Chromosomes and genes

The DNA molecule is one of a number of molecules located in the chromosomes of the nucleus. The sequence of nitrogen bases in the DNA is a code that the cell uses to construct **protein** molecules required for life functions. Protein molecules are very large molecules (polymers) that are constructed from smaller molecules called **amino acids**. The amino acids link together to form the long chains of the protein.

- Sets of three nitrogen bases form a triplet code.
- Each amino acid has a number of alternative triplet codes (eg. CCC and CCT both code for the amino acid called glycine)

Example

The sequence of triplet codes

CCC TTT AAA GAG

leads to the following sequence of linked amino acids in a protein chain:—glycine—lysine—phenylalanine—leucine—

Genes

Genes are codes that contain information about **inheritance.**

- Genes are **segments** of the DNA molecule containing many triplet codes.
- Each gene is responsible for the production of a certain protein.
- Gene segments of the DNA strands are separated from one another by other non-coding segments.

- Genes do not function at all times. They can be turned 'on' or 'off'.
- Each gene may have two alternative forms. These alternative forms are called **alleles**. These alleles can be represented by code letters.

Example

Y = gene for **yellow**-coated pea seeds

y = gene for **green**-coated pea seeds

B = gene for **black** coats in guinea pigs

b = gene for **white** coats in guinea pigs

- Some alleles are **dominant**. They are shown by a capital letter (eg. Y and B). Only one copy of a dominant gene is needed for an organism to show this characteristic or trait.
- Some alleles are **recessive**. They are shown by lower-case letters (eg. y or b). Two copies of a recessive gene are needed for an organism to show this trait.

Features of an organism

The features or characteristics of an organism are determined by the:

- genes they inherit;
- interaction between the environment and the genes.

Inherited genes

As a result of sexual reproduction, each child inherits 23 chromosomes from their father and 23 chromosomes from their mother. These 23 pairs of chromosomes contain many pairs of genes for each characteristic. The features of the child will depend on the types of alleles inherited.

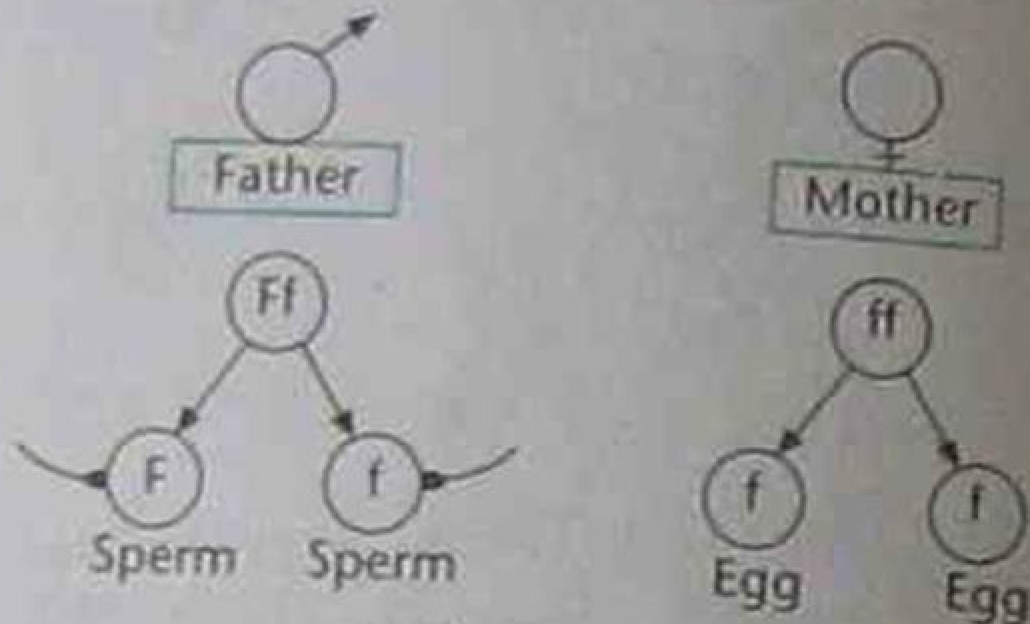
Example

A free ear lobe (F) is dominant to an attached ear lobe (f).

The genes are inherited in pairs—one from each parent.

The following table shows the features of three different children from different families.

Child	Gene from Parent 1	Gene from Parent 2	Gene pairs inherited by child (genotype)	Observed features (phenotype)
1	F	F	FF	free ear lobe
2	F	f	Ff	free ear lobe
3	f	f	ff	attached ear lobe



Father's genes

Mother's genes	F	f
f	Ff	ff
f	Ff	ff

Ff = Free ear lobe
ff = Attached ear lobe
50% chance of each child having a free ear lobe

Figure 3.10 Diagram of inheritance of gene pairs

Environmental effects

The inheritance of particular gene combinations can lead to features that are more suitable in certain environments. The following environmental factors influence the characteristics of a population.

