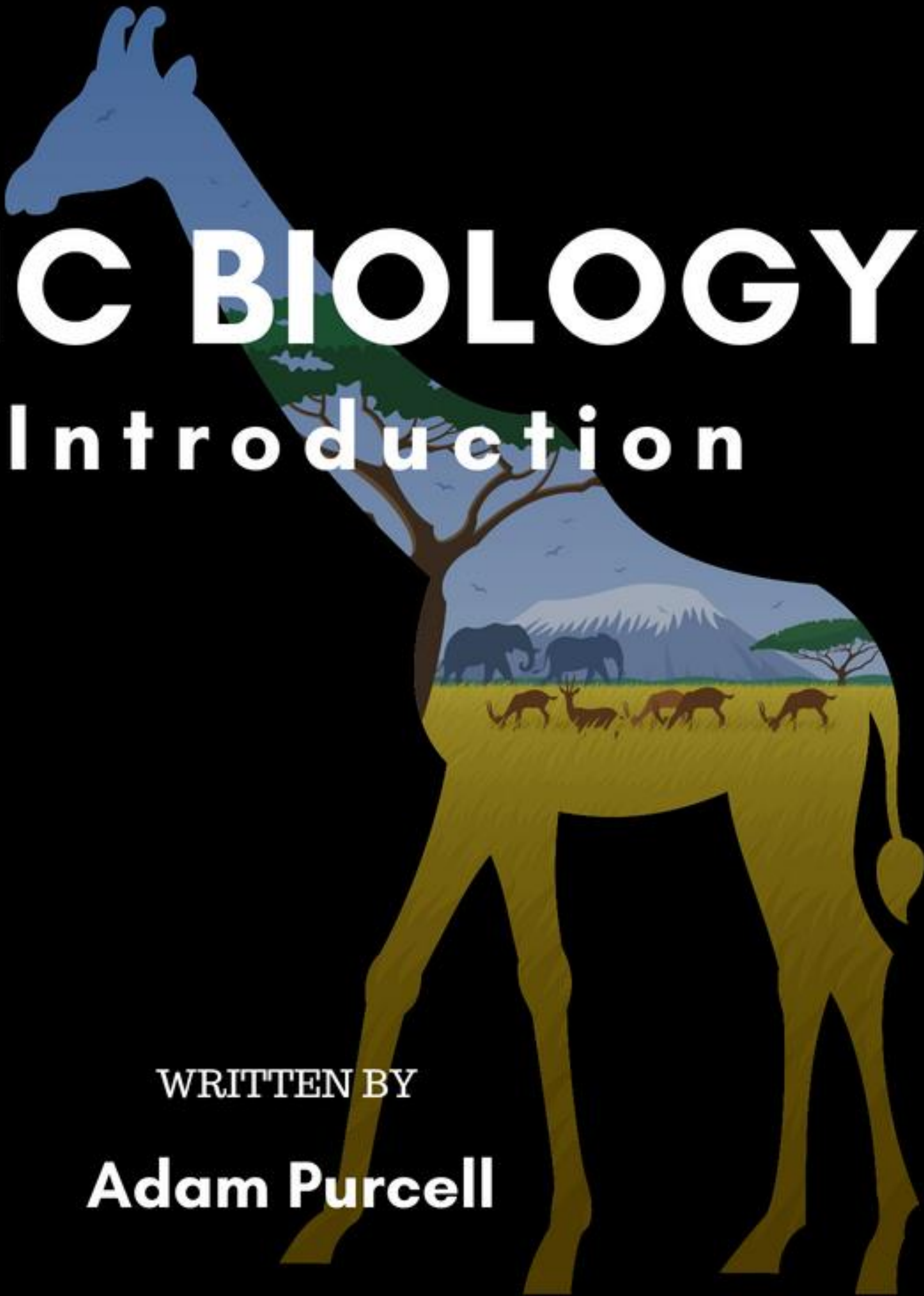
Knowledge on life

# BASIC BIOLOGY

## An Introduction

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# Chapter 1: Introduction to biology

Earth's most incredible feature is the presence of life. The probability of life existing is so small that it is remarkable to exist at all, yet we take it for granted every day. We are surrounded by life everywhere we turn. Plants grow in our gardens, paddocks and forests; birds sit on our power lines; spiders inhabit the corners of our homes; ants find their way into our kitchens; bacteria help us to digest food in our stomachs and intestines. In many ways, life defines this planet, yet so many of us know so little about it.

Biology is the field of science that investigates all aspects of life. The life of a human being – biology. Learning about microscopic bacteria, algae, or fungi – biology. Studying how rain and sunlight influences the growth of a plant, this is biology. This field of science incorporates anything and everything imaginable that is related to life on Earth.

Through biology, we can gain an understanding of the life that Earth has supported for 4 billion years. From microscopic bacteria in your stomach to active, intelligent animals and giant trees. There is an incredible array of life existing on this planet and learning about it can change the way you see and think about the world that you live in.

Our understanding and knowledge of the living world is continuously changing. There are, however, a few key principles that define how life is organized on Earth. These are:

1. Cells are the basic unit of life.
2. Genes are the basic units for the passing of traits from parent to offspring.
3. Evolution by natural selection is the process that has led to the great diversity of species on Earth.
4. Living things maintain the environment within their cells and bodies.
5. Living things can acquire and transform energy.

Each of these five universal truths of biology describes an important aspect of life on Earth and are the focus of this first chapter. The first three principles identify the importance of cells, genes, and evolution to life on Earth. The last two principles are mostly concerned with how organisms interact with their environment, both internally and externally.

Biology is a massive field of study. This is only the introduction of an introductory book and we will barely scratch the surface of everything there is to learn but we will cover the basics and discuss the information that everyone should know about the life on Earth. It is virtually impossible to know everything about life on Earth but everyone must start somewhere and this is as good a place as any.

Biology can be challenging. With complicated lingo, names, and processes, there are plenty of difficult topics to tackle. I myself dropped biology in my last year of high school because I found math and chemistry easier. In the end, my passion and appreciation of the natural world brought me back to biology. My advice, don’t give up, be patient with challenging topics, and work through issues one step at a time because, if you can stick at it, you will be rewarded with an enlightened understanding of your surroundings and gain a new perspective of the world around you.

## Glossary

Biochemistry – a field of biology that studies the molecules and chemical reactions within organisms

DNA – a type of molecule found in cells that contains genetic information. DNA is short for deoxyribonucleic acid

Habitat – the place or environment where an organism or multiple organisms live

Heredity – the passing of genetic material from parents to offspring

Membrane – a thin and pliable boundary, lining, or barrier

Microscopic – only visible with the use of a microscope

Molecule – a group of atoms bonded together

Organism – a living thing

Photosynthesis – the process of making sugars and other nutrients using carbon dioxide, the sun's energy, and water

Physiology – a field of biology that studies how organisms function

Respiration – the exchange of gases between an organism and the environment

## Life is Earth's greatest phenomenon

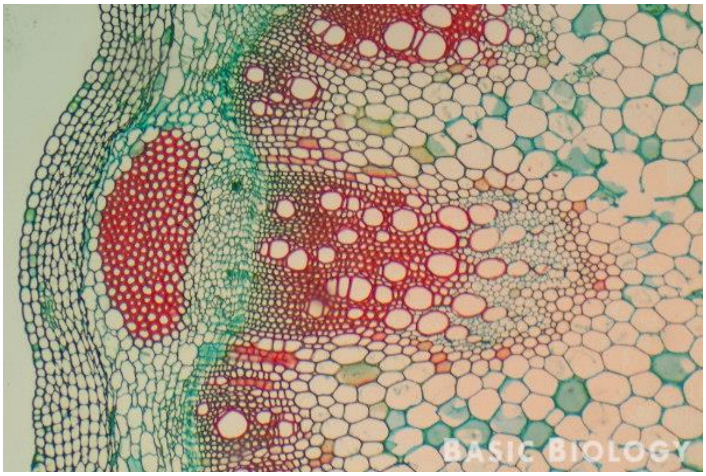
Of the trillions of planets known to science, only one is so far known to support life, Earth. Life makes Earth unique within our solar system and probably our galaxy. Chances are that there are other life-supporting planets in the universe but they are incredibly rare and the presence of life on Earth makes this planet very special.


Living things are known as organisms. To be considered 'alive', an entity must be able to perform seven processes referred to as the seven processes of life. The ability to perform these seven processes is what separates organisms from non-living objects such as water and rocks. The seven processes are movement, respiration, sensitivity, growth, reproduction, the release of wastes (i.e. excretion), and the consumption of food (nutrition). Another collective name commonly used for the seven processes of life is MRS GREN, an acronym of the first letters of each process.

Life has evolved into an incredible array of shapes and forms. Humans belong to the most advanced group of organisms, the animals. Other higher-level organisms include plants and fungi. More primitive life forms include microscopic groups such as bacteria and archaea. Viruses are an unusual group because they are unable to reproduce without the use of a host. As such, viruses are classed by some biologists to be living and by others to be not.

## Cells are the basic unit of life

A single cell has the potential to sustain life and is the simplest structure capable of doing so. Many livings things, such as bacteria, yeasts, algae, and archaea, live their entire lives as a single cell. Animals, including humans,




begin their lives as a single cell which reproduces into two cells. Those two cells reproduce into four cells, then eight cells, and so on until incredibly intricate animals are created from trillions of microscopic cells that can all be traced back to that single original cell.

Cells are typically divided into two main categories: prokaryotic cells and eukaryotic cells. Prokaryotic cells are found in two groups of microscopic organisms (bacteria and archaea) and have never evolved into multi-celled organisms. Eukaryotic cells are found in more advanced organisms such as animals, plants, and fungi. The main difference between the two types of cells is that eukaryotic cells have a nucleus and organelles. The nucleus of a eukaryotic cell contains the cell's DNA. Organelles are specialized structures within eukaryotic cells that perform specific functions such as photosynthesis and protein production. In prokaryotic cells, the DNA isn't encapsulated within a nucleus and organelles are absent.

## Genes are the basic units for the passing of traits from parents to offspring

Genes are the basic unit for heredity. A single gene provides the genetic information for the expression of a single trait. A complete set of genes provides all the necessary information to keep an organism functioning and alive. When organisms reproduce, the information from genes is passed from parent to offspring. The genes that are passed from parent to offspring then provide the information for cells to keep the new organism alive. Genes are the reason why children look similar to their parents.

