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INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
MAY 2024

BIOLOGY: PAPER II

SOURCE MATERIAL BOOKLET FOR QUESTIONS 1, 2 AND 3
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SECTION A**QUESTION 1**

Read the information below. Refer to this information, as well as your own knowledge, to answer Question 1 in the question paper.

Africa's strange, elusive creatures

There are eight living species of pangolin, distributed across Africa and Asia.

Pangolins eat ants and termites. They have evolved toothless jaws and long, flexible, sticky tongues with which to lick up these insects. They locate insects using their sense of smell. Special muscles seal their nostrils shut while they eat the ants and termites. This is to protect their noses from sand and dust. Their bodies are covered in scales which protect them from bacterial infections and bites, both from insects and large predators. They also have powerful forelimbs and claws to rip open anthills and termite mounds. When threatened, they roll up into a tight ball and will use their sharp-scaled tails to defend themselves.



Figure 1.1 – The pangolin (*Smutsia gigantea*)

Pangolins resemble other species like anteaters and armadillos, which also feed on insects. Even though pangolins, anteaters, and armadillos share many characteristics, they are not closely related. Pangolins were once grouped together with anteaters and armadillos. But pangolins are so unique that Pholidota, a new order, has now been defined, composed only of the eight known pangolin species.

Anteaters have independently evolved specific adaptations based on their diet of ants and termites. They also have strong forelimbs with long claws, used to dig for food. Their noses are long, and they have an acute sense of smell. The mouth is tube-shaped and contains a long tongue covered with thousands of tiny hooks, called papillae. Anteaters are much larger than pangolins and they do not have scales; their bodies are covered in hair, which protects them from insect bites. If they are threatened, they show their long claws to predators, hoping to scare them off.

Pangolins and anteaters have over time evolved toothless jaws. The toothless jaws have evolved independently of each other to serve the same purpose. There are interesting differences in the lower jaws of each animal. Pangolins have lower jaws showing no signs of teeth. Anteaters have no teeth but the nerves and blood vessels for the teeth are still there. These blood vessels and nerves no longer serve a purpose.

[Adapted: <<https://a-z-animals.com/blog/pangolin-vs-anteater-what-are-the-differences/>>]

[Adapted: <<https://ucmp.berkeley.edu/mammal/eutheria/pholidota.htm>>]

[Adapted: <<https://amazingwildlifepodcast.com/>>]



Figure 1.2 – The anteater (*Myrmecophaga tridactyla*)

[Source: <<https://www.britannica.com/animal/anteater>>]

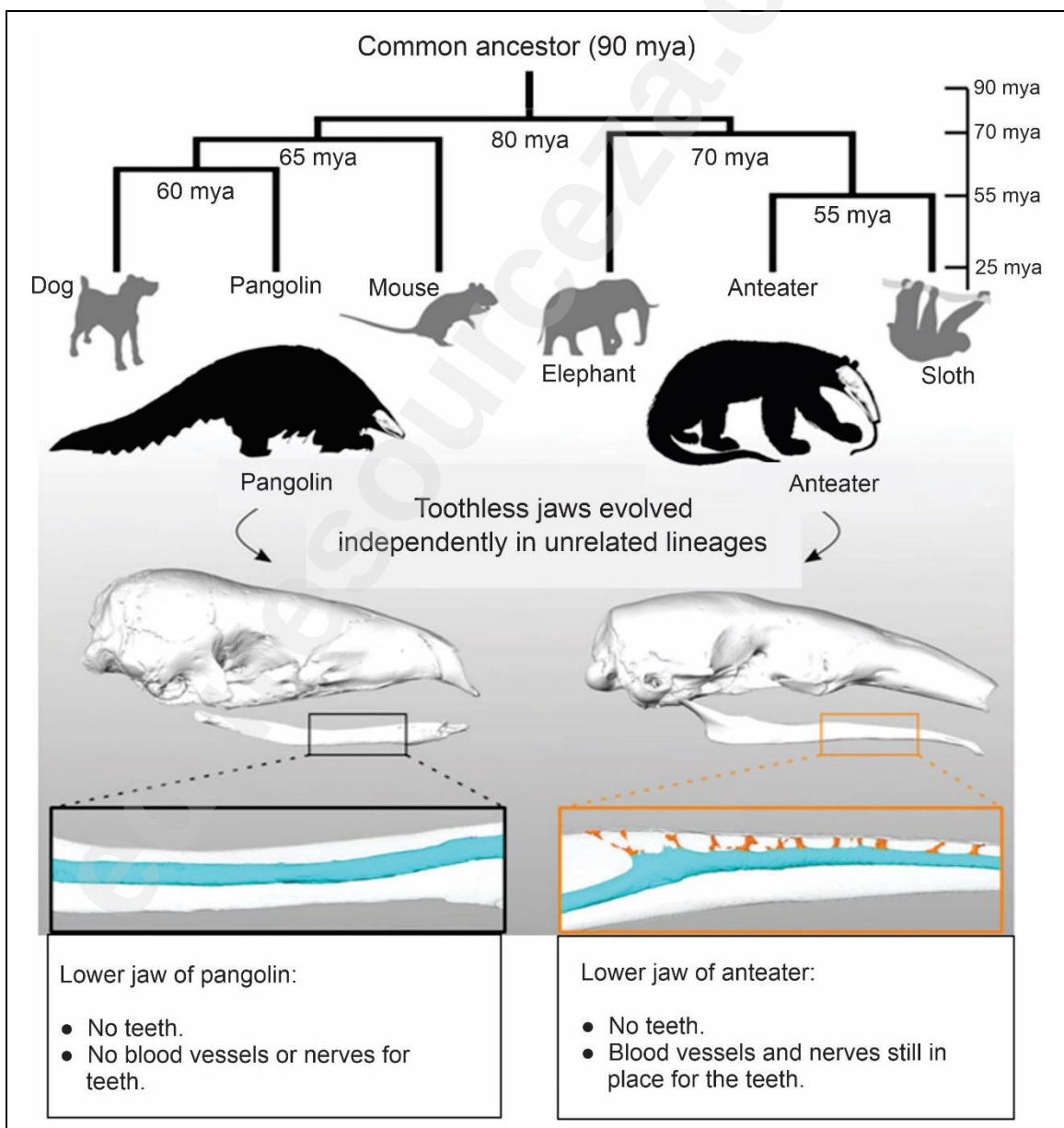


Figure 1.3 – Phylogenetic tree showing relationship between pangolins and anteaters and the evolution of toothless jaws

[Source: <<https://www.sciencedirect.com/science/article/pii/S0960982218316555>>]

Evolution of the pangolin – clues in the pangolin genome

To investigate pangolin evolution, it is necessary to study the pangolin genome. Pangolins are placental mammals. They are covered in scales, which is a rare trait in mammals. Since pangolins are covered in scales, their immune systems have evolved differently from other mammals. Other mammals have interferon genes, which code for proteins needed by the immune system. These proteins help deal with skin infections, skin inflammation and skin healing. Pangolins do not have these interferon genes in their genome. Their scales protect them from infections. Pangolin scales evolved by the process of natural selection. Mutations in the hair genes of the pangolin caused the hairs to harden, fuse, and overlap to form scales.

Other gene mutations may have played a role in the evolution of the pangolin, as shown in the table below.

