**Evolution**

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**TERMS and DEFINITIONS**

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| **Biological evolution:**  | any genetic change in a population that is inherited over several generations. These changes may be small or large, noticeable or not so noticeable. |
| **Hypothesis:** | a **suggested** explanation for an observable phenomenon or proposal that *predicts* a possible outcome.  |
| **Theory:**  | an explanation for something which is **reasonable** or *scientifically acceptable*, but which has not yet been proved to be true. |
| **Theory of evolution:**  | is regarded as a scientific theory since various hypotheses relating to evolution, have been tested and verified over time. |
| **Micro-evolution:**  | **small** changes that take place **within a species** to adapt to survive. |
| **Macro-evolution:**  | **large** changes in **many species** that take place over a **long period** of time. |
| **Fossil:** | the **imprint, traces or preserved remains** of an organism that once lived. A fossil may be plant and animal body parts as well as impressions in rocks or traces left by the organisms. |
| **Fossilisation:** | the process that took place to produce the fossil over a period of time. |
| **Anthropology:** | the study of the human race, including the different belief systems, customs and social habits. |
| **Palaeontology:** | the study of the earliest known periods of human existence, e.g.: the Stone Age. |
| **Archaeology:** | the study of ancient times by examining the buried remains of buildings, tools, animal and plant fossil remains found in rock strata. |
| **Archaeologist:** | a scientist that digs up, studies and traces fossil remains in rock strata. Archaeologists use carbon dating to determine when the animals and plants lived. |
| **Biodiversity:**  | the variety of different plant and animal species found on earth where diversity is the **result** of change over time. |
| **Natural selection:**  | is the **process** of change over time, that takes place in species. |
| **Species:**  | a group of organisms that are **similar in appearance**, share the **same DNA sequences**, perform the **same mating rituals** and **interbreed** to produce viable offspring.  |
| **Population:**  | a group of organisms of different ages, that belong to the **same** **species**, live in the **same area** and **interbreed**. |
| **Variation:** | small changes that will assist an organism where phenotypic variation (physical appearance) is as a direct result of genetic variation. |
| **Continuous variation:** | the variation of a trait in a population, where the trait ranges continuously from one extreme to another **preventing** the subdivision into distinct classes. |
| **Discontinuous variation:** | the variation of a trait in a population that can be ascribed to two or more **distinct forms.** |
| **Artificial selection:** | the selective breeding of plants and animals where specific traits are modified, to satisfy human needs. |
| **Speciation:** | the evolutionary process by which new biological species arise, due to the splitting of the lineage. |
| **Genetic diversity**:  | is the level of biodiversity and refers to the total number of genetic characteristics in the genetic makeup of a species. |
| **Genetic divergence**:  | the process of one species diverging over time, into two or more species where genetic characteristics are passed from one generation to the next. The sequence of the genes as they appear on the DNA that will differ from species to species, so when the genetics are altered, **divergence** takes place. |
| **Extinction:** | all the individuals of a species die and are eliminated permanently because they are unable to adapt to survive. |

**Evidence that Evolution has occurred:**

Theories of human evolution are based on research and scientific evidence that support the concept of **continual change.** Sources like geology, anatomy, embryology, genetics and physiology have been used as explanations for the theories. Further lines of evidence are fossil records, modification of descent, Biogeography and genetics.

**a) Fossil evidence:** The evidence that shows characteristics that make us similar to or different from African apes comes largely from a study of fossils (thousands of fossil fragments). The first record of living material preserved as a **fossil,** is from the **Palaeozoic era** (540 million years ago).

**b) Genetic evidence:** Scientists state that organisms are closely related and are likely to have a common ancestor if they have:

* Identical DNA structure
* Similar sequence of genes and
* Similar portions of DNA with no functions

Species that are closely related have a greater similarity to each other than distant species.

**c) Modifications by descent:**  modifications obtained from the study of the details of the structures of body parts and systems of organisms that belong to a specific phylum.