## Evolution by natural selection explains the great diversity of species on Earth

The traits of an organism determine how well they are adapted to certain environmental conditions. Different traits provide advantages in some habitats and disadvantages in other habitats. Traits that provide advantages make an individual better adapted to their environment. Natural selection is a process that occurs because individuals that are better adapted to their environment have a greater chance of surviving and reproducing. Because traits are passed from parents to offspring and individuals with beneficial traits are more likely to reproduce, beneficial traits spread through populations over multiple generations. Over time, this gradual change in traits in different environments due to natural selection leads to the evolution of new species.

With the help of genetic mutations, evolution has driven the development of species capable of thriving in almost any environment on Earth. Evolution is visible in all aspects of life and the collection of evidence supporting the theory of evolution has become undeniable. Evolution by natural selection has been sculpting life for over 4 billion years and is the cornerstone of modern biology.

## Living things maintain the environment within their cells and bodies

Homeostasis is the act of maintaining the internal environment within an organism's cells. Cells function most efficiently in a certain range of conditions and as the environment changes around them, they constantly work to keep their internal environment in an optimal condition. Cells are working to maintain factors such as the concentrations of water, salt, sugars, the temperature within the cell, and oxygen concentrations.

## Living things can acquire and transform energy

The final letter of MRS GREN stands for nutrition and all living things require nutrients to survive. Organisms collect nutrients from the environment and use the energy provided by nutrients to fuel the processes of life such as movement, growth, and reproduction. For organisms to use the energy of the nutrients they collect, however, they are required to transform the energy into usable cellular energy. When organisms collect nutrients from the environment, the energy within them is typically stored in large molecules. Organisms breakdown large molecules, through processes such as digestion and respiration, and transform the energy into a form that is usable by their cells.


## Fields of biology

Biology is a huge field of science. Considering that there are millions of different animal species, hundreds of thousands of plant species, and millions of species of microorganisms, it is understandable that biology is split into various different fields of study. Many have been around for hundreds of years whilst others are far newer and are often developing very rapidly with new technology.

Biology can broadly be separated into three areas of study:

1. Research into the microscopic world of life
2. The study of large organisms
3. The study of the interactions between organisms and their environment

Research into the microscopic world of life includes studying topics such as cells, genetics, microorganisms, physiology, biochemistry. Many biologists focus their study on large organisms like plants and animals. The study of animals is known as zoology and the study of plants is known as botany. The life of an organism is greatly influenced by other organisms and the environment that it lives in. Many biologists study these interactions in a field of study known as ecology.

Areas of study such as evolution, ecology, and genetics are themselves very broad topics and contain many specializations within each field. For example, an ecologist, who looks at how organisms interact with each other and the environment, might specialize in marine ecology, population ecology, plant ecology, or freshwater ecology.

As biology is such a broad field of study, the work from one biologist to another may be completely different. An agriculturalist, for example, who is interested in the production of crops, will focus on very different topics to that of an ethologist, who studies the behavior of animals. To be a well-rounded biologist, however, it is a good idea to have an understanding of the basics of the broad fields within biology.


# Chapter 2: Evolution

Evolution is the process that has led to the existence of Earth's huge diversity of organisms. Over billions of years, life has evolved from a single organism into millions of different species. By understanding that evolution is a core process to life on Earth, we can recognize the relatedness of all organisms and the influence of Earth's environment in sculpting the organisms found here.

Evolution has provided answers to many important questions about life on Earth. Questions such as why do so many different species exist on Earth? And why are the species of different regions so different to one another? Or why do different species in different areas but similar environments have similar traits? We can now confidently answer these questions and so many more because we understand the process of evolution.

## Glossary

DNA strand – a single long, linear molecule of DNA

Tissue – a collection of cells that work together to perform specific functions

Organ – a collection of tissues that work together to perform specific functions

Sperm cell – a reproductive cell of a male with half of a complete set of DNA

Egg cell – a reproductive cell of a female with half of a complete set of DNA

## Natural selection

Evolution works through a process known as natural selection. Natural selection is driven by three factors: the traits of an organism, the environment, and reproduction. The process of natural selection works like this:

Different traits are advantageous and disadvantageous in different environments. The individuals who possess the traits that provide the greatest advantage in an environment are more likely to survive and reproduce. During reproduction, traits are passed from parents to offspring. Because the individuals with the best traits are most likely to reproduce, beneficial traits are more likely to be passed down to the next generation. Over multiple generations, beneficial traits will continue to be passed down to more and more offspring and will eventually be spread through a population. If two populations of the same species are separated in two different environments, where different traits provide advantages, over enough generations, the natural selection of different traits will lead to the evolution of two distinct species.

A trait is any physical, behavioral or physiological characteristic of an organism. Physical traits include things such as height, hair, scales, eyes, fins, fingers, tails and so on. Behavioral traits include any behavior such as crying, scent marking, eating, playing, sleeping, etc. Physiological traits are an organism’s internal characteristics such as the inner workings of the stomach, intestines, heart, liver, lungs, gills, brain, and reproductive organs.

The traits of an organism are determined by their genes and the environment. An organism receives their genes from their parent or parents. Depending on the environment that they are exposed to, the genes will be expressed as different traits. As natural selection is selecting for beneficial traits in different environments, it is ultimately selecting for beneficial genes and it is really the evolution of genes over multiple generations which leads to the evolution of new species.

An organism’s environment is shaped by a range of factors such as temperature, rain, and competition. As these factors change, the amount of benefit gained from certain genes and traits change. If, for example, an environment got warmer, some genes and traits, such as producing sweat, become more beneficial for survival and/or reproduction while other genes and traits, such as storing fat, may have negative effects on an individual’s survival and/or reproduction. If the opposite was to happen and an environment got colder, the reverse would be true for these traits. In the images below, the green moths are likely to have a camoflage advantage over the orange moths in the green foliage, whereas, the orange moths are better camoflaged in the desert environment.


Over time, the organisms in different environments begin to evolve into different species because different adaptations are being selected for by natural selection. For example, on land, animals often have long, thin limbs to help them move around. In water, however, long limbs are not very helpful for swimming and animals are often streamlined with short, flattened fins.



## Genetic mutations

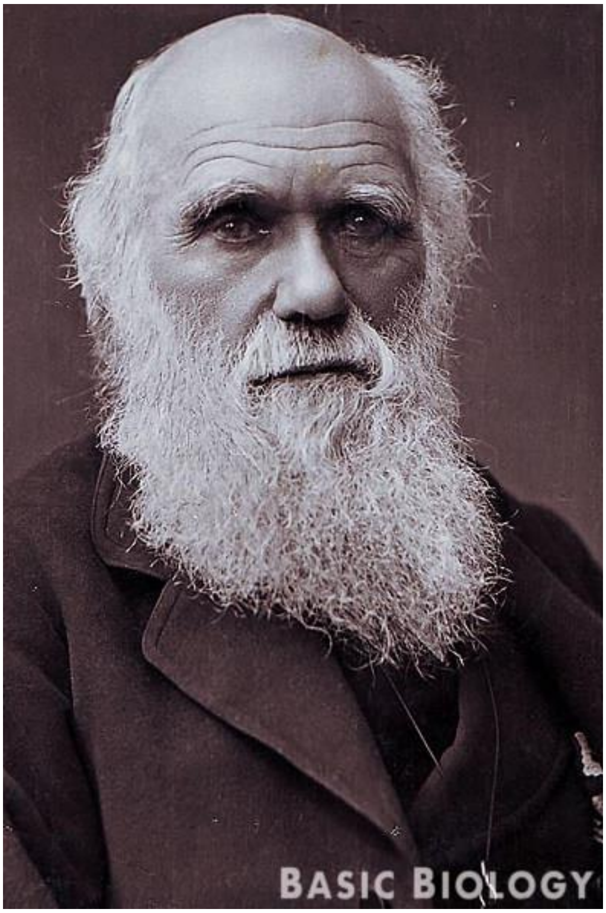
The only way new traits, and eventually new species, can evolve is through the creation of new genes. The most common way for new genes to form is through mutations in genetic material. Mutations can occur when the genetic material of a cell is being replicated.

Every time that a cell divides into two cells, it must replicate its DNA. If an error occurs during DNA replication, a mutant form of the DNA can be created. If an error is not corrected and remains present in the new DNA strand, then every time that mutant strand of DNA is replicated, the error will be replicated. If an error occurs in sperm or egg cells, the mutation can be passed to the next generation.

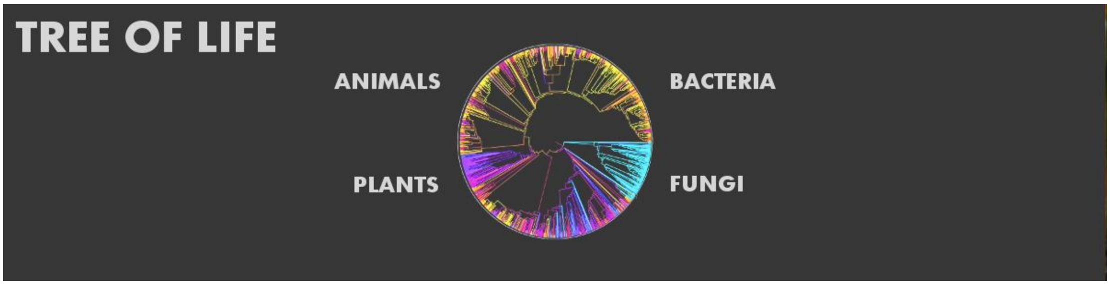
Most mutations are detrimental or have no effect on a cell's genetic information but some are beneficial and allow a cell to function better. Beneficial mutations improve an organism's survival and chances of reproducing. When organisms with beneficial mutations reproduce, their mutations can be passed on to their offspring who will also benefit from the mutation. Offspring with the beneficial mutation will have a better chance of reproducing than other individuals that don't possess the mutation.

## Charles Darwin

Charles Darwin is arguably the most significant biologist of all-time and can be credited with developing and presenting the theory of evolution by natural selection. In 1859, he published a book called ‘On the origin of species by means of natural selection’ which comprised 30 years of research and dramatically changed our understanding of the history of life on Earth. At the time of publishing his book, the common belief within society was that the natural history of the Earth was in line with the Old Testament which declared the Earth to be four thousand years old and that all life was created on a single day.




To shift the deeply rooted beliefs of society requires something truly special. Charles Darwin was that something. Nearly 150 years have passed since Darwin first published his theory and the quantity of evidence to support his work is staggering. Subsequently, much of the present day biological research is performed with the theory of evolution as its foundation.