Table 1. Gene mutations, results of these mutations and effects on the survival of the pangolin.

Genes that are mutated	Results	Effects on survival of the pangolin
Genes that code for tooth enamel	No tooth enamel	The pangolin has no teeth and does not need tooth enamel.
Genes that code for proteins that are necessary for scale formation	Scales form	Pangolins are protected from bacterial infections and predators.
Stress genes	Inability to deal with stressful conditions	Pangolins do not adapt well to a change in habitat or removal to a new area.
Interferon genes – genes that code for proteins needed by the immune system	Harmful bacteria are killed	Not used for protection from bacterial infections.
Vision genes	Poor vision	The pangolin is nocturnal.
Receptor genes involved in sense of smell	Excellent sense of smell	Pangolins have a superior sense of smell to find ants and termites.

Evolution of the pangolin – clues in the skeletal structure of the pentadactyl forelimb

The pentadactyl (five-fingered) forelimb is present in a variety of different animals and provides evidence of evolution from a common ancestor. Mammals, birds, and amphibians all share a similar arrangement of bones in their forelimbs. The pentadactyl limb of the common ancestor was modified for different uses or habitats and is a good example of a homologous structure. The pangolin pentadactyl forelimb has evolved to suit its lifestyle.

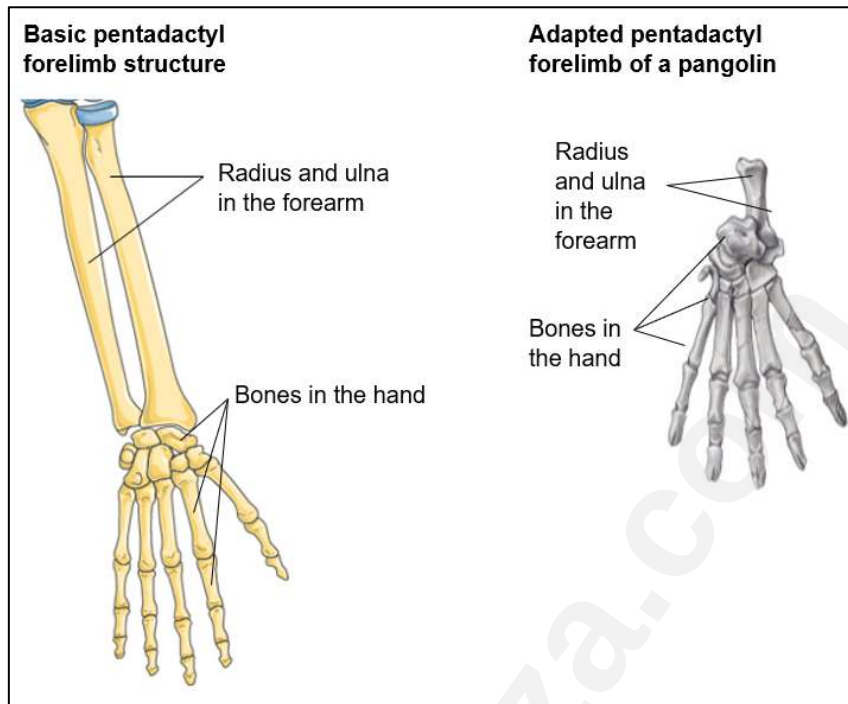


Figure 1.4 – Diagrams of the basic pentadactyl forelimb and the adapted pentadactyl forelimb of a pangolin

Ecological importance of the pangolin

Pangolins keep insect populations under control. When they dig for food, they also mix and aerate the soil, improving soil quality and promoting decomposition cycles. Abandoned burrows also make good homes for other animals.

Threats to the pangolin

All eight species of pangolins are protected under national and international laws, but there is still growing international illegal trade in pangolins. They are one of the most trafficked* mammals in Asia and, increasingly, Africa. The graph below shows the mass of pangolin scales seized by law enforcement officials in Africa – an indication of the trend in pangolin trafficking from 2011 to 2019.

*Trafficked refers to the illegal poaching, smuggling, killing, or selling of protected wildlife

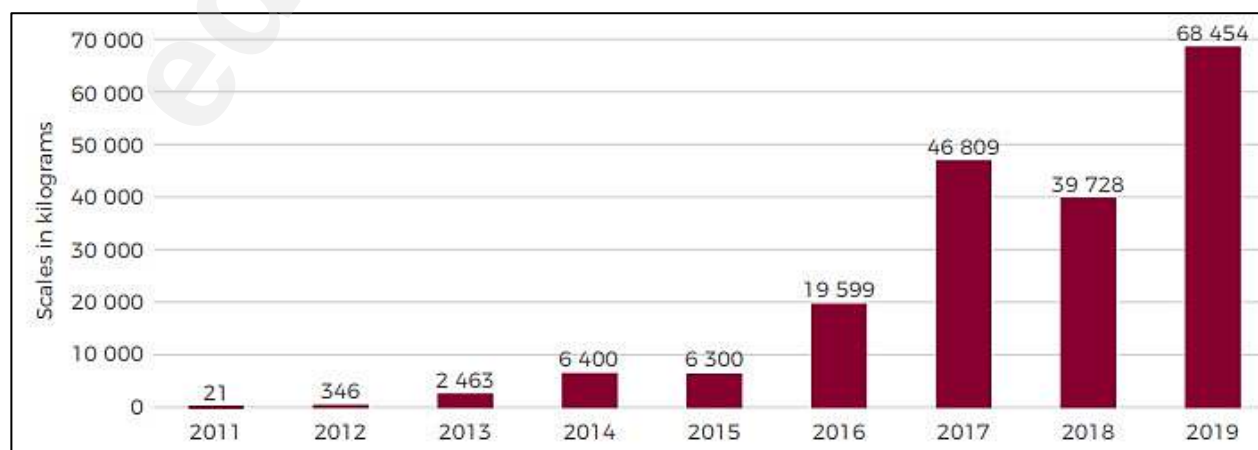


Figure 1.5 – Graph showing the mass of African pangolin scales seized by law enforcement officials from 2011 to 2019

Pangolins are killed because their meat is considered a delicacy and pangolin scales are used in traditional medicine and folk remedies. It is estimated that 80% of Africa's population uses traditional medicine. Even though it is illegal to hunt pangolins, traditional healers continue to use pangolin scales and bones to treat various medical or spiritual problems. While there are plant-based alternatives to pangolin scales and bones, not all traditional healers may know about them.

Out of the eight pangolin species, two are listed as critically endangered. Sequencing the mitochondrial DNA (mtDNA) of different species of pangolin has been useful in helping conservationists understand and trace the illegal trade of these animals, and this could help save them from extinction. mtDNA analysis has also revealed that some pangolin species have a low level of genetic diversity. Conservation goals are to increase heterozygosity within the species and avoid inbreeding.

[Adapted: <<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7782345/>>]

[Adapted: <<https://www.worldwildlife.org/species/pangolin>>]

[Adapted: <https://www.researchgate.net/publication/319975399_Mitochondrial_genomes_of_African_pangolins_and_insights_into_evolutionary_patterns_and_phylogeny_of_the_family_Manidae>]

[Adapted: <<https://www.pangolinsg.org/pangolins>>, <<https://www.worldwildlife.org/stories/what-is-a-pangolin>>]

[Adapted: <<https://peerj.com/articles/9690/>>, <<https://dnascience.plos.org/2016/10/20/how-the-pangolin-got-its-scales-a-genetic-just-so-story/>>]

[Adapted: <<https://pubmed.ncbi.nlm.nih.gov/17536179/>>, <<https://www.nature.com/articles/s42003-022-03757-3>>]

[Adapted: <<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4300090/>>]

[Adapted: <<https://www.frontiersin.org/articles/10.3389/fevo.2022.906398/full>>]

QUESTION 2

Read the information below. Refer to this information, as well as your own knowledge, to answer Question 2 in the question paper.

