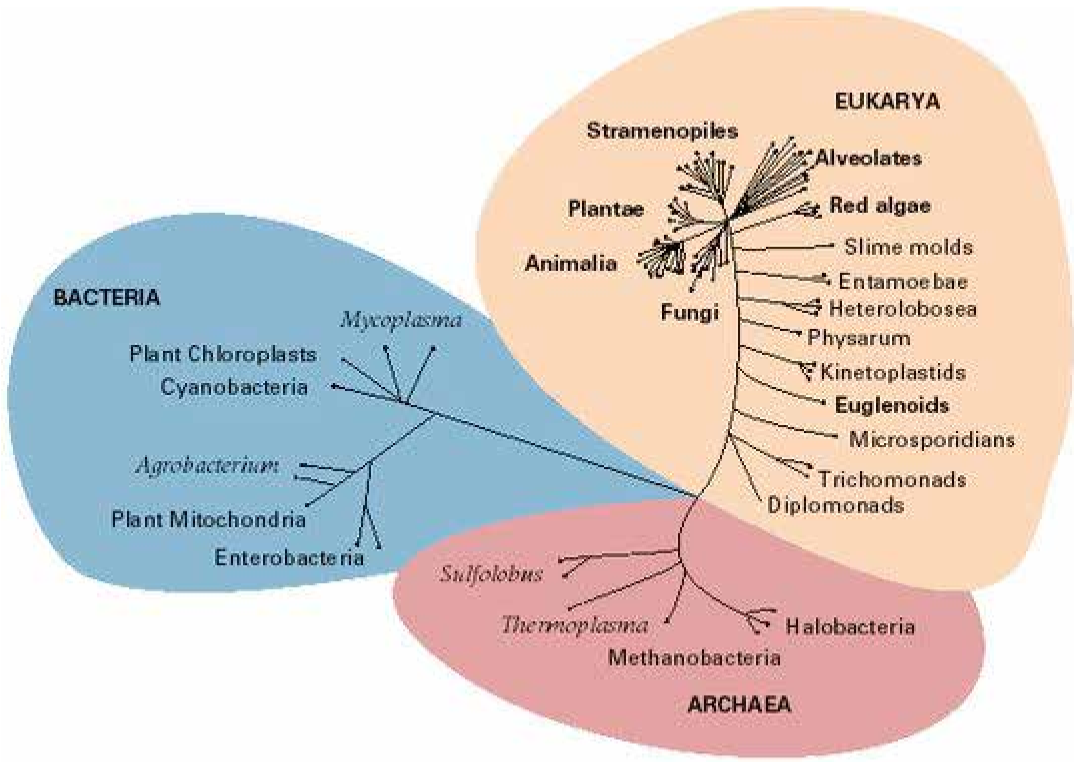


Figure1 : Three domains of life: prokaryotes (”ordinary” bacteria), archaea (thermophilic, methanogenic and halophilic bacteria), and eukaryotes (including both unicellular and multicellular organisms).

Most importantly, certain RNA sequences act as polymerases – enzymes that form strands of RNA from its monomers. This process of self replication is the crucial step in the formation of life. This is called the RNA world hypothesis. The common ancestor of all life probably used RNA as its genetic material. This ancestor gave rise to three major lineages of life (Fig. 1). These are: the prokaryotes (”ordinary” bacteria), archaebacteria (thermophilic, methanogenic and halophilic bacteria) and eukaryotes. Eukaryotes include protists (single celled organisms like amoebas and diatoms and a few multicellular forms such as kelp), fungi (including mushrooms and yeast), plants and animals. Eukaryotes and archaebacteria are the two most closely related of the three. The process of translation (making protein from the instructions on a messenger RNA template) is similar in these lineages, but the organization of the genome and transcription (making messenger RNA from a DNA template) is very different in prokaryotes than in eukaryotes and archaebacteria. Scientists interpret this to mean that the common ancestor was RNA based; it gave rise to two lineages that independently formed a DNA genome and hence independently evolved mechanisms to transcribe DNA into RNA.