# Chapter 3: Tree of life

As mentioned in the previous chapter, all living things have evolved from a single common ancestor. The tree of life is a family tree that traces the evolutionary relationships of all organisms back to that common ancestor. It has been approximately 4 billion years since that single common ancestor lived on Earth and since then evolution has produced an incredible range of species.

Working out the evolutionary paths of life from a single species to the millions that exist today, plus the many millions that are extinct, is a mammoth task. Many scientists devote their entire lives to working out life's evolutionary relationships. This is one field of biology that is really benefiting from ongoing advances in technology.

The tree of life is composed of many forked branches with each branch representing a unique group of organisms. If two branches are close together, the organisms that the two branches represent are closely related. The first and largest branches near the base of the tree of life represent the three domains of life. The branches of each domain splits into many more branches.

## Glossary

Bacterium – a single organism from the domain Bacteria

Cell wall – a layer surrounding the cell membrane of many organism's cells

Domain – the broadest grouping of organisms separating all organisms into three groups

Decomposing – the rotting or decaying of an organism

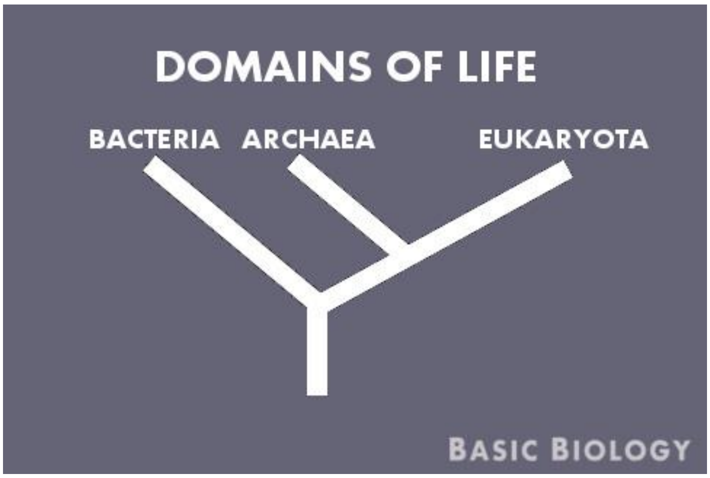
Lipids – a type of molecule that includes fats, oils, waxes, and some hormones

Kingdom – the second tier of categorization for organisms along the tree of life. Each domain has several kingdoms

Multicellular – containing more than one cell

## All life is categorized into three groups called Domains

All living and extinct creatures belong to one of three domains: Bacteria, Archaea, or Eukaryota. The domains Bacteria and Archaea contain only microscopic organisms whereas Eukaryota includes large organisms, such as plants and animals, as well as many microscopic organisms.




The organisms of the three domains are separated by differences in their cells. Eukaryotes are distinct from bacteria and archaea because they have cells which contain a nucleus and organelles. Bacteria and archaea have prokaryotic cells without a nucleus or organelles. Amongst other differences, bacteria and archaea cells differ in the structure of their cell walls and cell membranes.

## Bacteria

Organisms from the domain Bacteria first evolved more than 3.5 billion years ago. Since then, bacteria have evolved into a vast number of different species and this ancient group of organisms are still found almost everywhere on Earth. They can be found in the skin and guts of animals, drifting in oceanic water, in soil, in the air that we breathe, and on the walls of your home. Bacteria are everywhere and they're prolific. In a single handful of soil, there is more bacteria cells than humans that have ever existed.

All bacteria are microscopic, single-celled organisms. Although they are tiny, bacteria play a significant role within Earth's ecosystems and the health of human beings. Two examples of their importance include helping animals to digest food and decomposing dead organisms. Harmful bacteria are also the cause of many diseases in animals, plants, and other organisms.

As already stated, a bacterium cell does not have a nucleus or organelles. Other features of bacteria include cell walls, flagella, and ribosomes. Flagella are tail-like structures that protrude from cells and assist with movement. Ribosomes are entities found inside cells that help to produce proteins. Like all cells, bacteria cells contain genetic material in the form of DNA. DNA in bacteria comes in the form of a single circular molecule.

## Archaea

The domain Archaea is the second domain of entirely single-celled organisms. Organisms from the domain Archaea are the least well-known of the three domains and were only discovered in the 1970s. It was first thought that archaea were only found in extreme environments such as hot springs and salt lakes but we now know that some species of archaea can be found in more comfortable environments such as soil and oceans.

Because the cells of archaea lack a nucleus and organelles, they are prokaryotic cells but it is believed that archaea are more closely related to eukaryotes than bacteria. Archaea share several characteristics with bacteria and many with eukaryotes but they also have a number of unique features such as cell membranes made from branching lipids and cell walls made primarily from proteins.

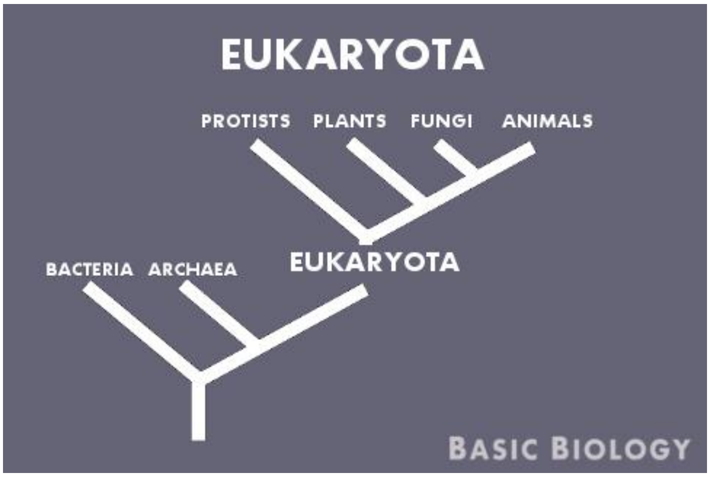
***Table 1. Unique and shared features of cells from the domains Bacteria, Archaea and Eukaryota***

| Trait | Bacteria | Archaea | Eukaryota |
|---|---|---|---|
| Cells contain a nucleus | No | No | Yes |
| Cells contain organelles | No | No | Yes |
| Cell wall – presence and structural molecules | Always present. Contains peptidoglycan | Always present. Primarily proteins | Sometimes present. Primarily carbohydrates |
| Cell membrane structural molecules | Unbranched lipids | Branched lipids | Unbranched lipids |

## Eukaryota

The domain Eukaryota includes all living things that are made from eukaryotic cells. This includes both single-celled organisms such as yeasts and amoebas as well as multi-celled organisms such as plants and animals.

The cells of eukaryotes have a nucleus and small cellular structures called organelles. A nucleus is a structure within a cell that encloses the cell's genetic material. Organelles are specialized cellular ‘factories’ that perform certain functions such as photosynthesis or protein production.




Eukaryotes are often discussed in four groups: animals, fungi, plants, and protists. Animals, fungi, and plants are each confined to a single branch from the domain Eukaryota. Protists, on the other hand, is a general group that includes all eukaryotes that are not an animals, plants, or fungi and are currently split into more than 20 branches extending from the domain Eukaryota.

**Protists**

Protists were once considered to be a distinct kingdom, just as plants, animals, and fungi are. It is now well-known that protists are not necessarily closely related to each other and many protists are more closely related to plants, animals, or fungi than they are to other protists. The term is still used for convenience to refer to any eukaryote that isn’t a plant, animal, or fungi.

Most protist species are single-celled organisms but some species are large, multi-cellular organisms. Examples of protists include algae, amoebas, slime molds, and diatoms. Seaweeds are a common multi-cellular protist group.

**Plants**

Plants are a kingdom within the domain Eukaryota. They are a group of multi-cellular, autotrophic organisms that dominate most land-based environments. Their basic structure typically consists of roots, stems, and leaves.


An autotrophic organism is an organism that can make its own food. Plants make food using energy from the sun, carbon dioxide gas from the atmosphere, and water. Through the process known as photosynthesis, a plant can turn carbon dioxide and water into sugars and oxygen. The sugars produced provide energy for plants to grow and reproduce.

The kingdom Plantae contains over 400,000 species of plants that currently exist on Earth. The vast majority of species are flowering plants from a group known as angiosperms. Other groups of plants include gymnosperms, ferns, lycophytes, and non-vascular plants such as mosses.

**Fungi**

Fungi make up another kingdom within the domain Eukaryota. The organisms within this kingdom are heterotrophic eukaryotes with unique cell walls. The term ‘heterotrophic’ refers to an organism that cannot produce its own food and obtains energy for growth from other organisms. Unlike plants, fungi are unable to make their own food and instead get nutrients by decomposing dead plants and other organisms.


Fungi come as both single-celled organisms and multi-cellular organisms. Most species of fungi are multi-cellular such as those that produce mushrooms, molds, and truffles. Single-celled fungi are referred to as yeasts. Approximately 100,000 species of fungi have been identified by biologists but it is estimated that around 1.5 million species currently exist on Earth. Of the 100,000 identified species, around 35,000 produce mushrooms.

**Animals**

The kingdom Animalia is the final group of eukaryotes. Animals are multicellular, heterotrophic organisms much like fungi. Animals obtain energy by eating other organisms such as plants, fungi and other animals.

Animals are often split into vertebrate animals and invertebrate animals. A vertebrate animal is any animal with a backbone such as a human, bird, fish, or lizard. An invertebrate is any animal without a backbone such as a snail, worm, octopus, or insect. Largely due to the huge diversity of insect species, the kingdom Animalia is likely the most diverse of all kingdoms of life.

Animals are the most advanced organisms on Earth. Many species can think, solve problems, and perform complex behaviors. Humans, in particular, are incredibly advanced.


# Chapter 4: MRS GREN

The organisms of Earth possess a set of characteristics that is absent in non-living things. To be considered 'living', an entity must be able to perform the seven life processes. These processes are Movement, Respiration, Sensitivity, Growth, Reproduction, Excretion, and Nutrition and are represented by the acronym MRS GREN.

## Movement

Movement is the first of the seven life processes. All living things can move in some way. Some organisms are quite immobile but they will always possess the ability to move either their entire body or particular body parts. For example, plants may seem completely immobile to us but they can slowly move their leaves and branches into more suitable locations i.e. where they will receive more sunlight.

Movement is evolutionarily important for organisms. The ability to move allows living things to respond to their environment and find more suitable environments to live in. Being able to move helps an organism avoid being eaten or increases their ability to catch food. Organisms that are unable to move freely will often have strong defenses against predators such as hard shells, spines, or poisons.