* **Homologous organs:** (homo = the same) similarity of the formation of a body part or organ due to a **common** evolutionary origin, e.g.:the structure of the pentadactyl limb in seals, bats and humans. The bones, muscles and nerves are arranged in a **similar** manner in a front paw, wing and arm.

**d) Cultural evidence:** Cultural evidence from studies of tools and weapons, as well as language is also used to show similarities and differences between humans and African apes.

**e) Biogeography:** Biogeography is the study of the distributions of organisms in space and time. It can be studied with a focus on ecological factors that shape the distribution of organisms, or with a focus on the historical factors that have shaped the current distributions

**VARIATION**

**Sources of variation**

The genotypes and therefore phenotypes (appearance) of individuals are different from each other because:

1. **Crossing over** in Prophase I of meiosis involves an exchange of genetic material, leading to new combinations of maternal and paternal genetic material in each new cell resulting from meiosis
2. **Random arrangement of maternal and paternal chromosomes** at the equator during metaphase allows different combinations of chromosomes/chromatids to go into each new cell resulting from meiosis making them different
3. **Chance/ Random fertilisation** between different egg cells and different sperm cells formed by meiosis result in offspring that are different from each other
4. **Random mating** between organisms within a species lead to a different set of offspring from each mating pair
5. **Mutation** changes the structure of a gene and therefore the organisms genotype. Since the genotype influences the phenotype, it creates organisms with new, different characteristics from one generation to the next.

**CONTINUOUS AND DISCONTINUOUS VARIATION**

**Continuous variation: Variation** within a population in which a graded series of intermediate phenotypes falls between the extremes. Height in human beings, for example, exists in **continuous variation**

**Discontinuous variation:**  This is where individuals fall into a number of distinct **classes** or categories, and is based on features that cannot be measured across a complete range. You either **have** the characteristic or you **don't**. Blood groups are a good example: you are either one blood group or another - you can't be in between.

**Origins about the ideas about origins:**

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| ***Lamarckism*****Jean Batiste de Lamarck****(1744 to 1829)** | ***Darwinism*****Charles Darwin****(1809 to 1888)** | ***Punctuated Equilibrium***(Theory proposed by Mayr in 1954 and recognised in 1972 after a paper was submitted by Eldredge and Gould) |
| De Lamarck suggested two main themes: 1. ‘**Use and disuse’**: the environment gives rise to changes in animals e.g.: blindness in moles, the presence of teeth in mammals, the absence of teeth in birds and **vestigial organs** (reduced pelvic structures present in a whale skeleton).2. ‘**Inheritance of** **acquired characteristics**’ that caused **change** in organisms de Lamarck used the giraffe to explain his theory - as the giraffe stretched its neck to reach higher leaves, it’s neck stretched and grew longer with each generation. Lamarck’s theories are based on his belief that there are two forces he saw as comprising evolution; * a force driving animals from simple to complex forms, and
* a force adapting animals to their local environments thereby differentiating them from each other.

**Reason for theory being rejected:**It is agreed that **physically** stretching the neck cannot alter the **gene make-up** of the animal. Only the genetics of the organism can cause a physical change.  | Charles Darwin wrote *On the Origin of Species*, published in 1859. Here he concludes that organisms have **evolved by small, gradual changes** that took place over many successive generations.Darwin was influenced by the writings of Alfred Wallace and stated that the present species are **modified descendants** from the species of the past, i.e.: one common ancestor. Evolution can be explained as the **constant change** that has taken place. Darwin’s book was the first theory about evolution to be published. His theory was supported by scientific evidence and was regarded as **credible**. The **process** of change was called **natural selection**. The **long-term** changes in the species were called **evolution**. The result of this change over time results in **Diversity.** | Punctuated Equilibrium explains the speed at which evolution takes place.* Evolution involves long periods of time where species do not change or change gradually through natural selection (known as equilibrium).
* This alternates with (is punctuated by) short periods of time where rapid changes occur through natural selection.
* During which new species may form in a short period of time.
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**Observations upon which Darwin based his theory:**

* Organisms of a species produce a large number of offspring.
* The offspring shoe a great deal of variation.
* Of the large number of offspring produced, only a few survive.
* Characteristics are inherited from the surviving parents to the offspring.