Figure 2 : Modern stromatolites in Shark Bay, Western Australia.

The first cells must have been anaerobic because there was no oxygen in the atmosphere. In addition, they were probably thermophilic (”heat-loving”) and fermentative. Rocks as old as 3.5 billion years old have yielded prokaryotic fossils. Specifically, some rocks from Australia called the Warrawoona series give evidence of bacterial communities organized into structures called stromatolites. Fossils like these have subsequently been found all over the world. These mats of bacteria still form today in a few locales (for example, Shark Bay Australia; Fig. 2). Bacteria are the only life forms found in the rocks for a long, long time –eukaryotes (protists) appear about 1.5 billion years ago and fungi-like things appear about 900 million years ago (0.9 billion years ago). Photosynthesis evolved around 3.4 billion years ago. Photosynthesis is a process that allows organisms to harness sunlight to manufacture sugar from simpler precursors. The first photosystem to evolve, PSI, uses light to convert carbon dioxide ($CO2$) and hydrogen sulfide ($H2S$) to glucose. This process releases sulfur as a waste product. About a billion years later, a second photosystem (PSII) evolved, probably from a duplication of the first photosystem. Organisms with PSII use both photosystems in conjunction to convert carbon dioxide ($CO2$) and water ($H2O$) into glucose. This process releases oxygen as a waste product. Anoxygenic (or $H2S$) photosynthesis, using PSI, is seen in living purple and green bacteria. Oxygenic (or $H2O$) photosynthesis, using PSI and PSII, takes place in cyanobacteria. Cyanobacteria are closely related to and hence probably evolved from purple bacterial ancestors. Green bacteria are an outgroup. Since oxygenic bacteria are a lineage within a cluster of anoxygenic lineages, scientists infer that PSI evolved first. This also corroborates with geological evidence. Green plants and algae also use both photosystems. In these organisms, photosynthesis occurs in organelles (membrane bound structures within the cell) called chloroplasts. These organelles originated as free living bacteria related to the cyanobacteria that were engulfed by ur-eukaryotes and eventually entered into an endosymbiotic relationship. This endosymbiotic theory of eukaryotic organelles was championed by Lynn Margulis. Originally controversial, this theory is now accepted. One key line of evidence in support of this idea came when the DNA inside chloroplasts was sequenced – the gene sequences were more similar to free-living cyanobacteria sequences than to sequences from the plants the chloroplasts resided in. After the advent of photosystem II, oxygen levels increased. Dissolved oxygen in the oceans increased as well as atmospheric oxygen. This is sometimes called the oxygen holocaust. Oxygen is a very good electron acceptor and can be very damaging to living organisms. Many bacteria are anaerobic and die almost immediately in the presence of oxygen. Other organisms, like animals, have special ways to avoid cellular damage due to this element (and in fact require it to live.) Initially, when oxygen began building up in the environment, it was neutralized by materials already present. Iron, which existed in high concentrations in the sea was oxidized and precipitated. Evidence of this can be seen in banded iron formations from this time, layers of iron deposited on the sea floor. As one geologist put it, ”the world rusted.” Eventually, it grew to high enough concentrations to be dangerous to living things. In response, many species went extinct, some continued (and still continue) to thrive in anaerobic microenvironments and several lineages independently evolved oxygen respiration.

The purple bacteria evolved oxygen respiration by reversing the flow of molecules through their carbon fixing pathways and modifying their electron transport chains. Purple bacteria also enabled the eukaryotic lineage to become aerobic. Eukaryotic cells have membrane bound organelles called mitochondria that take care of respiration for the cell. These are endosymbionts like chloroplasts. Mitochondria formed this symbiotic relationship very early in eukaryotic history, all but a few groups of eukaryotic cells have mitochondria. Later, a few lineages picked up chloroplasts. Chloroplasts have multiple origins.