## Respiration

Respiration is an internal process that occurs within all organisms. It is the process of converting energy from food into energy that can be used by cells. Although we often refer to breathing as respiration, true respiration occurs within our cells.

For all organisms from the domain Eukaryota (i.e. animals, plants, fungi, and protists) respiration requires oxygen which is used to help convert fats, carbohydrates, and other substances in food into cellular energy, water, and carbon dioxide. Humans breathe to acquire oxygen for our cells so that respiration can occur. Respiration that requires oxygen is known as aerobic respiration.

The simple equation for aerobic respiration is this:

sugar + oxygen → water + carbon dioxide + cellular energy

Many organisms from the domains Bacteria and Archaea also perform aerobic respiration but there are also many organisms within these domains that have evolved other methods of respiration. When respiration does not require oxygen, it is known as anaerobic respiration.

## Sensitivity


All organisms are sensitive to the conditions of their environment. Regardless of how primitive an organism may be, it has some ability to sense the conditions of its surroundings and respond accordingly. For example, an animal may be hot in the sun and move into the shade, a tree may be losing lots of water in the heat of midday and slow down its activity to prevent water loss, a bacterium might sense that it is heading into extra salty water and alter its course towards more tolerable, fresher water. In each case, the organism is responding to the conditions of its surroundings using information gathered by their senses.

## Control (Homeostasis)

MRS GREN is sometimes known as MRS C GREN. In such cases, the ‘C’ is there to identify the fact that all living things assert control over their internal environment. By ‘internal environment’ we refer to things such as the environment within a cell or body of an organism. For example, the human body is maintained at a temperature of around 99 °F (or 37 °C) and the water concentration, salt concentration, and concentrations of multiple other substances within a cell are maintained within certain ranges. The process of maintaining control of the internal environment by an organism is known as homeostasis.

## Growth

Growth is an irreversible increase in mass and all living things grow, even single-celled, microscopic bacteria. Growth is possible due to the process of respiration which provides organisms with cellular energy. The energy is first used to perform and maintain cellular functions but excess energy may be used for several things including the production and growth of new cells and tissue.

## Reproduce

Reproduction, the creation of new organisms from other organisms, is a vital part of life and is likely to be one of the key reasons for the very existence of life on Earth. Organisms that reproduce are known as parents and their children are referred to as offspring. Over billions of years, life has evolved an array of ways of reproducing.

The simplest form of reproduction is the splitting of one cell into two cells. This is how single-celled organisms, such as bacteria, reproduce. For large, multicellular organisms, reproduction is a bit more complex and requires an incredible coordination of cellular communication and action. For a human to reproduce, for example, it consists of two multi-trillion celled organisms each sharing a single cell that combine to form a new organism. The two combined cells then multiply again and again into trillions of cells following a distinct and organized pattern of reproduction and specialization of cells.


Reproduction is either sexual or asexual. Sexual reproduction requires two parents whereas asexual reproduction requires only a single parent. Sexual reproduction most commonly consists of combining of a male's sperm cell with a female's egg. In sexual reproduction, the offspring carries half of the genetic information of each of their parents. In asexual reproduction, the offspring is a complete clone of their single parent.

## Excretion

Excretion is the dirty side of life. All living things produce waste that needs to be removed from their bodies/cells. Excretion is the technical term for the process of removing wastes.

Normal bodily processes such as the digestion of food and respiration produce waste products that organisms don't use. Waste products include substances such as indigestible fibers, urine, dead cells, gases, and feces. Each of these waste products need to be released from the body/cell of an organism or else they will build up and become toxic to the organism. The process of excretion ensures the release of such waste products and helps to maintain the healthy internal state of an organism.

## Nutrition

Nutrition is the final process of MRS GREN. All living things require nutrients to survive and they obtain them from their surroundings. Without obtaining the necessary nutrients, organisms would not be able to perform other necessary life processes such as movement, growth, respiration, or reproduction.

Organisms acquire nutrients in a variety of ways. Many living things acquire nutrients and energy by engulfing other organisms e.g. animals eat plants, fungi, and other animals. Other livings things, such as many bacteria and fungi, are known as decomposers and absorb nutrients by breaking down dead tissue such as dead leaves, branches, and animals. Plants are different again and acquire nutrients both by absorbing nutrients from the soil into their roots and by using the sun’s energy, carbon dioxide, and water to create sugars.

Some non-living things possess certain MRS GREN characteristics but they won’t possess all the characteristics of MRS GREN. Fire and water, for instance, can move quite rapidly. Fire can also reproduce and grow but it fails to perform other necessary processes such as respiration.


# Chapter 5: Fields of biology

Biology is a massive field of science. Because there is so much to learn about, biology is split into different fields or sub-disciplines. There is a huge array of different fields of biology – all up more than 60. Many fields of biology have been around for hundreds of years but some are younger and are often developing very rapidly. In this chapter, you'll be introduced to six core sub-disciplines of biology: zoology, botany, microbiology, genetics, biochemistry and ecology.

Fields of biology such as zoology and ecology can be very broad topics and contain many specializations within each field. For example, an ethologist is an animal biologist that studies animal behavior. A microbiologist might specialize in the study of bacteria, microscopic fungi, or archaea.

## Glossary

Anatomy – a field of biology the studies the structure of organisms e.g. the human skeleton or muscular system

Chemistry – a field of science that studies the properties and reactivity of matter e.g. chemical reactions, atoms and molecules

Geology – a field of science that studies the structure and substance of Earth and other planetary bodies e.g. rocks and soil

Matter – a physical substance

Physics – a field of science that studies the motion and behavior of matter through space and time

## Zoology

Animal biology or zoology is the study of animals. It includes studying aspects such as an animal's behavior, evolution, physiology, anatomy, development, and their interaction with other organisms.


Biologists that study animals often focus on a particular group of animals such as reptiles, birds, or insects. A number of sub-disciplines within zoology relate to the different groups of animals. For example, herpetology is the study of reptiles, ornithology is the study of birds, entomology is the study of insects, ichthyology is the study of fish, and mammalogy is the study of mammals.

Learning about animals is important for several reasons to humanity. Firstly, humans are animals and studying how the human body and mind functions is technically all a part of biology. Secondly, humans depend on other animals for so many different things. Other animals are an important part of most people's diets, they are used for work (e.g. donkeys carrying equipment, police dogs), sport (e.g. horse racing, dog racing, polo), other recreation (e.g. birding, wildlife safaris), animals pollinate billions of flowers so we can enjoy fruits, and the list goes on.

## Botany

The study of plants is known as botany. Much like zoology, the study of plants looks at all aspects of the life of plants such as physiology, anatomy, and development. A key difference between studying plants and studying animals is that plants don't move (much). In many ways, this makes studying plants a lot easier.


The survival of a huge amount of life depends entirely on plants due to the food that plants provide through photosynthesis. Animals, for example, would not exist if plants did not exist. Many animals survive by eating only plants and such animals are important food sources for other animals.

Plants have also been incredibly important in the evolution of life on Earth because they changed the atmosphere of Earth. Through photosynthesis, plants reduced the amount of carbon dioxide and increased the amount of oxygen in the atmosphere. This increase in oxygen allowed for animals to evolve because they require oxygen for their aerobic respiration.

By studying plants, we can make better decisions about how best to help humanity. We can discover better and safer ways to grow plants to feed the world. We can develop more efficient ways to grow wood for building houses, furniture, and more. And by continuing to study the process of photosynthesis, it is likely that one day we will be able to directly use the sun's energy to synthetically make our own food.

## Microbiology

Microbiology is a field of biology that studies microscopic organisms, also known as microbes or microorganisms. The vast majority of organisms on Earth are microscopic. In fact, the number of microorganisms that currently exist on Earth outnumbers the total number of plants, fungi, and animals that have ever existed in the past 500 million years. Just within the human body, there are more microorganisms than there are human body cells.

Examples of microorganisms include bacteria, archaea, and protists. The field of microbiology is broken into sub-disciplines often defined by the different types of microbes. The study of bacteria, for example, is known as bacteriology and the study of fungi is known as mycology.

Studying microorganisms is not an easy thing to do and most species of microorganisms are yet to be identified. With the constant advancements in technology, microbiologists are developing better and better tools for studying microbes.

## Genetics

Genetics is a field of biology that studies how the traits of organisms are inherited from one generation to the next. The traits of organisms are largely determined by the genetic material that is passed down to them by their parents. Genetics is, therefore, mostly interested in the study of genetic material and how it is passed from parents to offspring.

All organisms have genetic material, almost exclusively in the form of molecules known as DNA. DNA molecules are the cornerstone of genetics and their structure and behavior has been, and continues to be, studied extensively.

The study of genetics is incredibly important and has many potential benefits to humans. By learning about DNA and the process of inheritance, we can develop ways to treat genetic diseases, grow better crops, and better understand the existence of life on Earth.

## Biochemistry

At its simplest, life can be reduced to thousands of chemical reactions occurring every second. Biochemistry is the field of biology that studies the chemical reactions that occur in organisms and make life possible. This field of science is a combination of both chemistry and biology.

Every process that allows your body and all other organisms to function is driven by chemical reactions. The beating of your heart, the digestion of food, the ability to think – all occur because of biochemical reactions. It is essential to understand the chemical side of biology before we can truly understand entire organisms.

## Ecology

Ecology is a field of biology that studies the interactions between the environment and organisms. All living things depend on the environment for survival. On the flipside, all living things influence the environment that they live in. Ecologists try to understand how organisms and the environment affect each other.


Environmental factors, such as temperature, rain, wind, and salt all influence how well an organism will survive in an environment. At the same time, organisms can change these factors within an environment. For example, plants provide shade which reduces the temperature beneath them and animals excrete waste which adds nutrients to the soil. As ecology deals with the physical environment and living things, it is an integration of biology, chemistry, physics and geology.