Fire – the catalyst in human evolution

The East African Rift Valley is known for its volcanoes, beauty, and biodiversity. Some volcanoes in this area are dormant and some have been active in the last 100 years. This fertile valley has played a vital role in human evolution. It is the location of the earliest hominid fossils and became an important route for human migrations 'out of Africa'. Volcanic-ash deposits provide the substance that preserves the bones of buried organisms. For millions of years, active lava flows in the valley provided a consistent source of fire providing very specific adaptive pressures and opportunities to small, isolated groups of hominids.

By about 1,8 million years ago, *Homo erectus* emerged as a fully bipedal, fire adapted species and mastered the technology necessary to make fire itself. This technology was one of the factors that allowed them to move into the rest of the world, taking a new kind of fire with them that would change ecosystems everywhere they went.

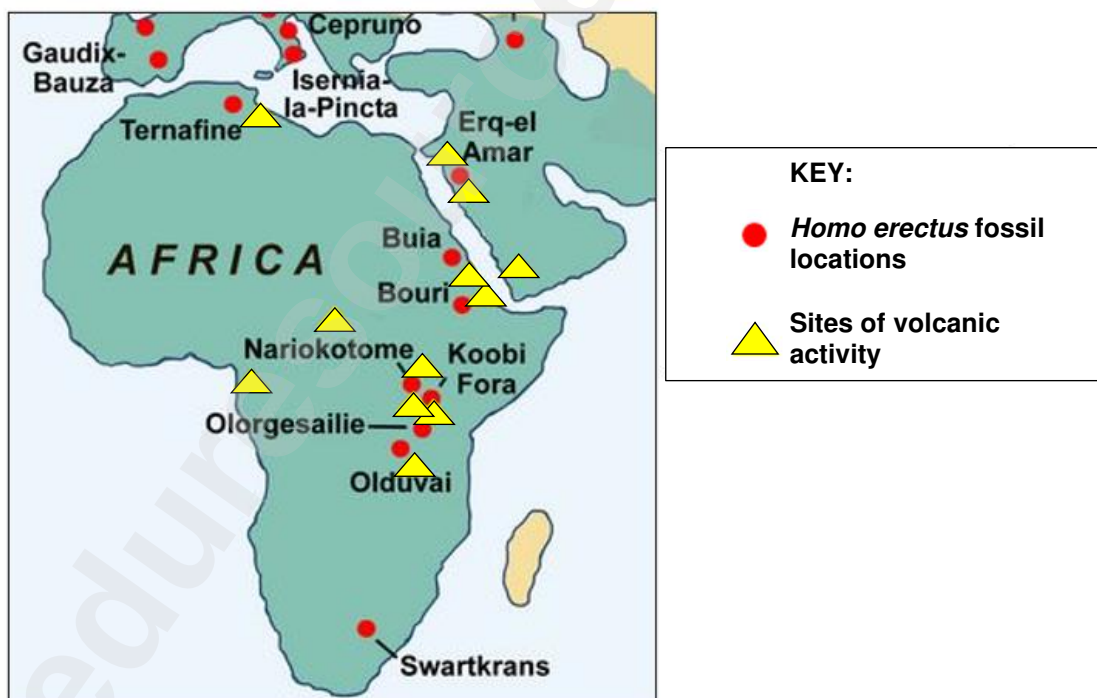


Figure 2.1 – Maps showing sites of volcanic activity and *Homo erectus* fossil sites in Africa

[Adapted: <<https://www.athenapub.com/aria1/PAL/17Records-44.html>>]

Fire and intelligence

Anthropologists have been debating the origins of human intelligence and evolution of the brain for a long time. One of the greatest advantages that fires offered hominids was the opportunity to cook their food. Cooking food detoxifies potentially harmful bacteria, which increased the diversity of food available. Cooked food is easier to chew and digest and supplies the body and brain with important nutrients. Large brains require more energy and more nutrients than smaller brains. Cooking food makes it easier for the body to extract the nutrients needed to sustain a large brain.

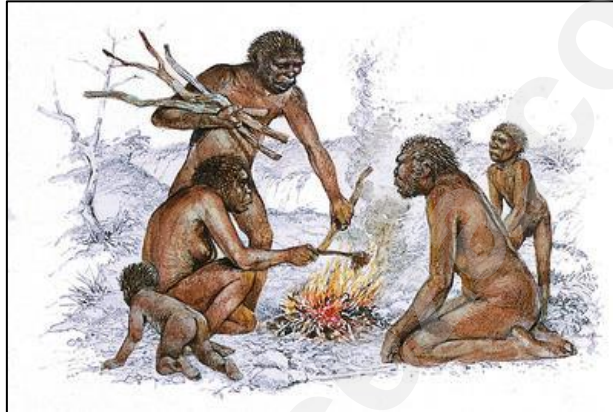


Figure 2.2 – *Homo erectus* sitting around a fire and cooking food

[Source: <<http://fubini.swarthmore.edu/~ENVS2/EarlyHumansEssays.html>>]

Evidence of deliberate use of fire

Finding reliable evidence of the controlled use of fire by hominids is challenging for palaeontologists. Unlike stone tools, evidence of burning, such as ash and charcoal, is easily destroyed by wind and rain. And even when such remains are found, determining whether the fire was caused naturally is difficult. Fires can easily be caused by lava flows and lightning, causing bush fires which can spread quickly in dry conditions. When fires were made in caves, the artifacts are preserved better and are easier to study.

***Homo naledi* may have used fire to cook and navigate**

In December 2022, Professor Lee Berger, an anthropologist from Wits University, revealed his latest dramatic discovery. He announced that he had found evidence of fire use by *Homo naledi* in the Rising Star Cave System in South Africa.

Evidence of fire in the cave system:

- Huge lumps of charcoal – pieces of burned wood.
- Thousands of burned bones.
- The remains of giant fireplaces.
- Baked clay – baked by the heat of a fire.

'This is a remarkable discovery, as the use of fire within a cave system is typically associated with larger-brained *Homo erectus*', says Berger. It is difficult to imagine that *H. naledi*, a primitive human species with a chimpanzee-like skull, **used fires** to cook food and navigate in the darkness of underground caves, despite having a brain one third of the size of *Homo sapiens*. This cave system has small narrow passages, making it difficult and dangerous to navigate.



Figure 2.3 – *Homo naledi*

[Source: <<https://www.express.co.uk/news/science/604208/>>]

H. naledi also seem to have used the cave system in interesting ways. 'There is evidence that they disposed of their dead in one space and made their fires in different spaces', says Berger. This suggests that *H. naledi*'s cultural development was more advanced than first believed.

Scans of *H. naledi* skulls reveal a human-like braincase. The frontal lobe of the brain appeared to be large. This is an area linked with emotion, language, and intelligence. This complex brain indicates that *H. naledi* may have been intelligent despite the small brain size.