- Availability of food and water—poor diets and nutritional disease will affect the survival of weaker members of a population.
- Infectious disease—individuals with high natural immunity have a greater chance of survival when infectious diseases appear.

- Latitude and sunlight—individuals with darker skins can survive in equatorial latitudes where there is strong solar radiation.

Example 1. Light brown and dark coloured moths

Light brown moths have a mottled body that helps to camouflage them in their natural woodland environment. Dark coloured moths have a gene mutation that leads to dark coloured bodies. They are easily seen by birds in the woodlands and are therefore more likely to be eaten. Consequently, a woodland population of moths usually has more mottled light brown moths than dark moths. The features of the population of moths have been affected by the environment.

Example 2. Salt-tolerant plants

Some plant species are able to colonise coastal dunes because they have inherited genes to deal with high salinity environments. Seeds from non-salt-tolerant plants will quickly die after germination in such environments.

In some parts of Australia increases in soil salinity (due to poor farming practices) have led to a change in the characteristics of native vegetation. The proportion of salt-tolerant plants increases at the expense of non-salt-tolerant plants.

The theory of evolution and natural selection

Charles Darwin (1809–1882) was the scientist who explained how living things had evolved (changed) over the millions of years of Earth's history. He developed a theory known as the theory of natural selection that provided an explanation for the evolution of species.

Glossary

Comparative anatomy—the science of comparing similar (homologous) structures in the bodies of animals

Embryology—the study of embryos

Evolution—the genetic change in organisms that leads to the production of new species

Extinction—the permanent disappearance of a species

Gene pool—the collection of all genes found in a population of organisms

Geographic isolation—habitats can be isolated from one another by geographical features such as oceans, rivers, cliffs, deserts, etc.

Half-life—the time for the radioactivity of a radioisotope to halve

Natural selection—the process in which species naturally reproduce and pass on to their offspring characteristics that make them more suited to their environment; this process is affected by the environment

Radiometric dating—a process of measuring the age of a rock, mineral or fossil by measuring the activity of various radioisotopes in the sample

Species—a group of organisms that can naturally breed to produce fertile offspring

Variation—differences in characteristics in a population

Evidence for evolution

There is considerable evidence that present-day organisms have developed from different organisms in the distant past. Let us examine some of this evidence.

1. Earth is extremely old

The primitive Earth formed about 4600 million years ago as matter condensed from the spinning disk of a newly formed planetary nebula. The hot Earth then cooled and the landmasses, oceans and atmosphere formed.

formed.

Using the technique of **radiometric dating**, scientists have determined the absolute age of various rocks and minerals. This technique is based on measuring the relative quantities of radioactive elements and their decay products. With this information and a knowledge of the **half-lives** of radioisotopes such as uranium-238, rubidium-87 and potassium-40, scientists can measure the age of the rock sample.

Example

Zircons. These minerals contain potassium-40 and its decay product (argon-40). The half-life of potassium-40 is 1300 million years. This means that it takes 1300 million years for half the original potassium-40 present in the zircon to decay into argon-40. The oldest zircons (dated by radiometric analysis) were formed 4200 million years ago.

Radiometric measurements of Earth rocks and Moon rocks (from the Apollo missions) give ages between 3300 and 4000 million years.

- The great age of Earth has allowed sufficient time for the processes of evolutionary change to occur.

2. Sedimentary strata and the law of superposition

Comparisons of rock sequences and sedimentary strata around the world led to the idea that the surface rock layers were younger than the deeper layers. William

Smith (1760–1839) expressed this observation in the Law of Superposition:

- In a sequence of sedimentary strata, the layers are increasingly older with increasing depth from the surface.

Radiometric measurements have since confirmed this law.

confirmed this law.

3. The fossil record over geological time

Fossils are the remains or record of ancient life. (See page 140, Natural Events.) The geologist Adam Sedgwick (1785–1873) was one of the first scientists to establish the great age of Cambrian fossils in Wales and Scotland. Sedgwick's work led to the idea that many fossils represented species that had become extinct in an ancient period of Earth's history.

earth's history.

As more fossils were collected and analysed from various strata, it soon became apparent that the fossils in deeper sedimentary strata were less complex in body structure than fossils in higher strata. Radiometric measurements showed that these lower layers and fossils were much older than fossils in strata closer to the surface. Thus the fossils of the most primitive fish are found in much deeper (and older) layers than the earliest mammal fossils. The oldest fossil layers contain impressions or traces of simple single-celled organisms. Stromatolite fossils (a type of cyanobacteria) found in the Pilbara region in Western Australia have been dated at 3500 million years old.