# Chapter 6: Molecules of life

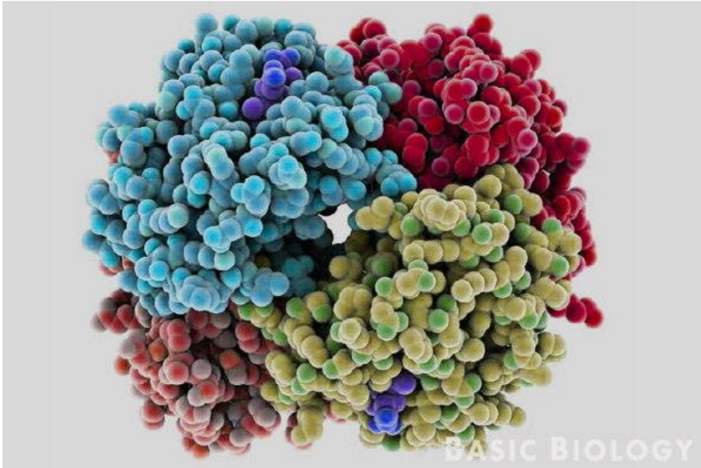
Every living thing is made from one or more cells. Cells are made from molecules. All life on Earth is primarily made from four types of molecules known as the molecules of life. Proteins, carbohydrates, lipids, and nucleic acids provide the foundations of cells for all organisms and are collectively the molecules of life.

Each of the four types of molecules is vital for life. Without any of the four, a cell or an organism would not be able to live. Water molecules are also vital for the survival of cells and organisms and technically could be included as a molecule of life. However, water usually isn't grouped with proteins, carbohydrates, lipids, and nucleic acids when the molecules of life are discussed.

## Proteins

Proteins are the most abundant molecules found in living tissue. If all the water is removed from a cell, protein molecules make up more than 50% of the cell's remaining mass. Proteins are really the building blocks of life.

Protein molecules perform a range of roles within cells. They're involved in muscle movement, digestion, immune defense, storage of energy, and more. The chemical structure of proteins allows them to have a massive variety of forms and functions.



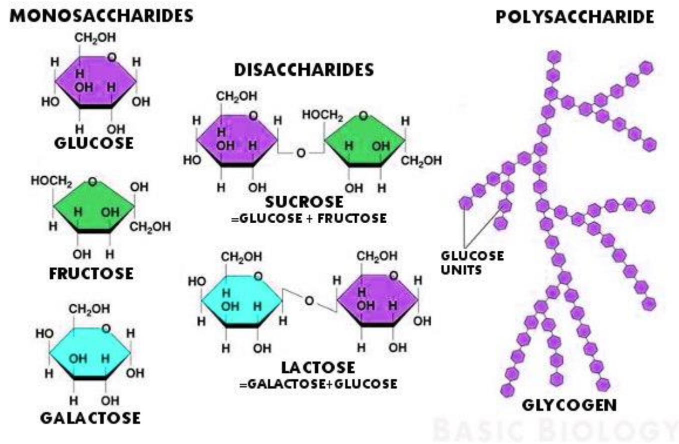

A protein molecule is a long chain made from many smaller molecules called amino acids. In total, there are 20 different amino acids found in proteins. Different arrangements of the 20 amino acids allows for trillions of unique proteins to exist. A long protein chain, made from lots of amino acids, twists and bends around itself to make a protein's final shape.

The amino acids of proteins contain nitrogen atoms. Because all cells need proteins, all cells need nitrogen. It is, therefore, necessary for all organisms to have some form of nitrogen in their diet. Plants get nitrogen from nitrates in the ground, some microorganisms can take nitrogen straight out of the atmosphere, and animals need to include proteins from plants or other animals in their diets.

## Carbohydrates

Carbohydrate molecules play several roles within cells and organisms. They are an important source of energy, they provide structural support in plant and fungal cells, and they help with communication between cells.

Carbohydrates are made from carbon, hydrogen, and oxygen atoms. A carbohydrate can either be a simple molecule known as a simple sugar or it can be a long molecule made up from multiple simple sugars bonded together. A simple sugar is known as a monosaccharide; two simple sugars bonded together is a carbohydrate known as a disaccharide; and a carbohydrate made from three or more simple sugars bonded together is known as a polysaccharide.




For most organisms, carbohydrates are the main source of energy. Plants use energy from the sun to convert $CO_2$ and water into carbohydrates which then provide cells with energy to continue functioning. The excess energy allows plants to grow and reproduce. Plants also store excess energy in their cells as carbohydrates. When they are eaten by animals, the stored carbohydrates provide an important source of energy for the animals.

The cells of most organisms contain what is known as a cell wall. Cell walls provide structural support and protection for cells. The cells of plants and fungi have cell walls made up from carbohydrates. The cell walls of plants are made from a carbohydrate known as cellulose and the cell walls of fungi are made from a carbohydrate known as chitin.

## Lipids

Along with other molecules, lipids include fats, oils, waxes, and some steroids. They are another long chain, carbon-based molecule and are built mostly from carbon and hydrogen. Of the four molecules of life, lipids are the only group that aren’t made by bonding many smaller molecules together.

Like proteins and carbohydrates, lipid molecules are important for several reasons. They provide insulation, they are used to store energy, they provide protection for vital organs, and they are used by cells to communicate with each other. Possibly the most significant role that lipids play is as the main component of cell membranes. A type of lipid known as a phospholipid is the main molecule that makes up the membranes of cells.

Lipids come in a variety of forms and their structure can vary quite significantly between the distinct types of lipids. A key similarity between all lipids though are fatty acids. Fatty acids are chains of carbon molecules surrounded by hydrogen atoms. To form the different types of lipids, hydrogen atoms of a fatty acid are replaced with different atoms or molecules. For example, a phospholipid is created when a hydrogen atom of a fatty acid is replaced by a phosphate molecule.

Another characteristic that is common amongst lipids is that they are almost all insoluble in water. Because of the chemical properties of lipids, they are repelled by water molecules. This is why fats and oils form globules in water and why vinegar and oil separate in vinaigrette.

## Nucleic acids

The fourth and final group in the molecules of life are the nucleic acids. Two types of nucleic acids are both essential to all life – DNA and RNA.

DNA, or deoxyribonucleic acid, is the well-known group of molecules that make up the genetic material of a cell. DNA molecules carry the information that tells a cell how to function and keeps life reproducing and in existence.

RNA is less well-known but is important for its role in translating the information in DNA molecules. DNA molecules are transcribed into RNA molecules which then translate the information to cells to build proteins. Without RNA, the information in DNA would be worthless.

Just as carbohydrates and proteins are made from many smaller molecules bonded together, nucleic acids are made by bonding many smaller molecules called nucleotides. Each nucleotide molecule contains a sugar, a base, and a phosphate group.

There are two key differences between DNA and RNA molecules. Their nucleotides have different sugars and different bases. DNA has a sugar called deoxyribose while RNA molecules have a sugar called ribose. As for the nucleotide bases, both DNA and RNA have four types of bases. Three bases are found in both DNA and RNA - adenine (A), guanine (G), and cytosine (C). The difference is in the fourth base. Where DNA has a base called thymine (T), RNA has a based called uracil (U).


# Chapter 7: Introduction to genetics

Genetics is a large field of biology that studies how traits are passed from parents to offspring. The phenomenon of traits being passed from parents to their offspring is known as heredity so genetics is really the study of heredity.

DNA molecules are the cornerstone of genetics. These molecules are responsible for holding the information that controls how an organism looks, grows, behaves and reproduces. In other words, DNA holds all the information that keeps a cell working and keeps an organism alive.

Heredity is the reason that children look like their parents. During reproduction, offspring receive DNA from their parents and, therefore, the same DNA that provided information on how to grow, develop, behave, and reproduce for parents is in the cells of their offspring. Offspring will, therefore, have DNA that will instruct their development and behavior to be similar to their parents.

## DNA

DNA (deoxyribonucleic acid) molecules are long chain molecules made from many nucleotides bonded together. Each nucleotide contains one of four bases – adenine, thymine, guanine, or cytosine. Genetic information is stored in DNA molecules using these four bases.

The language of DNA has four letters – A, T, C, and G – corresponding to the four bases. These letters can be arranged into a variety of different combinations to make three-letter genetic 'words' e.g. ATG, TAC, and so on. Certain arrangements of bases provide the instructions for cells to produce certain proteins. If a cell needs a specific job done, DNA will provide the instructions to create proteins that will help to achieve that job.


DNA molecules come in pairs. Each strand of DNA is bonded to a second strand of DNA and forms what is known as a double helix. Two DNA strands bond to each other via the four bases and form base pairs. The same bases always bond to each other i.e. adenine always bonds with thymine and cytosine always bonds to guanine.

During the reproduction of a cell, also known as cell division, the DNA of the cell is replicated so that both new cells have the same DNA. DNA replication occurs by splitting apart the two strands of a DNA double helix and using each strand as a template to create new DNA molecules. The process of DNA replication is likely one of the key processes responsible for the existence of life on Earth.

## Genes

A distinct and unique section of DNA that provides the information for one specific action is called a gene. For example, to grow a hair follicle, the information from a gene is used to create multiple different proteins. These proteins carry on to drive the process of growing hair. Many organisms have more than 100,000 different genes within their DNA. They therefore have more than 100,000 unique arrangements of DNA bases within their DNA molecules.

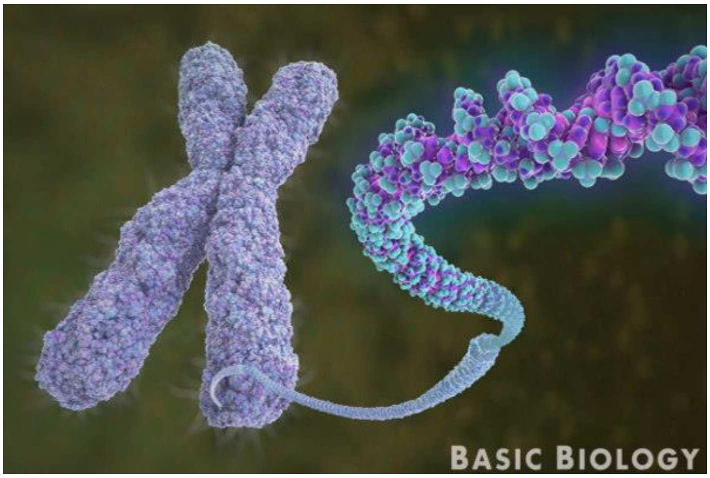
A gene is a distinct unit of DNA and is the basic unit of heredity. When organisms reproduce, their DNA, containing distinct genes, is replicated and passed down to the next generation. As genes are passed down, they provide the next generation with the same information and express the same traits as they did in the previous generation. A single gene can survive for hundreds of millions of years simply by being passed down from generation to generation.


Genes can have more than one form. For example, the human eye might be brown, blue, green, or hazel. Each different form of the same gene is known as an allele. In sexual reproduction, offspring receive one allele of each gene from each parent. If one parent has blue eyes and the other has brown eyes, the offspring might receive one blue eye allele and one brown eye allele from the two parents.

