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St Catherine's Convent

GRADE 12 LIFE SCIENCES

PRELIMINARY EXAMINATION 2023

PAPER II

**SOURCE MATERIAL BOOKLET FOR
QUESTIONS 1, 2 AND 3**

QUESTION 1**SOURCE 1**

SCIENCE | ARCHAEOLOGY

Prehistoric humans knew the dangers of inbreeding and formed complex social networks to avoid it

Recent research has found that early humans seem to have recognised the dangers of inbreeding at least 34,000 years ago and developed sophisticated social and mating networks to avoid it. The research was carried out by an international team of academics, led by the University of Cambridge, UK, and the University of Copenhagen, Denmark. They sequenced the genomes of four individuals from a late Palaeolithic site in Russia, called Sunghir, which is believed to have been inhabited about 34,000 years ago.

Skeletons of four individuals buried at Sunghir provided DNA for the new analysis. These individuals include a male in his own grave and two preteens or early adolescents placed head-to-head in the same grave. Both graves included fancy items such as ivory beads and spears, armbands, and carvings.

These fossils represent a rare and highly valuable source of information because it is a very unusual find from this period and the people buried there appear to have lived at the same time and were buried together. To the researchers' surprise, however, these individuals were not closely related in genetic terms. The DNA from the four Sunghir individuals includes parts of the sex chromosomes, which allowed the scientists to identify the adult male.

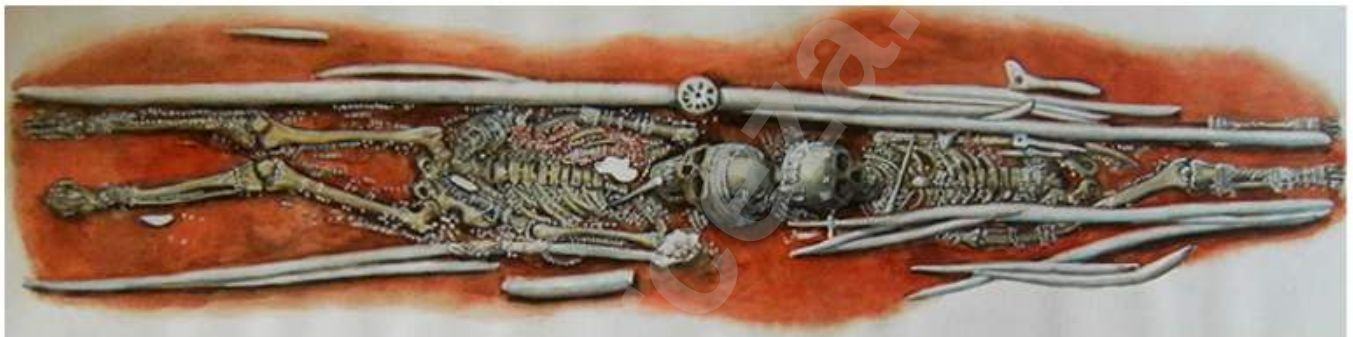
The study, reported in the journal of Science, examined genetic information from the remains of anatomically modern humans who lived during the late Palaeolithic, a period when modern humans from Africa first colonised western Eurasia. The results suggest that people deliberately sought partners beyond their immediate family, and that they were probably connected to a wider network of groups from within which mates were chosen, to avoid becoming inbred.

HUMAN FOSSILS BURIED AT SUNGHIR

IMAGE 1 - what they probably looked like at the time of death.



IMAGE 2 - shows how they looked when they were found.



This study suggests that our distant ancestors are likely to have been aware of the dangers of inbreeding, and purposely avoided it at a surprisingly early stage in prehistory and the key to humans' evolutionary success. It also suggests that much like hunter-gatherers today, the ancient Eurasians mated outside their groups and formed webs of social circles vital for eventually building cities and civilizations.

These hunter-gatherers lived in groups with few close relatives, thus limiting opportunities for inbreeding say the evolutionary scientists on this study. The scientists conclude it's likely that adolescents of both sexes found mates in communities other than their own, fostering social ties among groups that might otherwise avoid or fight each other. Modern hunter-gatherers likewise find partners among nearby groups. The Sunghir fossils did not display genetic markers of inbreeding previously observed in Neandertal DNA. The researchers propose that Neandertals lacked mating networks like those of ancient humans.