H. naledi highlights, once again, that we cannot think of human evolution in terms of ape-like ancestors gradually evolving more modern features in a linear pattern. Instead, many different hominid species evolved at the same time and coexisted, sometimes side-by-side.

The *H. naledi* bones were found in piles, covered with muddy sediment, and their geological age was determined to be between 235 000 and 336 000 years old. The bones make good specimens for the extraction of ancient DNA and proteins. The study of DNA and proteins (proteomics) are both technologies that scientists can now use to prove how closely related *H. naledi* and *H. sapiens* really are.

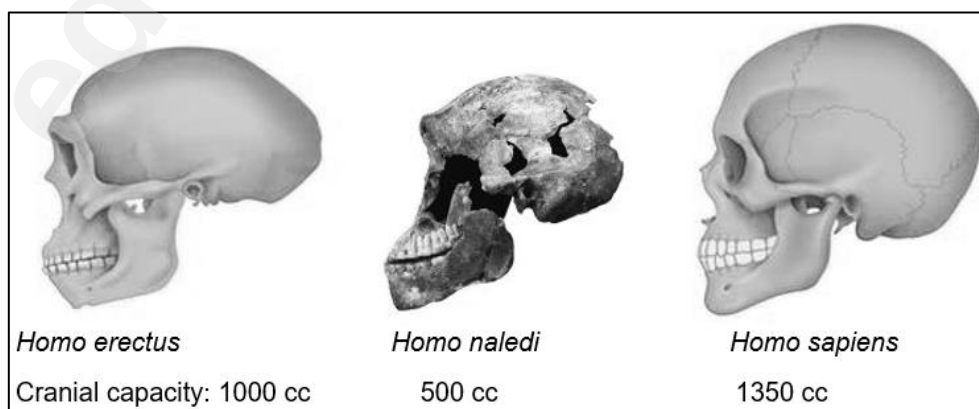


Figure 2.4 – Skulls and cranial capacities of three different members of the *Homo* genus

[Adapted: <<https://naturalishistoria.files.wordpress.com/2017/06/hominin-skulls-size-compared-lc-naledi-erectus-floresiensis.png>>]

Homo naledi is proof that a large brain is not the only determinant of hominid intelligence.

Anthropologists at the Evolutionary Studies Institute of Wits University have found a new way to estimate the intelligence of hominids. Measuring the rate of blood flow to the brain may be a better indication of cognitive ability than brain size alone.

It is possible to measure the rate of blood flow to the brain. This can be done by measuring the size of the openings for the internal carotid arteries on the base of the skull. The internal carotid arteries supply the brain with blood. Researchers have calculated that the rate of blood flow to the brain increased about 600% across human evolution. The brain size has increased by 350% across human evolution. Increased blood flow to the brain increases the brain's supply of oxygen and nutrients, increasing metabolism, neuron connections and brain complexity.

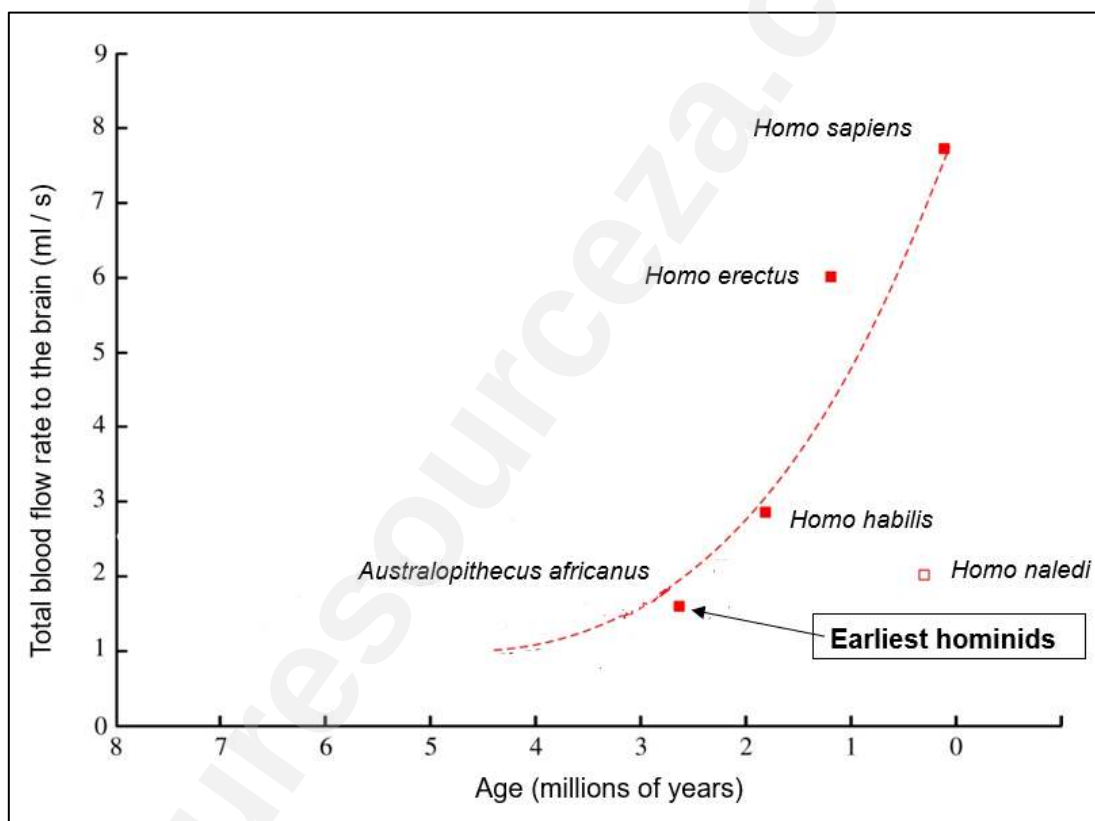


Figure 2.5 – Graph showing total blood flow rate to the brain (ml/second) in different hominids over time

[Image adapted: <<https://royalsocietypublishing.org/doi/10.1098/rspb.2019.2208>>]