Traits can be influenced by multiple genes and the environment. Height, for instance, is the result of several genes that impact the development of an organism through their entire body. In addition to genes influencing the traits of an organism, the environment that they live can also have an impact on the physical expression of traits. Ultimately, it is the combination of genes and the environment that determine the final expression of traits.

## Chromosomes

Chromosomes are structures formed in the nucleus of eukaryotic cells during cell division. During cell division, DNA is packaged into easily replicable structures. To do this, DNA strands are coiled tightly around proteins called histones to form worm-shaped structures called chromatids. A chromosome is formed when the middle sections of two chromatids are linked together. Chromosomes are relatively large microscopic structures and it is possible to see them under a standard light microscope if a cell is in the right stage of cell division.



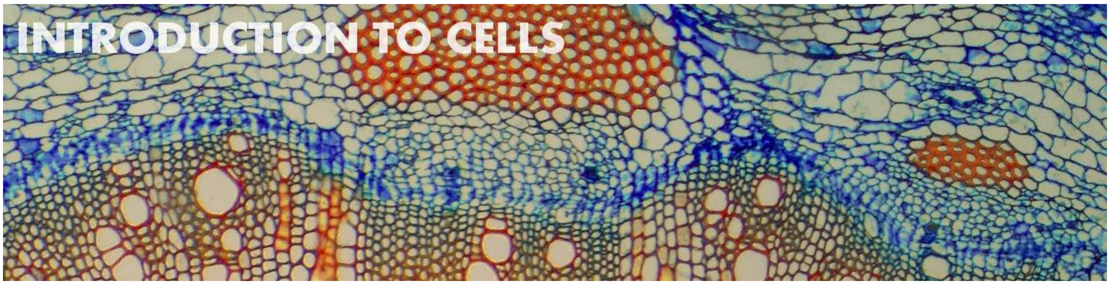

A complete set of chromosomes in a cell nucleus contains all the DNA of a cell. The number of chromosomes that make a complete set varies between species. Humans have 46 chromosomes, some species have more than 100 chromosomes, and others have as little as two.

## Genetic inheritance

Inheritance is one of the oldest areas of genetic study. Long before DNA was discovered or the term ‘genetics’ was coined, people were studying how traits were inherited from one generation to the next. Genetic inheritance occurs in the reproduction of all organisms and is one of the uniting principles of biology.

It is now well understood that traits are inherited from parents via DNA. In sexual reproduction, this requires the merging of DNA from two individuals, whereas in asexual reproduction, DNA is used to create a clone of the original organism with the exact same genetic material.

A monk named Gregor Mendel was the first person to understand the process of inheritance. He completed a series of experiments in the 1800s that unraveled how traits are passed from parents to their offspring. Mendel is considered the father of modern genetics as his work provides the foundations for this field of biology.




# Chapter 8: Introduction to cells

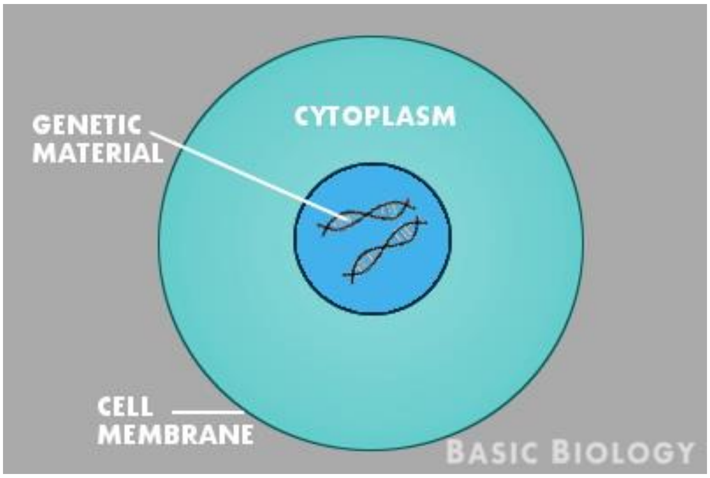
Cells are the basic unit of life and every organism on Earth is made from one or more cells. The first organisms that lived over 4 billion years ago contained only a single cell. Most of the descendants from these earliest organisms still survive with only a single cell but other descendants have evolved into complex, multicellular organisms.

There is a massive variety of cell types but they all contain a few common characteristics. These include genetic material, a cell membrane, and cytoplasm. Cells also have features that vary between cells including a range of organelles, ribosomes, flagella, and more.

The simplest categorization of organisms come down to the type of cell that they contain. All cells are either prokaryotic or eukaryotic. Prokaryotic cells do not contain a nucleus or organelles and are found in bacteria and archaea. Eukaryotic cells do contain a nucleus and organelles and are found in eukaryotes which include animals, plants, fungi, and protists.

## Structure of a cell

Cells come in a wide variety of shapes, sizes, and structures but there are couple of common characteristics in all cells. Essentially, a cell is genetic material in a gel-like substance enclosed in the cell membrane. Other features, such as ribosomes, are common amongst most cells but they are not part of the defining makeup of all cells.




Within a cell, genetic material is either found within a nuclear membrane or not. Together, a nuclear membrane and genetic material make a nucleus. Cells with their genetic material in a nuclear membrane are, therefore, eukaryotic cells and those without a nuclear membrane are prokaryotic cells.

The gel-like substance that a nucleus or straight genetic material (in the case of prokaryotic cells) is found in is known as cytoplasm. Cytoplasm fills a cell, provides it with shape, and is a consistency that allows molecules to move around within the cell. All cells have molecules and other structures within their cytoplasm that play a role in keeping the cell alive.

Surrounding the cytoplasm is the cell membrane also known as the plasma membrane. The cell membrane acts as the boundary of the cell and separates the internal components of the cell from the external environment. It also holds the contents of the cell together. For substances to enter a cell, they must pass through the barrier of the cell membrane.

## Eukaryotic cells vs. prokaryotic cells

The key difference between eukaryotic and prokaryotic cells is the presence of a nucleus and organelles. Prokaryotic cells do not have either, while eukaryotic cells have both. The word 'prokaryotic' can be literally translated to 'before nucleus'.

As already explained, a nucleus is a structure that consists of a cell’s genetic material and a nuclear membrane. Organelles are other membrane bound structures found within eukaryotic cells. Organelles work as cellular ‘factories’ performing specialized functions such as transporting substances, breaking down molecules, or building lipids, carbohydrates, and proteins. Most prokaryotic cells contain structures that help with specific functions but these structures are not enclosed in a membrane so they are not considered organelles.

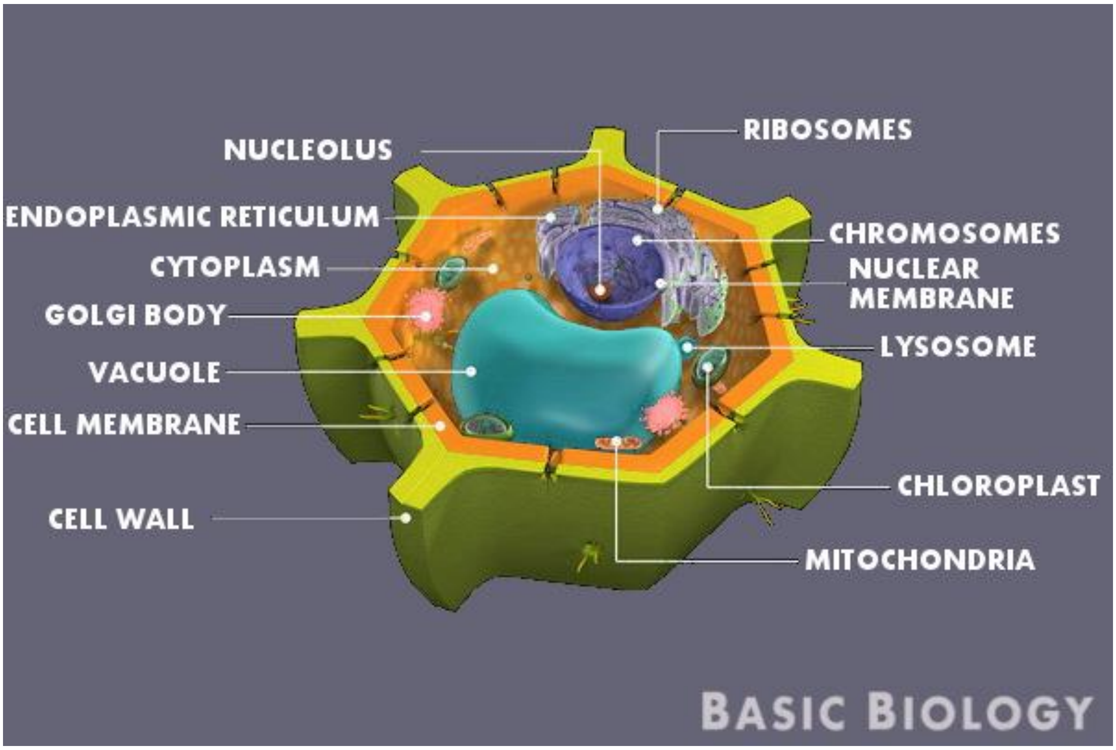
Organelles increase the efficiency of eukaryotic cells. This allows eukaryotic cells to grow larger than prokaryotic cells. A typical animal cell, for example, is roughly 50 times larger than a typical bacterial cell.

Evolution in eukaryotic cells has gone a step further than the specialization of organelles within the cell. Eukaryotic cells have evolved into multicellular organisms made from highly specialized cells that depend on other cells for their own survival. For example, a red blood cell is a specialized cell with the primary purpose of delivering oxygen to the cells of an animal. If for any reason the red blood cells of an animal stopped working, all other cells of that animal would perish as they cannot survive without the help of the red blood cells. On the other hand, if red blood cells were no longer protected by the specialized cells of veins, arteries, and capillaries, they would soon die in a different environment. The evolution of multicellular organisms was only possible because organelles provide greater efficiency and specialization in eukaryotic cells.

## Organelles

Eukaryotic cells contain a range of organelles that each perform certain roles within cells. Some organelles are common in almost all eukaryotic cells while others are only found in a few unique groups. Key organelles include mitochondria, the endoplasmic reticulum, and chloroplasts. Other important organelles include the golgi bogy, vacuoles, centrosomes, peroxisomes, and lysosomes.