Adapted from <https://www.globaldatinginsights.com/news/prehistoric-humans-may-have-survived-by-formed-complex-social-networks-to-avoid-inbreeding/>.

SOURCE 2

Homo sapiens are the only species of hominin alive today. The table below gives estimated ranges of existence for several hominin species, based on fossil evidence.

Species name	Earliest date found (number of years ago)	Latest date found (number of years ago)	Location
<i>Australopithecus anamensis</i>	4200 000	3800000	East Africa
<i>Australopithecus afarensis</i>	3850000	2950000	East Africa
<i>Australopithecus africanus</i>	3300000	2100000	South Africa
<i>Homo habilis</i>	2400000	1400000	East and South Africa
<i>Homo rudolfensis</i>	1900000	1800000	East Africa
<i>Homo erectus</i>	1890000	110 000	North, East and South Africa West and East Asia
<i>Homo floresiensis</i>	700000	50 000	South-East Asia (Indonesia)
<i>Homo neanderthalensis</i>	400 000	40 000	Europe South-West and Central Asia
<i>Homo sapiens</i>	300000	present	earliest in North Africa, now worldwide

Data: Smithsonian National Museum of Natural History, 'What does it mean to be human'

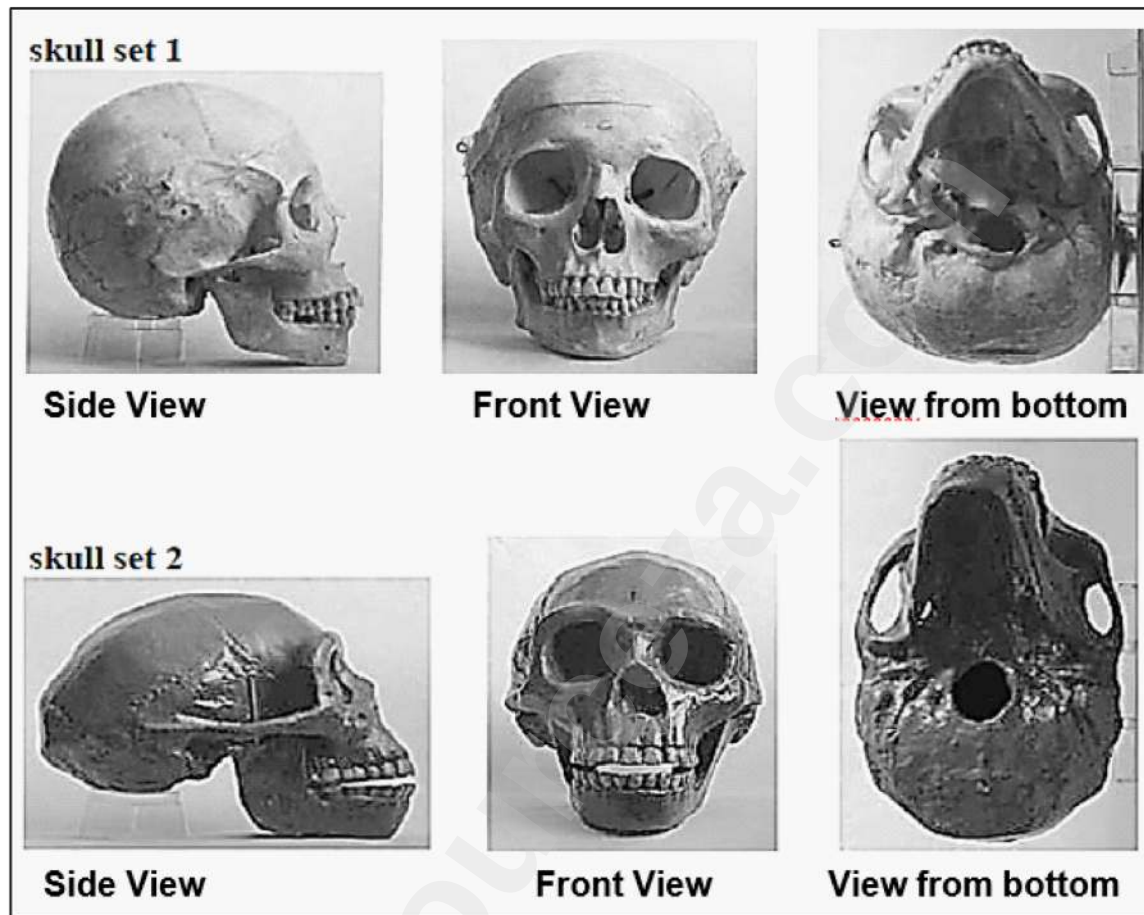
SOURCE 3 FIGURE 1

Figure 1: Migration of *Homo Sapiens*



<https://www.worldhistory.org/image/6605/map-of-homo-sapiens-migration/>

SOURCE 3 FIGURE 2

Figure 2: Different views of skulls from *Homo erectus* and *Homo sapiens*Adapted from <https://studylib.net/doc/6899171/human-evolution-exam->

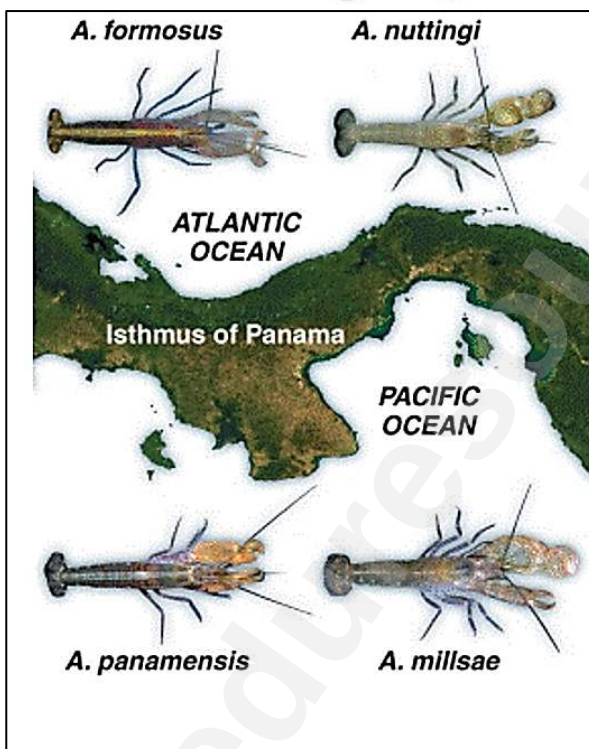
QUESTION 2

SOURCE 4

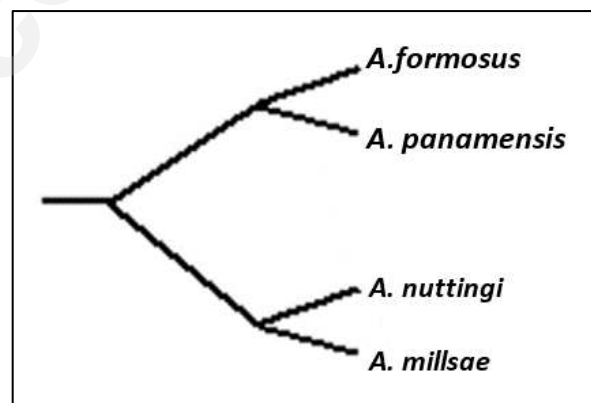


The Isthmus of Panama developed approximately 3 million years ago. The formation of this land mass separated the continents of North and South America. Many marine populations also become separated. One such example is that of the population of snapping shrimp.

Researchers have noticed that shrimps from both sides of the isthmus appear nearly identical to one another. However, when male shrimp from one side of the isthmus is paired with female shrimp from the other side of the isthmus, the shrimp display aggressive behaviour toward one another and will not mate.



Cladogram showing relationship between snapping shrimp.