- The fossil evidence therefore supports the view that the earliest life forms were very simple and that they changed into more complex organisms over geological time.
- Fossils reveal that the appearance of new life forms did not occur at an even rate over geological time.
- The fossil record has shown that more than one new species sometimes

developed from a pre-existing species.

- The fossil record is incomplete since not all organisms become fossilised after death.

4. Evidence from horse fossils

The evolution of the modern horse (*Equus*) has been firmly established from fossils dating back to 60 million years ago. The ancient ancestor of the horse (*Eohippus*) had four toes (compared with one toe in *Equus*) and was as small as a dog. The sequence of fossil forms thus shows that the modern horse developed from a different organism in the distant past.

- Fossil evidence describing the development of the horse supports evolution because it shows that organisms change over a long time.

5. Evidence from comparative anatomy

Georges Cuvier (1769–1832) compared the anatomy of fossils and related living organisms. He showed that these fossils were different from those of living species.

Since then

Since then, comparative anatomy has shown that the bones at the ends of the forelimbs of many different vertebrates (including humans) are based on a common pattern or structure. Figure 3.14 compares the forelimbs of several different species.

different species.

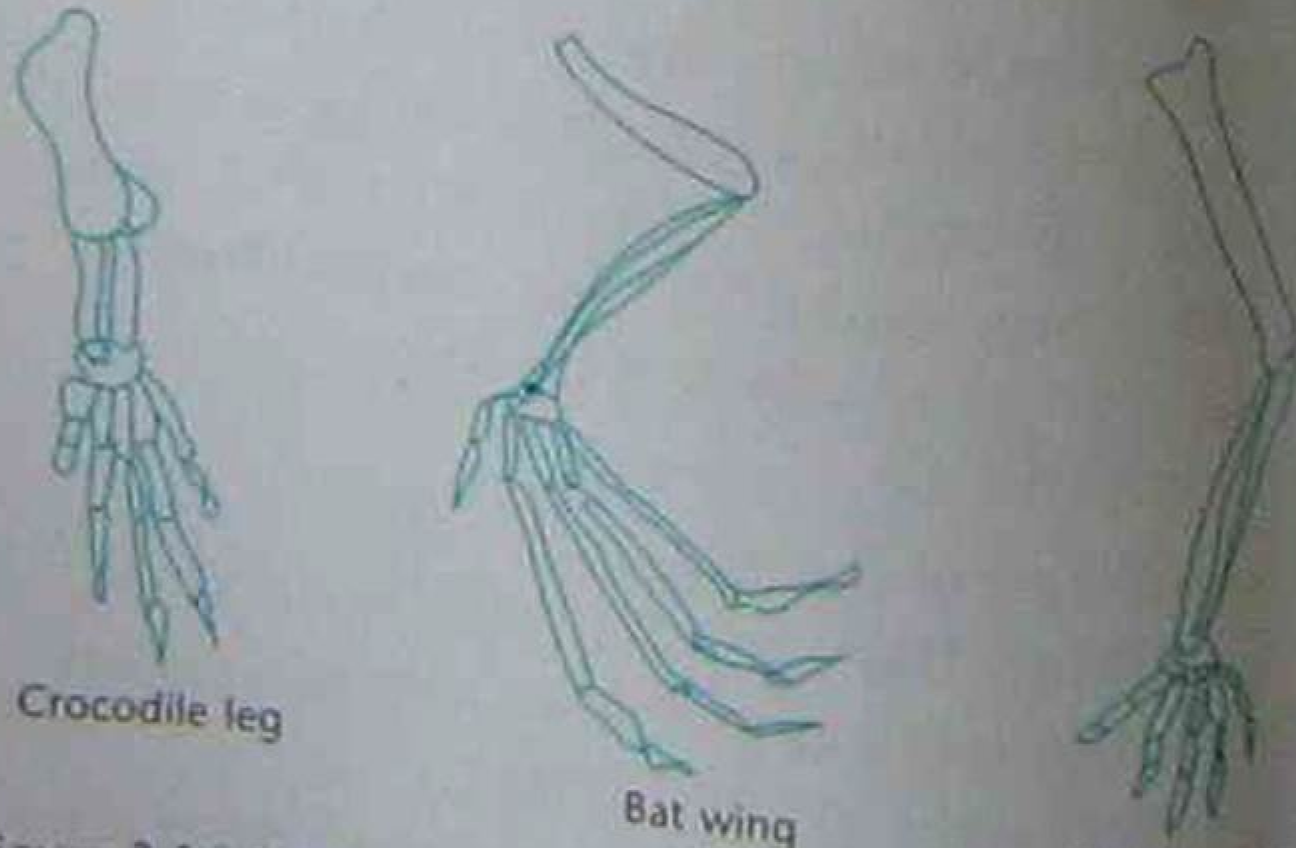


Figure 3.14 Comparison of the forelimbs of vertebrates

- **The comparative anatomy data are used as evidence of evolution from a common ancestor in the distant past.**

6. Evidence from comparative embryology

Vertebrate embryos in their early developmental stages from the fertilised egg show great similarity in structure. This suggests that the genes controlling this *early development* have been inherited from a common ancestor in the distant past. All the young vertebrate embryos show gill slits, even though fish are the only vertebrates to use gills in adult life.