**Darwin’s theory of evolution by natural selection:**

* Organisms produce a large number of offspring.
* There is a great deal of variation amongst the offspring.
* Some have favourable characteristics and some do not.
* When there is a change in the environmental conditions or if there is competition,
* the organisms with characteristics that make them more suited, will survive.
* While organisms with characteristics that make them less suited, will die.
* The organisms that survive, will be able to reproduce,
* thus they will pass the allele for the favourable characteristics on to their offspring.
* The next generation will therefore have a higher proportion of individuals with the favourable characteristics.
* In this way the characteristics of a population gradually change over a long period of time.

The **variation** between individuals is due to differences in **genes.** Only individuals who have characteristics that are adapted to the environment will survive. They reproduce and **pass the suitable** characteristics to the next generation by **natural selection** and so, **evolution** results. If the characteristics are not suitable for survival, the organism cannot adapt and will die leading to eventual **extinction** of the species. **Conservation** is a process to ensure that biodiversity is maintained so that populations do not become extinct.

**Artificial selection in plants and animals**

Artificial selection is the selective breeding of plants and animals, where specific traits are modified, to satisfy human needs. Humans have conducted experiments to develop organisms with selected and desirable characteristics, like cattle that produce better quality and quantity meat and milk, drought resistant wheat and sugar cane with more sugar etc.

This is an **evolutionary mechanism** that results in:

* **new breeds** (animals)
* **new strains** (micro-organisms) and
* **new varieties** (plants).

**New varieties** of plants and animal breeds are produced relatively quickly by selecting parent organisms with the **desired traits**. The commercially viable organism would be homozygous for all the genes involved, whether dominant or recessive, for their desired trait.

**Animals**

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|  | **Inbreeding** | **Outbreeding** |
| **What is it?** | **Inbreeding** is the mating or breeding of two **genetically related** individuals to enhance the desirable traits.  | **Outbreeding** is the mating of individuals of totally **unrelated strains**. This leads to offspring that are better adapted for survival, than either of the parents. This phenomenon is termed **hybrid vigour**.  |
| **Examples:** | * thorough bred racing and show jumping horses
* milk producing cows
* many varieties of dog breeds
* sheep with better quality and quantity of wool production
 | * mongrel dogs are crossed from two different dog sub-species and are far stronger and hardier than highly pedigreed purebreds.
* mules are a cross between a horse and a donkey and are much stronger and better suited to many more tasks than either parent.
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| **Advantages:** | Desirable traits are enhanced in the species without contamination from other species, resulting is a very pure breed. Animals with undesirable or weak traits should be culled. | When sub-species are crossed, a stronger more resilient breed results since desirable traits are bred into the species.  |
| **Disadvantages:** | The gene pool becomes restricted. The strain may become **homozygous** for multiple defective traits:* certain dog breeds like German shepherds are vulnerable to hip dysplasia (weak hips) and congenital femur dislocation
* fighting dogs like the South African Boerboel often become very aggressive and go mad as adults resulting in them having to be put to sleep.
 | In some cases of cross species breeding, the hybrid may not be able to reproduce, because chromosomes cannot form homologous pairs during meiosis. This will result in **hybrid sterility**, e.g.: mules are unable to breed.  |

**Plants:** Artificial selection in plants is the **deliberate altering** of the genetic make-up. The interbreeding of desired traits continues until a new variety is produced. **Homologous recombination** of the chromosomes is used to generate genetic diversity. **Cross-pollination** between varieties would be part of the process. For example, fast growing wheat may be crossed with high-yielding but slow growing wheat. The offspring will be crossed again until a new species result that is fast growing and high yielding. Refer to Mendel’s tall and short varieties of pea plants. Plant breeding and genetic engineering is used to produce crops that are high-yielding, fast growing, pest and disease resistant, drought resistant, frost resistant and require less water.