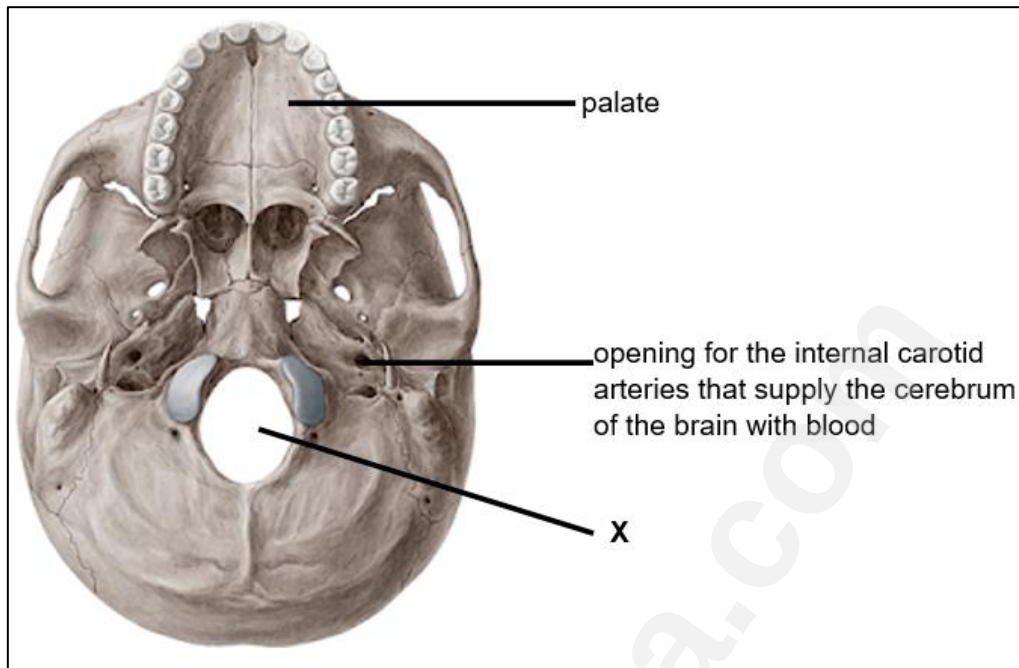


Figure 2.6 – Base of the human skull

[Adapted: <https://gridclub.com/subscribers/info/fact_gadget_2009/1001/human_world/prehistoric_people/639.html>]

[Adapted: <<https://www.scientificamerican.com/article/does-brain-size-matter1>>]

[Adapted: <<https://fireecology.springeropen.com/articles/10.4996/fireecology.0701013>>]

[Adapted: <<https://www.nature.com/articles/nature.2012.10372>>]

[Adapted: <<https://www.newscientist.com/article/2350008-homo-naledi-may-have-used-fire-to-cook-and-navigate-230000-years-ago/>>]

[Adapted: <<https://news.wisc.edu/homo-naledi-had-a-tiny-brain-but-it-looked-a-lot-like-ours/>>]

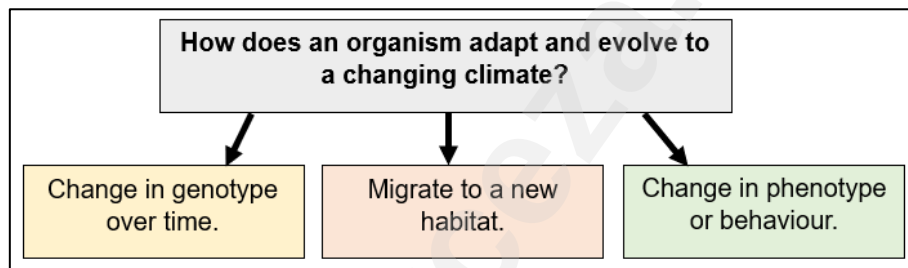
[Adapted: <<https://www.sbs.com.au/topics/science/humans/article/2016/08/31/could-blood-flow-brain-have-driven-evolution-human-intelligence>>]

SECTION B**QUESTION 3**

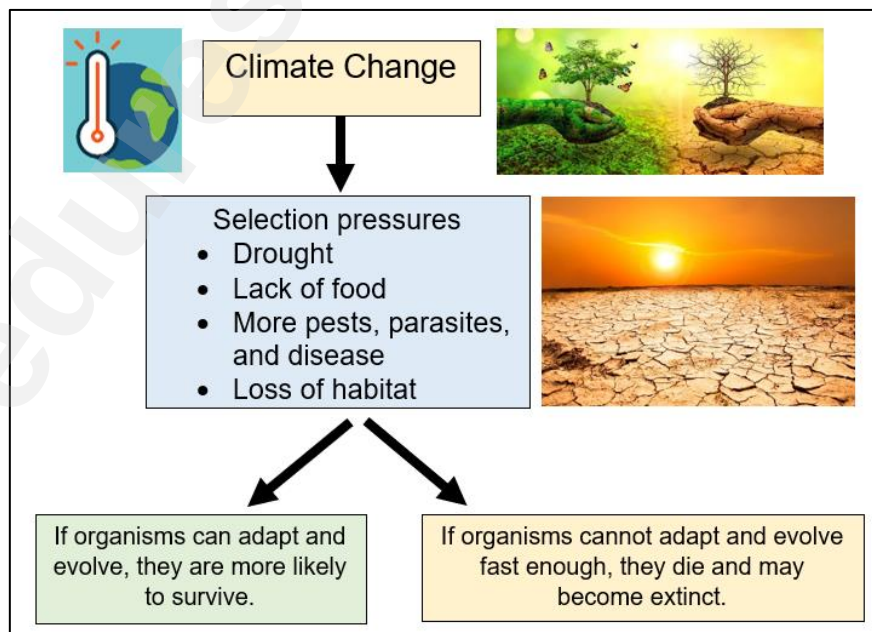
Read the information below. Use this information as well as your own knowledge to answer Question 3 in the question paper.

SOURCE A Climate change and the evolution of organisms

Climate change refers to a change in the average weather conditions – such as temperature and rainfall over a long period of time. Consequences of climate change are intense droughts, water scarcity, wildfires, rising sea levels, flooding, melting polar ice, and severe storms. Natural selection is a mechanism of evolution. It is the process through which species adapt to changes in their environments. However, the rapid and extreme changes brought about by climate change are making it more challenging for organisms to adapt and evolve successfully.



Each adaptation acts as a source of variation that natural selection can act on, which could result in the evolution of the species. The process of evolution is not always a slow one. If the selection pressures are strong enough, evolution can happen over a few decades.

How does climate change affect evolution?

[Adapted from a Biological Sciences Journal article, which has been peer-reviewed<<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2817147>>]

[Adapted from an article published by the United Nations: <<https://www.un.org/en/climatechange/what-is-climate-change>>]