Red algae picked up ur-chloroplasts from the cyanobacterial lineage. Green algae, the group plants evolved from, picked up different urchloroplasts from a prochlorophyte, a lineage closely related to cyanobacteria.

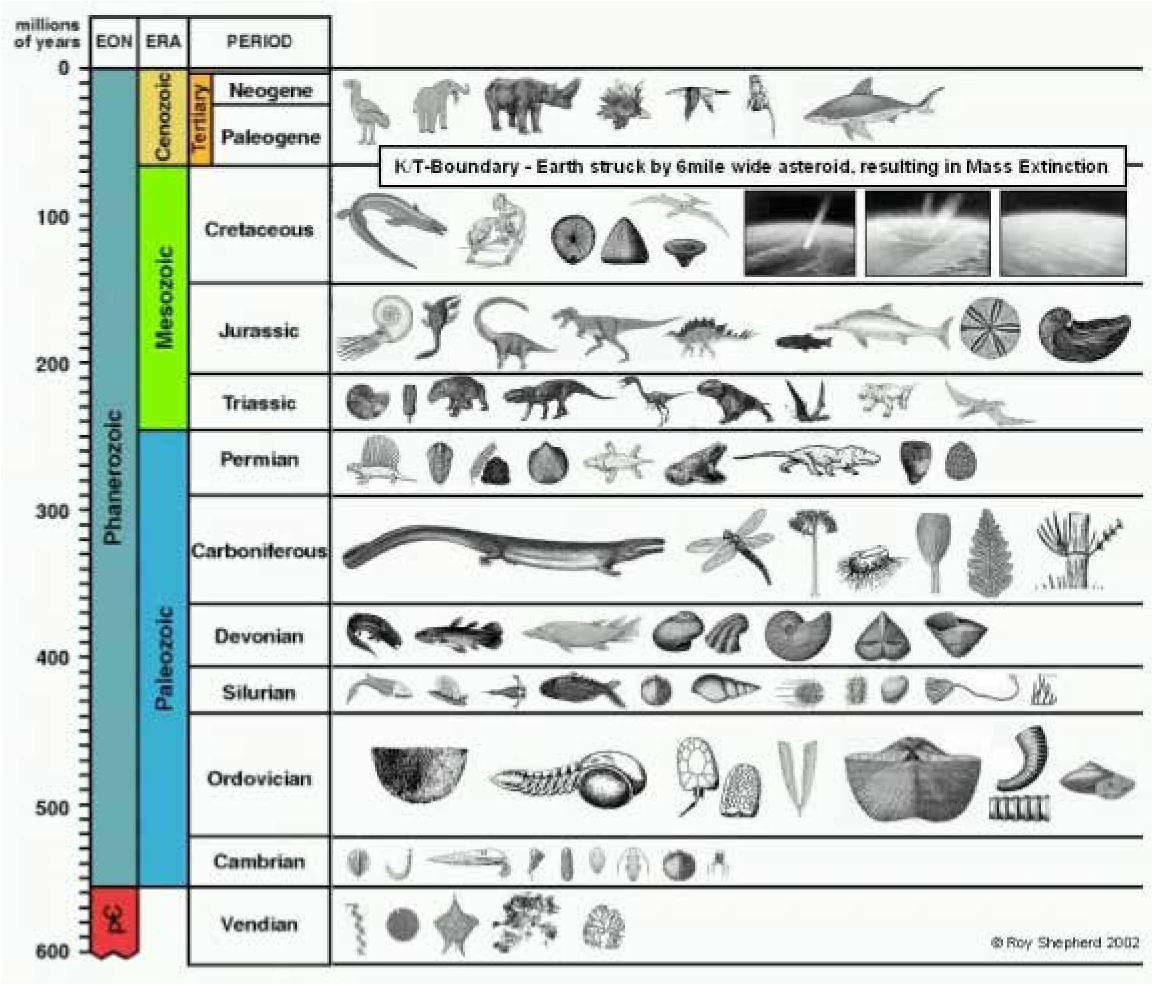


Figure 3 : Overview of geological periods and examples of life forms existing at various time points.