**Similarities between natural selection and artificial selection (Not in Exam Guideline but can be asked):**

* Organisms with the desirable traits survive and pass these traits on to their offspring
* Organisms that are weak or with the undesirable traits do not survive
* Hybrids are often sterile e.g.: mules, seedless fruit etc.

**Differences between natural selection and artificial selection (Not in Exam Guideline but can be asked:**

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| **Natural Selection** | **Artificial Selection** |
| The environment or nature is the selective force | Humans are the selective force |
| Selection is in response to suitability to the environment | Selection is in response to satisfying human needs |
| It occurs within a species | May involve 1 or more species e.g.: cross breeding different traits in each species |

**Formation of new species**

Speciation results because of:

* + If a population of a single species
	+ Becomes separated by a **geographical barrier** (sea, river, mountain, lake)
	+ Then the population splits into two populations.
	+ There is now no gene flow through the two populations.
	+ Since each population may be exposed to different environmental conditions/the selection pressure may be different,
	+ Natural selection occurs independently in each of the two populations
	+ So that the individuals of the two populations become very different from each other
	+ Genotypically (their genes are different) and phenotypically (their physical appearance)
	+ Even if the two populations were to mix again,
	+ They will not be able to interbreed
	+ The two populations are now different species.

**Keeping species separate:**

When one species gives rise to two new species (speciation), the two new species cannot reproduce with each other if they mix. They remain as separate species due to mechanisms that restrict gene flow between them. This is termed r**eproductive isolation** and result because of:

* **Seasonal isolation:** when breeding/reproduction takes place at **different times** of the season or year. In plants, anthers and stigma mature at different times, to prevent cross-pollination.
* **Behavioural isolation:** animals behave differently during **courting and mating** rituals - females are not responsive, so no mating takes place.
* **Mechanical isolation:** when male and female **reproductive parts change**, making gene transfer impossible. In flowers, the stigma normally releases enzymes to stimulate the growth of the pollen tube. In this case, the enzyme will not stimulate growth, so pollen grain will not grow. In animals, the genitals change so the sperm cannot be transferred into the female, should mating be attempted.
* **Gamete isolation:** when genes change, gametes become chemically altered, so fusion of the gametes is impossible. Should the gametes fuse, gamete isolation will prevent the recycling of the genetic material, e.g.: donkey + horse = **infertile offspring** called a mule.

**Evolution in present times:**

Natural selection and evolution are still taking place in present times.

* **DDT (d**ichloro-**d**iphenyl-**t**richloroethane)

Many years ago, mosquito breeding areas were sprayed with an insecticide called DDT to prevent malaria by killing the mosquito larvae and were initially very effective. However, some insects with mutations in their **sodium channel gene** were resistant to DDT and with breeding took about 7 years for DDT to lose its effectiveness. The genetic trait that caused the resistance to DDT was **homozygous recessive** and eventually resulted in the evolution of the mosquito into a new DDT resistant species. However, the impact of DDT on the environment continues because it is non-biodegradable and toxic. DDT was washed from the soil and leached into underground water and eventually the sea. The weak solution of DDT was absorbed by micro-organisms and through the food chain link, the **concentration increased** and resulted in **bio-accumulation**. Cancer and many other diseases may result in humans. In animals and birds, the **toxin accumulation** results in uncharacteristic behaviour, egg-shell thinning and death. In 1972, the use of DDT was officially banned worldwide.