Mitochondria are organelles found in almost all eukaryotic organisms. These organelles are responsible for the process of cellular respiration. Mitochondria make eukaryotic cells far more efficient at breaking down fats and carbohydrates and converting the energy from these molecules into a form of energy that cells can use.




The endoplasmic reticulum (ER) is a network of membranes that is connected to the exterior of the nucleus. It completes tasks such as creating proteins and breaking down fats and carbohydrates. The endoplasmic reticulum is split into the smooth ER and rough ER. The rough ER contains ribosomes that are involved in creating proteins whereas the smooth ER does not contain any ribosomes and does not create proteins.

Chloroplasts are key organelles in plant and other photosynthetic cells. Chloroplasts make it possible for plants to make food using the sun’s energy. They contain unique molecules called chlorophyll that has the remarkable ability to kickstart the process of photosynthesis with the help of light energy from the sun.

## Cell division

Cell division is the simplest form of reproduction. Reproduction of a bacterial cell and all other single celled organisms is merely cell division. In multicellular organisms, the division of cells occurs in order to grow new tissue and to replace older, dying cells within tissues and organs.

Two types of cell division occur in nature: mitosis and meiosis. Mitosis is the most common type of cell division and is simply the division of one cell into two cells. Meiosis occurs in order to generate reproductive cells for sexual reproduction and is a process of two cell divisions that results in the production of four new cells.

For sexual reproduction to occur (where the DNA of two parents is combined to produce offspring), it is necessary to halve the DNA of each parent prior to merging DNA. To achieve this, the process of meiosis splits one cell into four cells over two stages of cell division and each of the four new cells contain half the DNA of the original cell. The first cell division is normal mitosis and splits one cell into two cells. The second stage of the process involves splitting the DNA of the two cells in half and dividing the cells without replicating the DNA, thereby creating four cells each with half of the DNA of the original cell.

To help remember the difference between mitosis and meiosis, think ‘T’ for mitosis, ‘T’ for two. Mitosis has a ‘t’ and divides cells into two new cells. Meiosis doesn’t have a ‘t’ and results in four new cells being produced.


# Chapter 9: Introduction to plants

Let's not hold back here, plants are amazing. They take the sun's energy, carbon dioxide, and water and make themselves some food. I'm pretty sure the greatest chef in the world can't make a meal with those ingredients. And the food they make for themselves, ends up providing the foundation of almost every food chain on Earth. Without plants, humans and all other animals would not exist.

A plant is a multicellular organism with the ability to perform photosynthesis. They have relatively simple body plans with roots, stems, leaves and often flowers and fruit. There are currently over 400,000 species of plants on Earth so there is plenty to study and the study of plants is known as botany.

The majority of plants belong to a group called the angiosperms. This includes all plants that produce flowers and fruit. Other key evolutionary groups include gymnosperms, ferns, lycophytes and non-vascular plants.

By using the sun's energy to fix carbon dioxide, plants are able to produce sugars through the process of photosynthesis. The sugars produced through photosynthesis provide plants with the energy to survive, grow, and reproduce. As plants grow, they become a food source for animals and other organisms.

## Photosynthesis

Photosynthesis is the process that unites plants. It is a process that occurs in the cells of plants where the sun's energy is used to kick start a series of chemical reactions which ultimately leads to the production of sugars. The process is probably the most important set of chemical reactions on Earth.

The green of leaves is due to molecules called chlorophyll *a*. Chlorophyll *a* is found in plant cells and has the ability to absorb energy from the sun. The energy that these molecules absorb is then used to prompt reactions with carbon dioxide and water. The result of the chemical reactions is the production of sugars and oxygen.

The overall reaction looks like this:

$$\text{carbon dioxide} + \text{water} + \text{energy} \rightarrow \text{sugar} + \text{oxygen}$$

Through photosynthesis, plants remove carbon dioxide from the atmosphere, convert it into sugars for food, and release oxygen back into the atmosphere. Over millions of years, this process has altered the Earth's atmosphere by increasing the amount of oxygen in the air and reducing the amount of carbon dioxide.

## Vascular vs. non-vascular

A crucial step in the history of plants was the evolution of vascular tissue. Vascular tissue is any tissue that is built specifically to transport substances around an organism's body. Just as humans have veins to transport blood and other substances, many plant species have their own system of vascular tissue that transports water and nutrients through their leaves, stems, and roots.


Before the evolution of vascular tissue in plants, water and nutrients were only able to move through a plant by diffusing through the plant's cells. This prevented plants from growing very large because this method of transport isn't very efficient. As vascular tissue evolved, plants could grow much larger and allowed for the evolution of the large trees that currently exist on Earth.

There are still a lot of non-vascular plants on Earth but the vast majority of plants now contain vascular tissue. The most common type of non-vascular plant that currently exists are mosses. Other groups include liverworts and hornworts and some biologists also consider a group called charophytes to be plants. Because non-vascular plants have inefficient methods for transporting water, they are usually found in moist environments so they can easily keep their cells hydrated.

Over 90% of all plant species currently on Earth contain vascular tissue. Some of the more primitive groups of vascular plants include lycophytes and ferns. More advanced groups are gymnosperms and angiosperms.

## Plant body plan

Over 500 million years ago, plants gradually moved from living in water to living on land. Living on land posed different issues for plants to deal with and the body plan of plants reflects the conditions of living on land. Living in water, nutrients and water are available all around a plant but on land, nutrients and water are only really available belowground. To adjust to nutrients and water only being available underground, plants redesigned their body plans into roots, stems, and leaves. Roots grow underground to absorb water and nutrients; stems transfer water and nutrients between leaves and roots and provide structural strength; and through the process of photosynthesis, leaves produce sugars and provide a plant with energy to grow and reproduce.

The evolution of the root system was key to the success of plants moving onto land. As roots grow into soil in search for water and nutrients, they also anchor a plant to the ground and prevent it from being blown or washed away by wind and water. Roots are also used by many plants to store energy. Vegetables such as carrots, beetroots, onions, and potato are all edible roots where the plant has used its root system to store energy. More than half of a plant's mass can be underground in its roots.

Above the soil, a plant is split into stems, branches and leaves. Stems and branches connect the roots and leaves to each other. They have two main purposes: 1) providing passages for water and nutrients to travel through; and 2) providing height and stability for a plant aboveground. The taller a plant is, the more likely it will be able to receive sunlight but the further it has to transport water and nutrients between leaves and roots. The height of a plant is ultimately a trade-off between outcompeting your neighboring plants for light and being able to transport water and nutrients between your roots and leaves.

Leaves have evolved primarily to photosynthesize and they hold the responsibility of providing a plant with the energy it needs to survive and reproduce. Leaves are optimized for this challenge. They are packed full of chlorophyll *a*, the magic molecule that absorbs energy from the sun and gets the process of photosynthesis rolling. Leaves also typically have large surface areas so that they can catch as much of the sun's light as possible and perform as much photosynthesis as they possibly can.

## Types of plants

The 700+ million-year history of plants has led to more than 400,000 species currently existing on Earth. Several traits led to the evolution of key groups of plants. The evolution of vascular tissue, seeds, wood, fruits, and flowers has separated Earth's plants into non-vascular plants, lycophytes, ferns, gymnosperms, and angiosperms.

### Angiosperms

Angiosperms are the largest group of plants and it includes all plant species that produce fruit and flowers. Angiosperms also produce seeds, have vascular tissue, and many species produce wood. They are the most advanced group of plants and include many of the plants that we are very familiar with such as roses, lavender, grasses, daffodils, oaks, willows plus any plant that produces any fruit, vegetable, grain, or nut that we regularly eat.

Flowers and fruit evolved because they improved a plant's reproduction. Flowers produce pollen (which contains sperm) and an ovary. If the pollen of one flower reaches another flower and the pollen's sperm enters the flower's ovary, the eggs


within the ovary can be fertilized. This is known as pollination. Once an egg is fertilized, it develops into a seed and the ovary develops into a fruit.

Many species of angiosperms have close relationships with animals. Many animals, particularly birds and insects, assist in the process of pollination. Flowers produce nectar and pollen which is a rich source of food that is enjoyed by many animals. Animals that feed on the nectar and pollen of multiple flowers often unknowingly carry pollen from flower to flower. The pollen that they carry has the potential to fertilize any flowers that they visit.

**Gymnosperms**

Gymnosperms are the closest relatives of angiosperms. Like angiosperms, they are seed-producing, vascular plants and also produce wood. In contrast to angiosperms however, gymnosperms do not produce fruit and flowers. The seeds of gymnosperms are frequently found in cones rather than fruit.

Many incredible species of plants are gymnosperms. In fact, the world's largest, tallest, widest, and oldest organisms are all gymnosperms. Some gymnosperms can live for over 3000 years.

All gymnosperms can be split into four groups: gingko, cycads, gnetophytes, and conifers. Conifers are the most common group of gymnosperms and include the well-known pine trees. Gnetophytes are a strange group of plants that exhibit some


flowering characteristics which has led biologists to speculate about them being the predecessors of angiosperms. Cycads are palm-like plants with an unbranched stem with a crown of leaves at the top. The gingko is a single species in a group of its own. It has fan shaped leaves, produces fleshy seeds that resemble fruit, and is often planted in gardens.

**Ferns and lycophytes**

Ferns and lycophytes are vascular plants that don't produce wood, seeds, flowers, or fruit. Instead, ferns and lycophytes reproduce with spores. These two groups of plants were once the most common plants on Earth but have since been surpassed by angiosperms and gymnosperms.

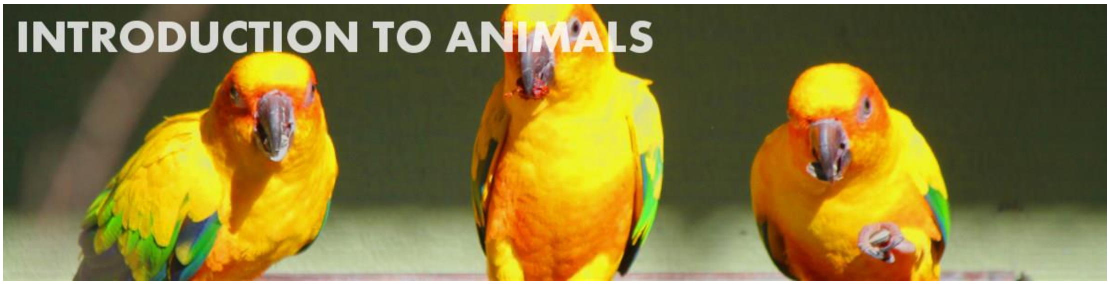
Both of these types of plants are still common in many parts of the world. Approximately 12,000 species of ferns and 1,200 species of lycophytes still exist. Because their spores (equivalent to seeds) are very small, ferns and lycophytes are distributed all around the world and you'll find them pretty much anywhere you find the combination of land and rain.