Animals start appearing prior to the Cambrian, about 600 million years ago (see Fig. 3 for an overview of geological periods and examples of life forms existing at various time-points). The first animals dating from just before the Cambrian were found in rocks near Adelaide, Australia. They are called the Ediacarian fauna and have subsequently been found in other locales as well. It is unclear if these forms have any surviving descendants. Some look a bit like jellyfish, sea anemones and the like; others resemble earthworms. The Cambrian ’explosion’ may have been a result of higher oxygen concentrations enabling larger organisms with higher metabolisms to evolve. Or it might be due to the spreading of shallow seas at that time providing a variety of new niches. In any case, the radiation produced a wide variety of animals. Plants evolved from ancient green algae over 400 million years ago. Both groups use chlorophyll a and b as photosynthetic pigments. In addition, plants and green algae are the only groups to store starch in their chloroplasts. Plants and fungi (in symbiosis) invaded the land about 400 million years ago. The first plants were moss-like and required moist environments to survive. Later, evolutionary developments such as a waxy cuticle allowed some plants to exploit more inland environments. Still mosses lack true vascular tissue to transport fluids and nutrients. This limits their size since these must diffuse through the plant. Vascular plants evolved from mosses. The first vascular land plant known is Cooksonia, a spiky, branching, leafless structure. At the same time, or shortly thereafter, arthropods followed plants onto the land. The first land animals known are myriapods – centipedes and millipedes.

Vertebrates moved onto the land by the Devonian period, about 380 million years ago. The recently discovered *Tiktaalik* illustrates the transition from sea to land (Fig. 4). *Tiktaalik* lived approximately 375 million years ago. Paleontologists suggest that it was an intermediate form between fish such as Panderichthys, which lived about 385 million years ago, and early tetrapods such as Acanthostega and Ichthyostega, which lived about 365 million years ago.