* **Resistant strains of TB**

Tuberculosis is caused by abacterium called *Mycobacterium tuberculosis* that attacks the lungs, kidneys and bones. Symptoms would include chest pains, fever, coughing, weight loss and shortness of breath. Eventually, mucus and pus block the alveoli causing them to burst, resulting in the person coughing infected spray droplets of blood. Loss of alveoli causes lack of oxygen, resulting in physical weakness. TB is also transmitted in infected milk. The TB bacteria are destroyed when exposed to sunlight and infected people should be isolated and treated with **antibiotics** for a minimum of six months. Children are immunised with inoculations at the local clinics. The TB bacteria have evolved into **‘multi-drug resistant strains’** (MDR-TB), where normal drugs are ineffective. In 2006, **‘extensively drug-resistant tuberculosis’** (XDR-TB) was identified. MDR-TB tends to develop when patients miss doses of antibiotics or do not complete the full treatment. This strain seems less virulent and does not appear to dominate naturally. But XDR-TB has a much higher mortality rate than MDR-TB and does not seem to transmit in healthy populations but appears to be more prevalent in individuals who are **HIV positive**. With the XDR-TB strain, from onset of the disease to death takes approximately 15 to 20 days as this strain does not respond to any of the drugs presently available in South Africa.

**Human evolution**

**Evidence of common ancestors for living hominids, including humans**

The term ‘*Homo*’ refers to the genus and means ‘human’. Studies of human evolution must include hominids such as the Australopithecines, as it is theorized that the *Homo* genus diverged (split) from them about four million years ago in Africa. Scientists have estimated that humans branched from their common ancestor with the chimpanzee about five to six million years ago. Other species of *Homo* like *Homo erectus* and *Homo neanderthalensis* have all become extinct. Substantial fossil proof exists to explain hominid evolution, although it is not enough to make specific conclusions.

**Fossil Evidence:**

* Archaeologists have provided **fossil evidence** to prove that relationships existed between the Early Stone Age cultures in Europe and Northern Africa.
* Discoveries in South Africa, Kenya and Zimbabwe have been used to prove and validate that Africa was the home of early man.

**Genetic Evidence:**

* **Mitochondrial DNA:** MtDNA is the smallest chromosome located in the mitochondria and forms part of the organisms’ genome. In most species, mtDNA is inherited from the mother (maternal inheritance). The sequencing of the mtDNA shows a link in **phylogenetics** and **evolutionary relationships** between species. The age of the common ancestral mtDNA can be estimated to have existed approximately 140,000 to 290,000 years ago linking humans to **Mitochondrial Eve**.

**Cultural evidence: tool-making**

* The earliest hominids to use simple tools known as **Oldowan stone tools**, were *Homo habilis* that lived around 2.6 Ma and signifies the start of the Stone Age.
* *Homo habilis* fossils have been found in many parts of Africa with tools that were made of stone and used to aid hunting and cutting of food.
* *Homo erectus* developed more advanced tools that included **sharpened stones** placed on wooden handles, like an axe.
* They were also the first species to use **flints** and quartzite to make fire.
* Later fossil evidence shows tools like **scrapers** probably used to clean animal skins, slicers and **needles** used to sew animal pelts into the first form of clothes.
* From this point, tools progressed to **knives and blades** used by the Neanderthals used for hunting and protection.
* Fossil evidence shows that as the different species developed larger brains and greater intelligence, so their tools became more complex.

**Characteristics that humans share with African apes:**

* Olfactory brain centres reduced/ reduced sense of smell
* Eyes in front/ Binocular vision / stereoscopic vision
* Eyes with cones/ colour vision
* Freely rotating arms
* Elbow joints allowing rotation of forearm
* Flat nails instead of claws/ bare, sensitive finger tips
* Opposable thumbs
* Bipedal/ upright posture / foramen magnum in a more forward position
* Sexual dimorphism/ distinct differences between males and females
* Parts of the brain that process information from the hands and eyes are enlarged
* Longer upper arms
* Large brains / skulls compared to their body mass
* Five digits per limb