Adapted from:

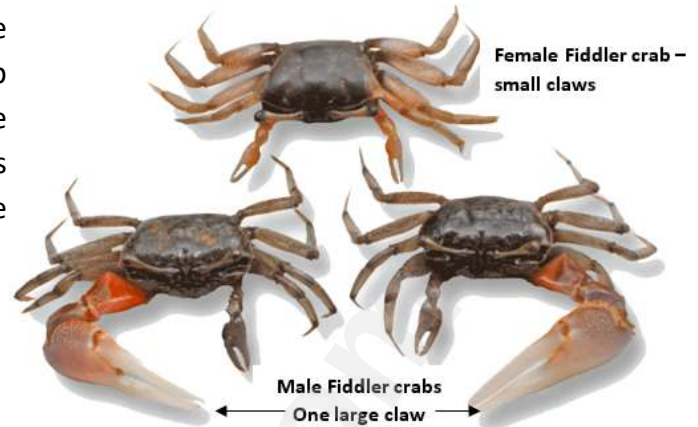
<https://www.toppr.com/ask/question/the-isthmus-of-panama-developed-around-3-million-years-ago-the-formation-of-this-land/>

<https://www.chegg.com/homework-help/questions-and-answers/1-2-pts-please-state-true-false-statements-related-snapping-shrimp-species-tree--two-speci->

SOURCE 5

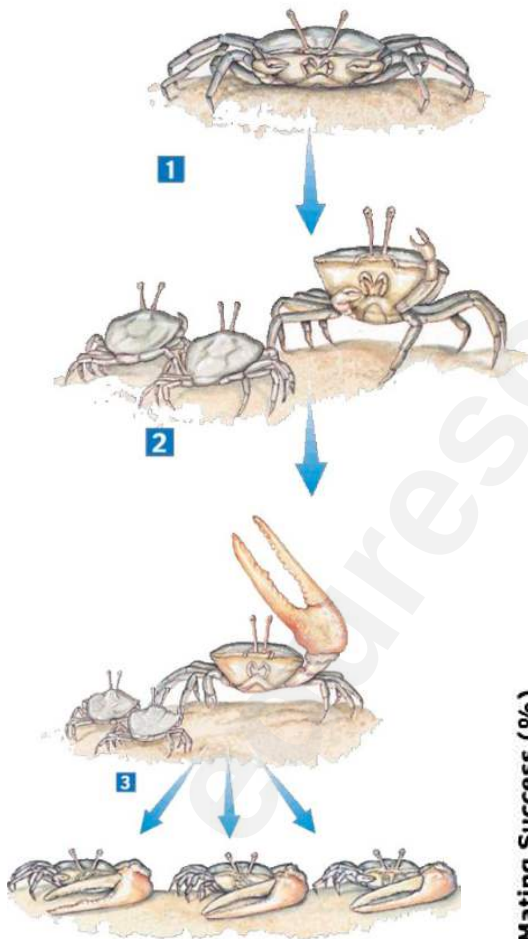
The researchers wanted to study another marine organism – the fiddler crab. Although the shrimp and the fiddler crabs are both crustaceans, the researchers noticed that the male fiddler crabs had a large claw unlike the shrimp species she observed.

Male fiddler crab uses front big claw to ward off predators and to attract mates.



SOURCE 6

Diagram showing how male fiddler crabs develop a large claw.



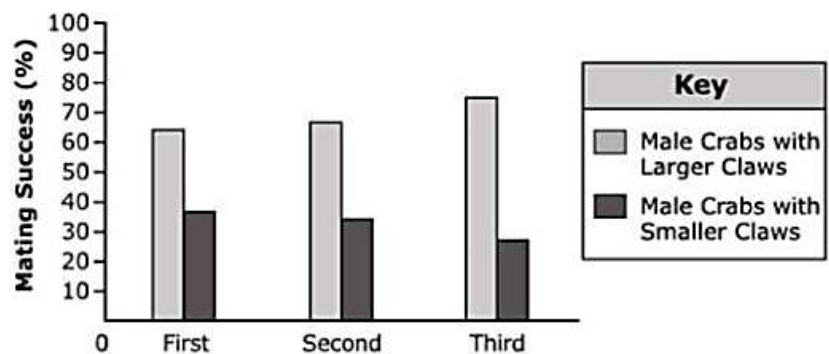
Adapted from <https://slideplayer.com/slide/17297460/>.