SOURCE B**Is climate change happening too quickly?**

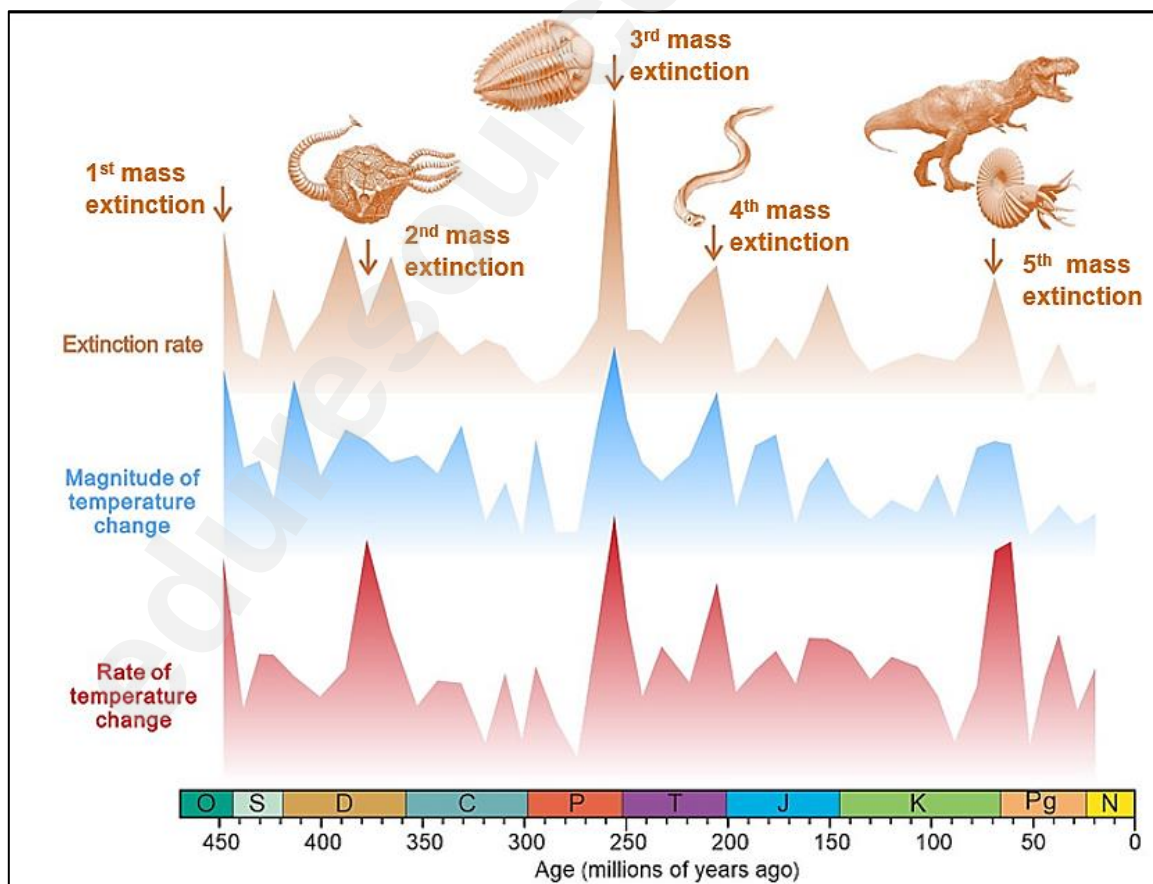
Evolution is usually a gradual process that takes place over generations. If the environment changes too quickly, species do not have the time to adapt. As the present climate is changing so quickly, researchers do not expect to see the same evolutionary adaptation in the future as has happened in the past. Smaller species, with shorter reproductive cycles can adapt faster. The larger the species, the longer it takes to evolve; their slow breeding rate may make them less able to adapt to a rapidly changing climate.

One of the reasons the woolly mammoth became extinct is because of climate change.

[Adapted from an environment magazine article. Magazine articles have not been peer-reviewed:
<<https://ec.europa.eu/research-and-innovation/en/horizon-magazine/changing-climate-may-have-speeded-evolution>>]

[Adapted from The Scientist: a magazine for Life Sciences professionals that publishes articles written by scientists and journalists: <<https://www.the-scientist.com/news-opinion/finding-the-cause-of-mammoth-extinction-70463>>]

The woolly mammoth
is extinct

**Temperature change and mass extinctions over the past 450 million years.**

[Adapted from a Research Community blog: <<https://ecoevocommunity.nature.com/posts/mass-extinctions-correlate-with-the-extent-of-climate-change>>]

Larger animals are less likely to evolve fast enough to changing climates

[Taken from a Twitter account: <<https://twitter.com/AssaadRazzouk/status/1270804714242936832>>]

SOURCE C**Evolution in birds due to climate change**

There is an interesting link between climate change, the timing of seasonal events and evolution in birds. These seasonal events include bird migrations and breeding times. As climate change affects temperature and rainfall patterns, it exerts selective pressures on the birds and adjusts the timing of these seasonal biological events.

Many African birds have evolved by changing their behaviour or phenotypic characteristics in response to changes in the environment. These changes occur because some genes can produce more than one effect when exposed to different environments. Environmental factors cause genes to be switched on or off, which causes phenotypic changes in the birds. These changes can be reversed once the environment returns to normal. Over time, the phenotypic changes can become an evolutionary adaptation.

Diagram showing the possible effects of climate change on the evolution of birds

- Birds have adapted to warmer temperatures by using more energy to keep cool (thermoregulation). The consequence is that birds have less energy for breeding.
- Changes in rainfall change the development of ovaries and testes. This phenotypic adaptation to climate change has a negative impact on reproductive success in birds.
- An example is the red-backed shrike.



- Changes in rainfall change times when insects hatch.
- Birds feed on insects and adapt by changing their breeding times.
- Later breeding means fewer offspring are produced.
- Rainfall encourages nesting behaviour in birds.
- Climate change affects rainfall patterns.
- Birds adapt by changing their nesting behaviour, but they breed less regularly.
- An example is the African olive thrush.



[Adapted from a scientific journal article, which has been peer-reviewed:
<https://link.springer.com/chapter/10.1007/978-3-319-91689-7_12>]

[Adapted from an article published on a scientific news website: <<https://www.science.org/content/article/global-warming-shrinks-bird-breeding-windows-potentially-threatening-species>>]

[Adapted from a news article published by Columbia University:
<<https://news.climate.columbia.edu/2018/03/30/helps-animals-adapt-not-climate-change>>]

Examples of other interesting evolutionary responses to climate change**Table corals**

Higher temperatures cause many corals to lose their colour and turn white. Table corals have adapted and evolved to become heat tolerant. They can survive in higher temperatures without turning white. They can also regenerate and restore damaged coral reefs 14 times faster than any other coral species.



[Adapted from a blog: <<https://blog.nature.org/science-brief/table-corals-could-be-the-key-to-a-resilient-great-barrier-reef>>]

The tawny owl

The tawny owl is a common nocturnal predator in Europe. The owls come in two colours: one light grey and the other a darker brown. As temperatures rise, there is less snow. Natural selection favours the darker brown owls. They are more camouflaged and can hunt more successfully.



[Adapted from Nature Communications, a peer-reviewed scientific Journal:
<<https://www.nature.com/articles/ncomms1213>>]

Mosquitoes

Climate change could speed up mosquito evolution. This could worsen the spread of mosquito-borne diseases like malaria, dengue, and Zika. Humans are developing the abnormal sickle haemoglobin gene as an evolutionary response to malaria. As malaria continues to spread, more humans will carry this gene.



[Adapted from *Yale University Climate Connections magazine* – this magazine publishes articles written by university graduates. <<https://yaleclimateconnections.org/2019/04/climate-change-could-foster-rapid-mosquito-evolution/>>]

Cape ground squirrels

As the Earth warms, it is important for animals to be able to regulate their temperature, to survive. The Cape ground squirrel lives in the dry grasslands of South Africa. Over the last 18 years, the squirrel's foot length has increased by 9%. Squirrels lose heat through their feet. This adaptation enables the squirrel to stay cooler when temperatures are hotter.

This adaptation has its limits. A squirrel's foot can only evolve to a certain maximum length. If temperatures keep rising, this adaptation may not be enough for continued survival.



[Adapted from the *Journal of Mammalogy*, a peer-reviewed scientific journal: <<https://academic.oup.com/jmammal/article-abstract/>>]

SOURCE D**Climate change impacts whole ecosystems**

Climate change not only affects individual species; it affects entire ecosystems. The intricate web of interactions between species can be disrupted by slight differences in temperature and rainfall. Species often work together in mutualistic relationships. One species relies on the other for survival. Even if one species adapts, the other might not adapt or take longer to adapt. This leads to a breakdown in these essential interactions.