**Anatomical differences between Humans (*Homo sapiens*) and African Apes**

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| **FEATURE** | **Humans (*Homo sapiens*)** | **African Apes** |
| Cranium | Large cranium/brain | Small cranium/brain |
| Brow Ridges | Brow ridges are not well developed | Brow ridges well developed |
| Spine | More curved spine | Less curved spine |
| Pelvic girdle | Short, wide pelvis | Long, narrow pelvis |
| Canines | Small canines | Large canines |
| Palate shape | Small and semi-circular | Long and rectangular |
| Jaws | * Small jaws
* Less protrudingjaws/less-prognathous
 | * Large jaws
* More protruding jaws/

 more prognathous |
| Cranial ridges | No cranial ridge | Cranial ridge across the top of the cranium |
| Foramen Magnum | Foramen magnum in a forward position | Foramen magnum in a backward position |

**Out of Africa hypothesis and evidence for African origins of modern humans**

This hypothesis states that modern *Homo sapiens* evolved in Africa about 200,000 years ago and migrated outwards to Europe and Asia, according to the Southern Dispersal theory.

Most scientists agree that **modern humans** *(Homo sapiens*) **evolved in Africa and spread outwards across the continents.**

The following lines of evidence have been used to support this hypothesis:

* Fossils of *Ardipithecus* were found **ONLY** in Africa
* Fossils of *Australopithecus* and *Homo habilis* were found **ONLY** in Africa
* The **oldest** fossils of *Homo erectus* and *Homo sapiens* have been found in Africa
* Analysis of mitochondrial DNA shows that the **oldes**t female ancestors of humans are from Africa
* Analysis of Y chromosome shows that the **oldest** male ancestors of humans are from Africa

**Fossil Records:**

| **Organism** | **When organism existed** | **Fossil site** | **Discovered by** | **Characteristics** |
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| *Ardipithecus ramidus* | 5-4 mya | North-East Ethiopia | Tim White | Brain size: 300-350 mlForward position of foramen magnum. Very prognathous (more protruding jaws). Heavy brow ridges. Pelvis structure: bipedal and tree climbing. |
| *Australopithecus afarensis* | 4-2,7 mya | EthiopiaKenyaTanzania | Donald Johanson | Brain size: 375 – 550 mlForward position of foramen magnum Very prognathousHeavy brow ridgesCanines large and pointedLong armsNo cranial ridge |
| *Australopithecus africanus* | 3-2 mya | TaungSterkfontein | Raymond Dart | Brain size: 428-625 mlForward position of foramen magnumPrognathousBrow ridgesTeeth large; canines not longLong armsNo cranial ridge |
| *Australopithecus sediba* | 1,9-1,8 mya | Malapa Cave – in the cradle of humankind | Lee Burger | Brain Size: 420 mlLee prognathousBrow ridgesLarge teeth; canines not longLong armsNo cranial ridge |
| *Homo habilis* | 2,2-1,6 mya | Tanzania | Louis and Mary Leakey | Brain size: 650 mlLess prognathousLess pronounced brow ridgesHuman-like teeth; smaller caninesLong arms |
| *Homo erectus* | 2-0,4 mya | Java in Indonesia and then Swartkrans | Eugene Dubois | Brain size: 900 mlPrognathousCranial ridgesShort caninesLonger legs and shorter arms |
| *Homo sapiens* | 200 000 years ago - present | Makapansgat in LimpopoBorder Cave in KZNBlombos Cave in the Western Cape | Tim White | Brain size: 1200-1800 mlNo brow ridgesSmall teethShort arms |

**Phylogenetic trees:**

A phylogenetic tree is a schematic form that shows the evolutionary relationships within a set of organisms or groups of organisms. *Phylo* = organism’s phylum group and *genetic* = from the genes/relationship between the genes

**Hints on interpreting phylogenetic trees:**

**(Modified from Mind the Gap: Grade 12 Life Sciences)**

Reading a phylogenetic tree is similar to understanding a family tree. The base of the tree represents the oldest ancestor and the tips of the branches represent the most recent descendants of that ancestor. As you move from the base of the tree, to the tips of the branches, you are moving forward in time. *.*



When speciation occurs, it is represented as branching on the tree.



Each lineage has a part of its history that is unique and parts that are shared with other lineages.



Similarly, each lineage has ancestors that are unique to that lineage and common ancestors that are shared with other lineages.