The key difference between ferns and lycophytes is in the veins in their leaves. Ferns have fronds with multiple veins. In contrast, the leaves of lycophytes only contain a single vein.

**Non-vascular plants**

As already discussed, non-vascular plants are all plants that do not contain vascular tissue. They also lack wood, seeds, flowers and fruit. Non-vascular plants are the most primitive of all plants.


There are still many non-vascular plant species that exist on Earth. Most non-vascular plant species are mosses and more than 14,000 species of mosses still exist. Other non-vascular plant groups include liverworts, hornworts, and arguably charophytes.




# Chapter 10: Introduction to animals

Animals are the most advanced organisms on Earth. They are thought to have begun evolving around 550 million years ago and since then have diversified into more than one million species. Humans are one of those species.

An animal is a multicellular, heterotrophic organism. All animals have more than one cell and many animals are made from trillions of cells. Heterotrophic simply refers to the inability of animals to create their own food in the same way plants can through photosynthesis. Animals are also eukaryotic because they are made from cells that contain a nucleus and organelles.


Animals are often divided into vertebrate animals and invertebrate animals. A vertebrate animal is any animal with an internal backbone such as a human, dog, fish, or lizard. An invertebrate is any animal without an internal backbone. Examples of invertebrates include insects, spiders, jellyfish, crabs, worms, and snails.

## Invertebrates

The first animals to evolve were invertebrates and, still today, more than 90% of animal species are invertebrates. We know very little about many invertebrate animals and there are a large number of species that are yet to be discovered.


Some of the most ‘primitive’ animals are invertebrates such as sponges, corals, and jellyfish. Many of these animals bare almost no resemblance to the animals we’re most familiar with. They have no eyes, head, limbs, or organs and many primitive invertebrates are almost completely immobile.

Sponges are thought to be similar to some of the first animals that evolved. They are so primitive that they are able to live and reproduce as a single-celled organism for a period of time. Corals, jellyfish, and anemones all belong to the same group of primitive invertebrates and share the common trait of having a specialized stinging cell.

The most abundant and diverse group of invertebrates is a group known as arthropods. The defining features of an arthropod is a hard, external skeleton and jointed limbs. Insects, spiders, scorpions, and crustaceans are all examples of arthropods. In total, more than 80% of all animal species are arthropods and the vast majority of arthropod species are insects. Many arthropods are very advanced animals with complex bodies and behaviors. For example, bees communicate with each other by shaking their backsides in certain ways. Spiders can produce


intricately designed webs and then wait as long as needed until an unsuspecting insect is caught in their web.

In between sponges and arthropods there is a huge range of other invertebrates. Other examples include various different worms, molluscs (octopus, oysters, snails), starfish, and centipedes. Different groups of invertebrates vary widely in structure, behavoir, and other aspects of life but they are all united by the absence of an internal backbone.

## Vertebrates

As already mentioned, a vertebrate is any animal with an internal backbone. This includes many of the larger and better known of Earth's animals such as fish, reptiles, birds, and mammals. The largest animals and the most intelligent animals are vertebrates but vertebrates can also be very small and/or not particularly intelligent.

All vertebrates can be split into four groups: fish, amphibians, reptiles, and mammals. Fish were the first vertebrate animals to appear and are now the most diverse group of vertebrates. Amphibians were the first group of vertebrates to move onto land and include animals such as frogs, toads, newts, and salamanders. Reptiles are a group of mostly scaly animals that includes snakes, lizards, crocodiles, and turtles. Birds are also a class of reptiles but have taken a unique root in evolution and have evolved feathers and wings. Mammals are the most advanced group of animals and are distinguished by having hair and mammary glands.

## Fish

Fish were the first vertebrates to evolve and all other vertebrate animals have since evolved from prehistoric fish. A fish is an aquatic animal with gills and fingerless limbs. All fish species belong to one of four groups: bony fish, cartilaginous fish, jawless fish, and hagfish.


Fish are well adapted to life in water. Their bodies are streamlined and limbs are flattened for fast and efficient swimming; their organs are designed to help with maintaining ideal buoyancy and salt levels within their tissue; their gills are designed to efficiently extract dissolved oxygen from water; and they have some very clever camouflage to help them catch dinner or avoid becoming dinner.

## Amphibians

Of the vertebrate animals that exist today, amphibians were the first group to evolve to life on land. They still live a partially aquatic life and begin life as larvae in water, breathing through gills. As they grow older, amphibians go through a process called metamorphosis where they transform from a water breathing larvae into an air breathing adult. Most species also develop legs so they can walk on land.

Amphibians are the most threatened group of all vertebrate animals. They have been around for over 360 million years but many species are currently under threat of extinction. Humans are the main cause of their problems as we have destroyed a lot of their natural habitat and introduced new predators all around the world.

## Reptiles (including birds)

Reptiles are an ancient group of animals that includes lizards, snakes, crocodiles, turtles, tuatara, and birds. Aside from birds, reptiles have scales or scutes rather than hair. Most species are cold-blooded and lay eggs instead of giving birth to live young.

Reptiles were the first vertebrate animals to evolve to live entirely on land and several species have since moved back to live in water.

Birds are a nique class of reptiles. They have evolved wings and are the only group of animals to have evolved feathers. Wings and feathers have several functions but their most obvious is providing birds with the ability to fly. Birds are renowned for their flying and many species are capable of flying thousands of miles every year.

## Mammals

Mammals are warm-blooded, vertebrate animals with hair and mammary glands. There are two main groups of mammals that diverged in evolution more than 100 million years ago: marsupials and placentals. Marsupial mammals possess a pouch over their abdomen where their young live while they are suckling. Examples of marsupials mammals include opossums, kangaroos, and

koalas. Placental mammals provide assistance to their unborn offspring by supplying nutrients via a placenta as they develop pre-birth. Examples of placental mammals include primates (including humans), goats, cats, rodents, dolphins, dogs, and bears.


# Chapter 11: Taxonomy

Taxonomy is the practice of identifying different organisms, classifying them into categories, and naming them. All organisms, both living and extinct, are classified into distinct groups with other similar organisms and given a scientific name. The classification of organisms has various hierarchical categories. Categories gradually shift from being very broad and including many different organisms to very specific and identifying single species.

## Taxonomic categories

There are eight distinct taxonomic categories. These are: Domain, Kingdom, Phylum, Class, Order, Family, Genus, and Species. The broadest category splits all organisms into three groups called 'Domains'. As discussed in chapter 3, the three Domains of life are Bacteria, Archaea and Eukaryota. With each step down in classification, organisms are split into more and more specific groups. For example, all of the animals in the Kingdom Animalia are split into multiple phyla (plural of phylum). All of the animals in the phylum Chordata are split into multiple classes such as mammals, reptiles, and amphibians.

**Kingdom**

For a long time, all life was separated into five or six kingdoms. These included kingdoms such as animals, plants, fungi, protists, archaea, and bacteria. With new genetic data, we now know that some protists are more closely related to animals, plants, and fungi than they are to other protists. This suggests that the protist kingdom could be separated into multiple kingdoms. Thoughts are similar for the bacteria and archaea kingdoms.

**Phylum**

A phylum (plural phyla) is still a very broad classification but it splits kingdoms into multiple groups. An example of phyla from the animal kingdom is Arthropoda which includes all insects, spiders, crustaceans, and more. All vertebrate animals belong to one phylum called ‘Chordata’. Invertebrates are separated into many different phyla.

**Class**

A class is the next level down. As mentioned earlier some classes from the phylum Chordata include mammals, reptiles, and amphibians. Arthropod classes include the likes of insects and arachnids (spiders, mites, and scorpions).

**Order and family**

From class, organisms are placed into an Order and then a Family. Using grasses as an example from the plant kingdom, they belong to the order Poales and the family Poaceae.

**Genus and species**

The final two categories are genus and species. The genus and species that an organism belongs to are how an organism receives its scientific name. This naming system is called ‘binomial nomenclature’ and was invented by a brilliant biologist named Carl Linnaeus.

Every identified species is placed into a specific group in each of these categories. For example, the taxonomic classification of the human species is:

| | |
|---|---|
| Domain: | Eukaryota |
| Kingdom: | Animalia |
| Phylum: | Chordata |
| Class: | Mammalia |
| Order: | Primates |
| Family: | Hominidae |
| Genus: | *Homo* |
| Species: | *Homo sapiens* |

To remember the order of the taxonomic hierarchy from domain to species, people often use mnemonics to make it easier. The phrase that I was taught and still use to help me remember is ‘King Phillip Came Over From Germany Swimming’.

## Carl Linnaeus

Carl Linnaeus was a Swedish naturalist from the 18th century and is considered the father of taxonomy. Linnaeus developed the method of organizing organisms into the taxonomic categories. He also developed the system that we use to name new species called ‘binomial nomenclature’. Linnaeus is credited with identifying over 10,000 different plant and animal species in his lifetime, more than any other biologist.

## Systema naturae

When Linnaeus developed his system of hierarchical categories, he called it ‘Systema Naturae’. It contained three kingdoms, classes, orders, genera, and species. We have since added two more categories – domains and phyla. Linnaeus’s original classification had three kingdoms – animals, plants, and minerals (natural, non-living elements). We now only use this system for classifying organisms and we have since separated all of life into more than two kingdoms.

## Binomial nomenclature

Binomial nomenclature is the method that we use to uniquely name every different organism on Earth, living or extinct. All organisms have a scientific name that includes two Latin words. The two words are made from the names of the genus the species belongs to and a second word to separate each of the species within the same genus. The second word is known as the 'specific epithet'. Hence, the scientific names of all organisms are made from the name of their genus and a specific epithet. For example, the scientific name given to humans includes their genus *Homo* and the specific epithet *sapiens.* The overall name is *Homo sapiens*. Scientific names are also written in either *italics* or <u>underlined</u>.

Taxonomy is not a perfect science and, as you will find out, there is a lot of disagreement and uncertainty about the structure of taxonomic classifications. In general, however, taxonomy is a great way to quickly learn about how an organism slots into the tree of life.


# Additional resources

- Animals – Basic Biology
- Plants – Basic Biology
- Micro – Basic Biology
- Campbell Biology