[Adapted from Wikipedia, a website that can be edited by the public: <https://en.wikipedia.org/wiki/Effects_of_climate_change_on_ecosystems>]

Plants and their pollinators

Plants and their pollinators have evolved together over millions of years. Flowering plants rely on pollinators for reproduction. Pollinators, such as bees, depend on flowers for pollen and nectar. Climate change can cause differences in the timing of the plant flowering or the bee hatching. If bees do not pollinate the flowers of fruit trees or staple crops, it will affect the survival of both bees and plants.

Cape sugarbirds rely on nectar-rich fynbos plants to flower at specific times of the year. If climate change affects either the bird or the flower's habitat, this delicate bond between pollinator and plant could be broken. Species in the fynbos biome may become extinct because the birds are no longer pollinating them.

[Adapted from a blog: <<https://acdi.uct.ac.za/articles/2015-02-25-bee-or-not-bee>>]

Cape sugarbird feeding on nectar

[<<https://www.greenmatters.com/p/bees-population-decline-crops>>]

Bees pollinate fruit trees

[<https://www.sa-venues.com/wildlife/birds_cape_sugarbird.php>]

Hybridisation

Hybridisation is the process of an animal or plant breeding with an individual of another species. This process results in offspring that have a mix of genes from two different species. Hybridisation can allow the rapid exchange of beneficial genes, such as those related to temperature tolerance or disease resistance, allowing species to better cope with the challenges caused by climate change.

Hybridisation in Lake Victoria in East Africa

Lake Victoria is home to a wide variety of cichlid fish species. In recent years, the lake's ecosystem has been affected by rising temperatures and changes in water quality. These changes are increasing the likelihood of hybridisation in the cichlid fish.

Hybridisation occurs in two different ways:

1. Hybridisation between different indigenous cichlid species

Hybrids possess a unique combination of favourable genes that help them adapt and survive in the altered aquatic environment.

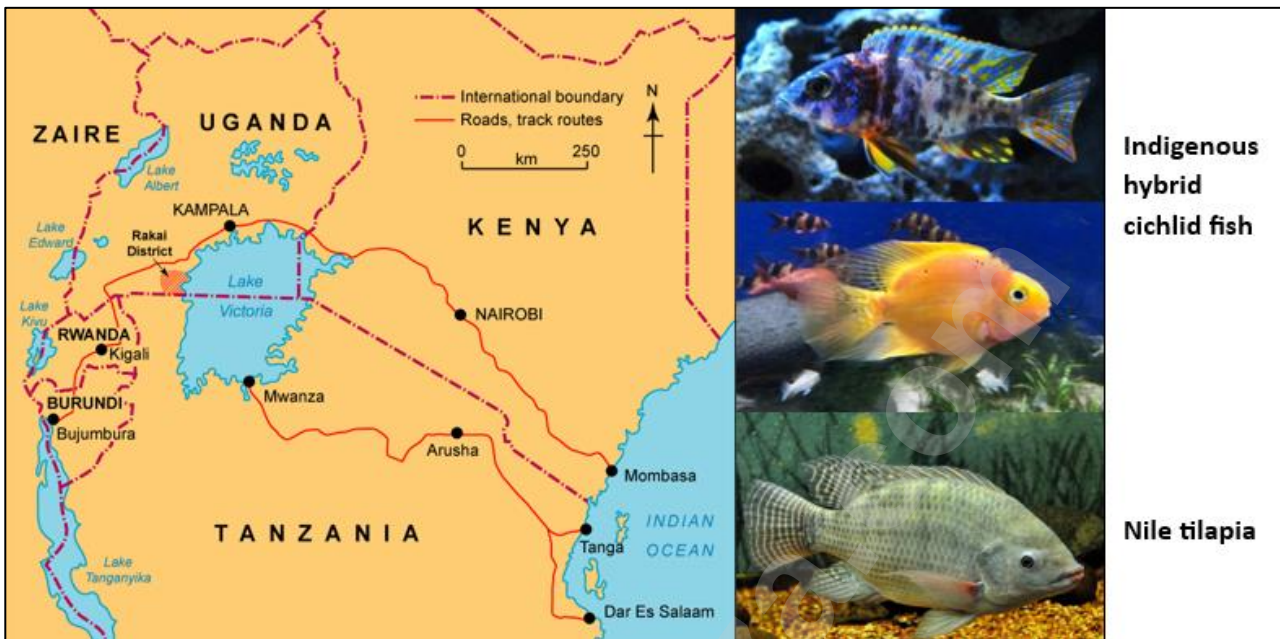
2. Hybridisation between indigenous cichlids and alien cichlid species

The Nile tilapia is a large, alien invasive species of cichlid.

Hybridisation of indigenous cichlids with this species can decrease genetic diversity of the cichlid fish population and cause the loss of native species.

Map of Lake Victoria

Cichlid fish in Lake Victoria



[Adapted from peer-reviewed articles published in the journal of Molecular Ecology and the Nature Climate Change Journal: <<https://onlinelibrary.wiley.com/doi/10.1111/mec.15638>>]

[Adapted from Nature : an international journal that publishes peer-reviewed research: <<https://www.nature.com/articles/s41558-022-01585-1>>]

SOURCE E

The effect of changing migration patterns on evolution

The Earth's changing climate is causing a change in migration patterns of many different animals, including birds. As habitats change, species need to explore new territories to ensure their survival. The benefits of these new migration patterns are increased gene flow.

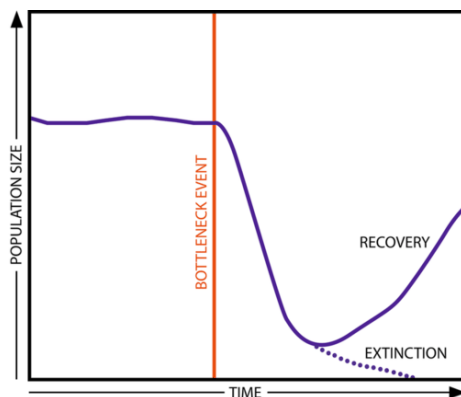
Gene flow is the transfer of genes between populations. This increases genetic diversity in a population, which is especially important for species living in small, fragmented habitats. Gene flow enhances a population's ability to adapt to future environmental changes.

[Adapted from a magazine article: <<https://ec.europa.eu/research-and-innovation/en/horizon-magazine/changing-climate-may-have-speeded-evolution>>]

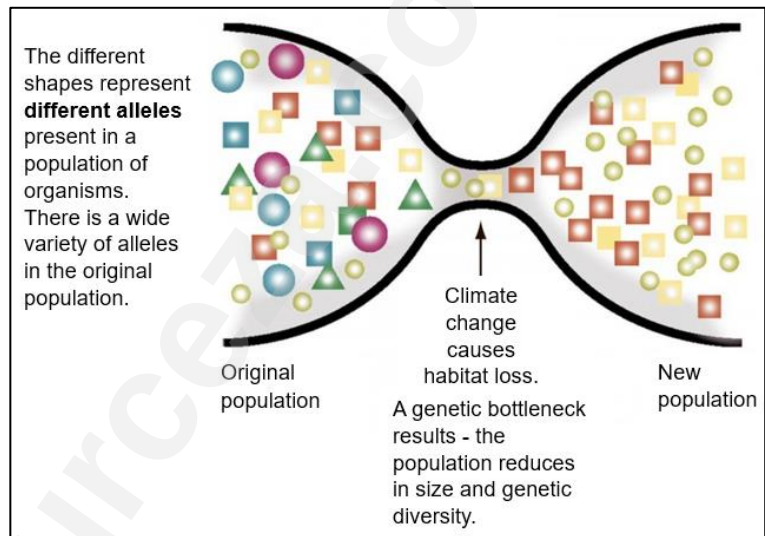
SOURCE F Climate change and genetic bottlenecks

A genetic bottleneck event occurs when a population is greatly reduced in size, limiting the genetic diversity of the species. Climate change can cause habitat loss which decreases the populations of many different species. Climate change also causes habitat fragmentation which isolates populations and reduces gene flow.