- The comparative embryology data are used as evidence of evolution because they show that ancient characteristics have been passed on as organisms evolved.

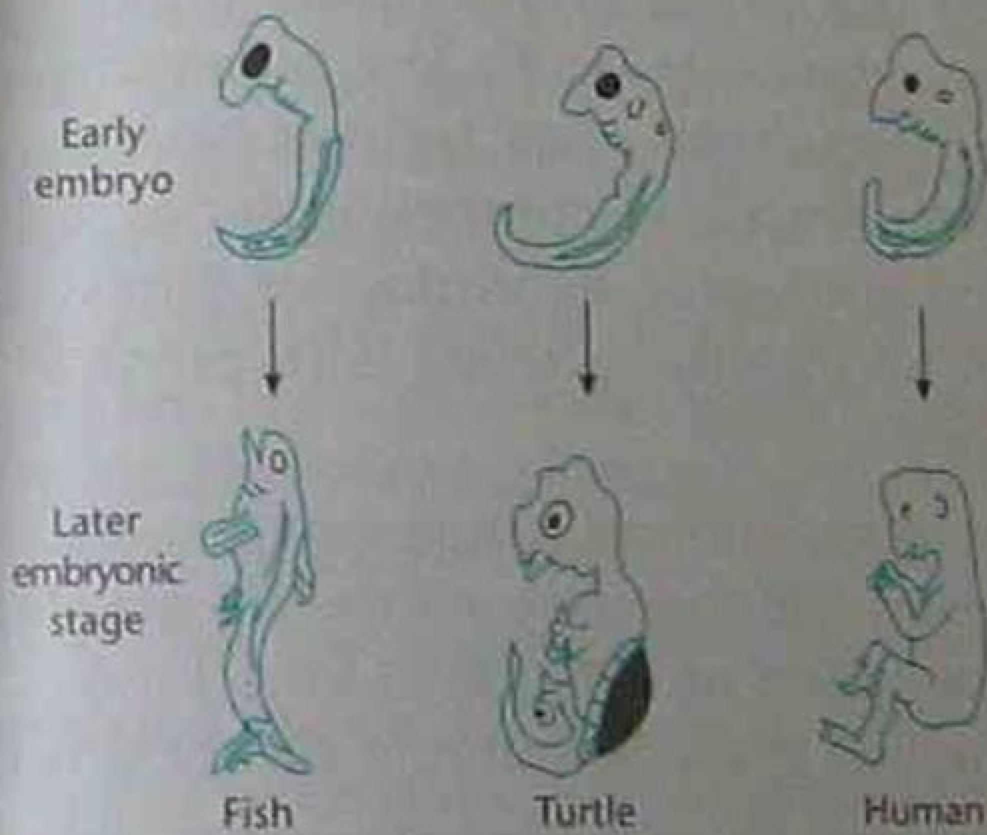


Figure 3.15 Comparison of early vertebrate embryos

7. Evidence from geographic distribution of living things

The theory of plate tectonics explains that the continents of Earth are in constant motion. (See page 130.) In the distant past the continents were joined and animals and plants were not geographically isolated as they are today. They were able to disperse across vast areas of land. As the giant continent (Pangaea) split up (about 225 million years ago) and the smaller landmasses moved to different latitudes, animals and plants became **geographically isolated**. Under these new environmental conditions, the animals and plants evolved to produce new species which were quite different to the common ancestral species, since the environments were so different.

The east coast of South America and the west coast of Africa were formerly joined in a large continental mass called Gondwanaland. Australia, India and Antarctica were also part of this landmass. It began to break apart 100 million years ago.

- Comparisons of various fern and reptile fossils from along the margins of these separated continents show that many modern species shared a common ancestor.

8. Catastrophes and extinction events

The fossil record shows many examples of sudden mass extinctions. These mass extinctions (which usually accounted for at least 75% of species alive at the time) seem to be related to worldwide catastrophes. The extinction of the dinosaurs at the end of the Mesozoic Era (65 million years ago) is a well-known example of a catastrophic event. Over 99.9% of all species that have existed on Earth are now extinct. Scientists have collected evidence of catastrophic events that may be related to extreme climate change, sea level changes and collisions of comets/meteorites with Earth.