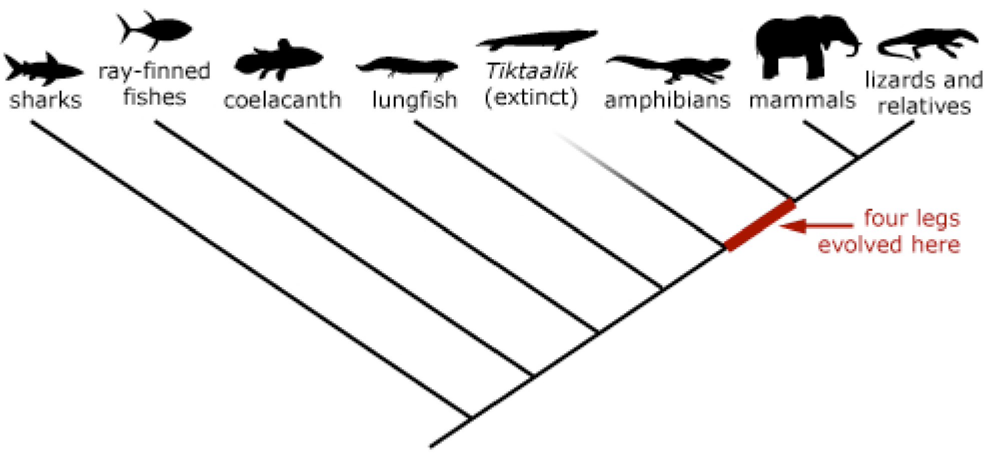
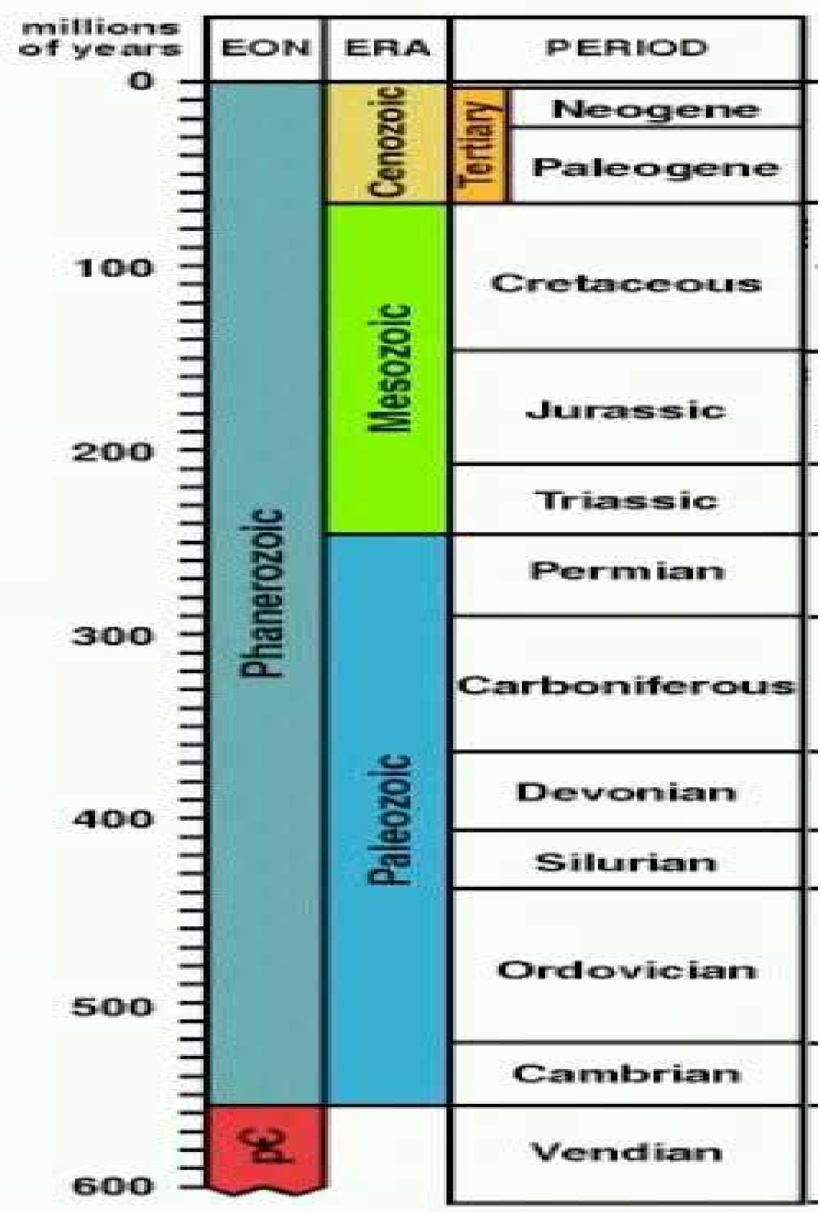


Figure 4: ***Tiktaalik is a transitional form between fish and land-dwelling tetrapods living about 375 million years ago. Its fins show the beginnings of elbow and wristlike features.***

Tiktaalik generally had the characteristics of a lobe-finned fish, but with front fins featuring arm-like skeletal structures more akin to a crocodile, including a shoulder, elbow, and wrist. The rear fins and tail have not yet been found. It has rows of sharp teeth of a predator fish, and its neck was able to move independently of its body, which is not possible in other fish. The animal also had a flat skull resembling a crocodile's; eyes on top of its head, suggesting it spent a lot of time looking up; a neck and ribs similar to those of tetrapods, with the latter being used to support its body and aid in breathing via lungs; well developed jaws suitable for catching prey; and a small gill slit called a spiracle that, in more derived animals, became an ear. The incomplete specimens found thus far suggest animals that ranged from 4 to 9 feet (1.2 to 2.75 meters) in length.