Graph representing the effect of a genetic bottleneck event on the population size of an organism.



A diagram representing changes in alleles in a population because of a genetic bottleneck event.



[Image adapted: <<https://naturalishistoria.files.wordpress.com/2016/03/bottleneck.jpeg>>]

SOURCE G Climate change and effects on DNA**Mutations**

Mutations are an important source of genetic variation in a population. Extreme temperature changes can increase the rates of mutations within DNA. Resulting genetic changes could be beneficial or harmful to organisms.

**Changes in gene expression**

Plants are affected by and respond to the external environment. Climate change is a source of environmental pressure for plants. Plants have developed many adaptations and strategies to these pressures. One of them is a slight change in the DNA molecule that changes the activity of a DNA segment without changing the DNA sequence. Gene expression changes and these changes help plants become drought resistant.

[Adapted from an article published on a news site: <<https://www.uu.se/en/news/archive/2021-02-03-warmer-climate-may-make-new-mutations-more-harmful>>]

[Adapted from The International Journal of Molecular Science, which is peer-reviewed: <<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9266845/>>]

SOURCE H**Climate change and assisted evolution**

Assisted evolution refers a range of human interventions aimed at speeding up naturally occurring evolutionary processes in organisms. The goal is to help species adapt to a changing environment more quickly than they would through natural selection. Common approaches include:

Assisted hybridisation – humans can control hybridisation between species to ensure that hybrids have a combination of only the best traits from both parents.



Genetic modification can be used to produce crops that reduce agricultural greenhouse gas and are resistant to disease.



Assisted evolution

Assisted gene flow – a technique used to speed up species adaptation to climate change by bringing in genetic diversity into at-risk populations. Can involve moving individuals from one location to another, such as corals.



Artificial selection can be used to produce desired qualities in plants and animals like drought resistance and resistance to pests and disease.

Dr Maliata Athon Wanga has developed drought-resistant sorghum in Namibia.



Unfortunately, artificially selected plants can take resources away from naturally selected plants because they adapt faster.

[Adapted from a blog: <<https://vittana.org/16-advantages-and-disadvantages-of-selective-breeding>>]

[Adapted from a news site: <<https://saees.ukzn.ac.za/news/designing-namibias-drought-tolerant-sorghum/>>]

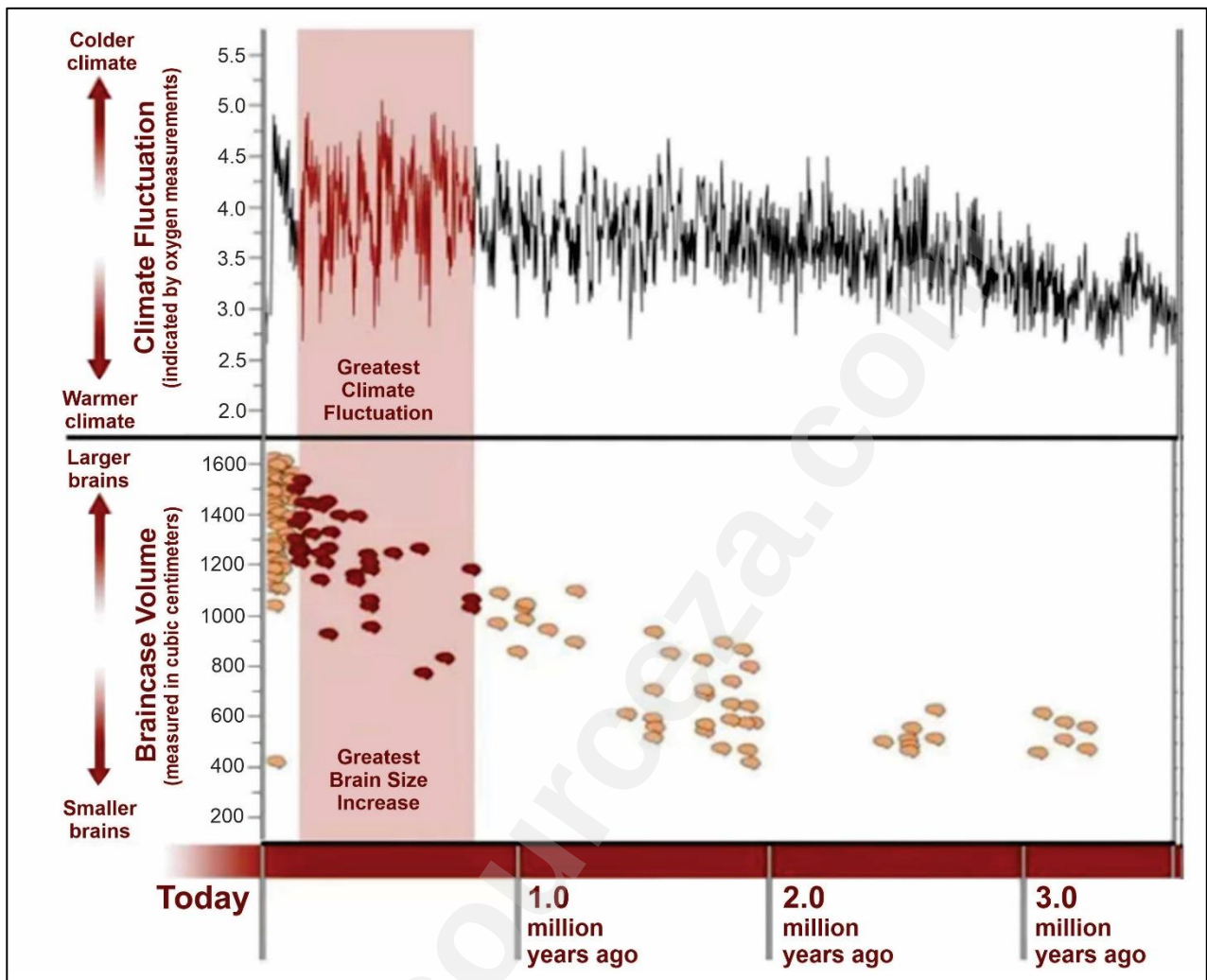
[Adapted from an article published by the Australian Institute of Marine Science: <<https://www.aims.gov.au/research-topics/environmental-issues/climate-change/assisted-evolution>>]

[Adapted from a journal article available on: <<https://pubmed.ncbi.nlm.nih.gov/35148945/>>]

[Adapted from an online magazine: <<https://www.food-management.com/news-trends/viewpoint-gmos-are-good-farmers-consumers-and-environment>>]

[Adapted from Wikipedia, a website that can be edited by the public: <https://en.wikipedia.org/wiki/Assisted_evolution>]

SOURCE I **Impact of climate change on hominid evolution**



[Image: <<https://humanorigins.si.edu/research/climate-and-human-evolution/climate-effects-human-evolution>>]