The Permian extinction was the largest extinction in history. It happened about 250 million years ago. The last of the Cambrian Fauna went extinct. The Paleozoic fauna took a nose dive from about 300 families to about 50. It is estimated that 96% of all species (50% of all Families) met their end. Following this event, the Modern fauna, which had been slowly expanding since the Ordovician, took over. The Modern fauna includes fish, bivalves, gastropods and crabs. These were barely affected by the Permian extinction. The Modern fauna subsequently increased to over 600 marine families at present. The Paleozoic fauna held steady at about 100 families. A second extinction event shortly following the Permian kept animal diversity low for awhile. During the Carboniferous (the period just prior to the Permian) and in the Permian the landscape was dominated by ferns and their relatives. After the Permian extinction, gymnosperms (*e.g.*, pines) became more abundant. Gymnosperms had evolved seeds, from seedless fern ancestors, which helped their ability to disperse. Gymnosperms also evolved pollen, encased sperm which allowed for more outcrossing.



Geological periods

Angiosperms (flowering plants) evolved from gymnosperms about 245-202 million years ago. Two key adaptations allowed them to displace gymnosperms as the dominant fauna – fruits and flowers. Fruits allow for animal-based seed dispersal and deposition with plenty of fertilizer. Flower evolved to facilitate animal, especially insect, based pollen dispersal. Petals are modified leaves. Angiosperms currently dominate the flora of the world – over three fourths of all living plants are angiosperms. Dinosaurs evolved from archosaur reptiles, their closest living relatives are crocodiles. One modification that may have been a key to their success was the evolution of an upright stance. This allowed for continual locomotion. In addition, dinosaurs evolved to be warm-blooded. Warmbloodedness allows an increase in the vigor of movements in erect organisms. Birds evolved from sauriscian dinosaurs. Cladistically, birds are dinosaurs. The transitional fossil Archaeopteryx has a mixture of reptilian and avian features. Insects evolved from primitive segmented arthropods. The mouth parts of insects are modified legs. Insects are closely related to annelids. Insects dominate the fauna of the world. Over half of all named species are insects. One third of this number are beetles. The end of the Cretaceous, about 65 million years ago, is marked by aminor mass extinction. This extinction most likely was the result of a large meteor impact that eliminated over half of all species on the planet. This extinction marked the demise of all the lineages of dinosaurs save the birds. Up to this point mammals were confined to nocturnal, insectivorous niches. Once the dinosaurs were out of the picture, they diversified. Morgonucudon, a contemporary of dinosaurs, is an example of one of the first mammals.

Extinction of dinosaurs 65 mio years ago

Mammals evolved from therapsid reptiles. The finback reptile Diametrodon is an example of a therapsid. One of the most successful lineages of mammals is, of course, humans. Humans are neotenous apes. Neoteny is a process which leads to an organism reaching reproductive capacity in its juvenile form. The primary line of evidence for this is the similarities between young apes and adult humans.

Louis Bolk compiled a list of 25 features shared between adult humans and juvenile apes, including facial morphology, high relative brain weight, absence of brow ridges and cranial crests. The earth has been in a state of flux for 4 billion years. Across this time, the abundance of different lineages varies wildly. New lineages evolve and radiate out across the face of the planet, pushing older lineages to extinction, or relictual existence in protected refugia or suitable microhabitats. Organisms modify their environments. This can be disastrous, as in the case of the oxygen holocaust. However, environmental modification can be the impetus for further evolutionary change. Overall, diversity has increased since the beginning of life. This increase is, however, interrupted numerous times by mass extinctions. Diversity appears to have hit an all-time high just prior to the appearance of humans. As the human population has increased, biological diversity has decreased at an ever-increasing pace. The correlation is probably causal.