Investigation on Fiddler Crabs

The researcher conducts an investigation on fiddler crabs to understand the importance of claw size in mating. She places 15 male crabs with different sized claws into an enclosure with conditions similar to those in their natural habitat.

The researcher then releases 15 female crabs into the enclosure.

The graph below shows: the percentage of male crabs of different claw size that successfully mated for three consecutive trials.



Adapted from <https://www.chegg.com/homework-help/questions-and-answers/be-describe-natural-selection-affects-proportion-traits-population-researcher-conducts-inv-q47552458>.

QUESTION 3

SOURCE A: How do species adapt when there are environmental changes and there is migration?

Environmental changes during the Pleistocene may have led to the emergence of resilient hybrids, scientists in Germany believe, raising the possibility that periods of climate change can speed up evolution via hybridisation.

The GENEFLOW project looked at fossils of animals living during the Pleistocene period, a period which spanned from 2.5 million years to 12 000 years ago and was marked by frequent shifts between glacial and inter-glacial periods. Due to the changing climatic conditions, animals often migrated between north and south, allowing researchers to explore gene flow – the extent to which genes are transferred from one species or population to another as animals mix. The fossil record indicates response to climate change may have been migration of large herds, local extinction, and replacement events. For example, fossil records indicate mammoths crossed the Bering Strait from North America into Siberia and replaced the native species of that region.

‘We looked at ancient DNA in the bones of species such as cave bears, mammoths, extinct elephants, wolves, hyenas, lynx or gray whales,’ said Professor Michael Hofreiter from the University of Potsdam, Germany, who is the principal investigator for GENEFLOW.

The team analysed DNA in the cell nucleus, which is passed along both the female and male line. This is advantageous when looking at the flow of genes between migrating animals, because male animals tend to be more mobile.

The researchers have found that there is evidence of a lot of gene flow between populations that were separate as well as evidence of gene flow or hybridisation between different species. “In effect, evolution is being speeded up in this manner making creatures more resilient to climate change” said Hofreiter. “In the same way, polar bears must have survived several inter-glacial periods – there may have been gene flow with brown bears,” Prof. Hofreiter said.

Hofreiter points to modern day examples where different species have interbred with beneficial results to the hybrid. For example, many European house mice are now resistant to the poison warfarin thanks to breeding with Algerian mice, when inadvertently transferred from one region to another by humans.

Another example of gene flow is between Neanderthals and humans, with some humans thought to carry 2 % of their archaic relative's DNA

However, climate change also leads to large-scale extinctions because the environment changes too fast for species to adapt. Prof. Eeva Furman of the Finnish Environment Institute says that while large-scale movements of animals during Pleistocene may have increased gene flow among populations and been beneficial for adaptation, she does not expect to see the same thing happen in the future..

‘The present human-caused climate change will not lead to similar extensive mixing and adaptation of populations, partly because movements of most species are greatly hindered in human dominated landscapes, and partly because the present climate warming is extremely rapid in comparison with Pleistocene climate fluctuations,’ she said. ‘There is much research showing that the negative effects of climate change will dominate and add to the threat of populations, species and ecosystem services.’

*Adapted: D. Pearse (2015), European Commission for research and innovation Horizon Magazine
<https://ec.europa.eu/research-and-innovation/en/horizon-magazine/changing-climate-may-have-speeded-evolution>*

SOURCE B: Genetics and selection pressures still drive evolution

Professor Stanley Ambrose, an anthropologist from the University of Illinois, explains that "any change in the proportions of genes or gene variants over time is also considered evolution. The variants may be functionally similar, so evolution does not automatically equate with 'improvement'". Whilst some genes can be affected by natural selection (e.g. genes that help us run faster), other changes in our DNA might have no obvious effect on us. 'Neutral' variations can also spread through a population by a different mechanism called 'genetic drift'.

Genetic drift works by chance: some individuals might be unlucky and die for reasons which have nothing to do with their genes. Their unique gene variations will not be passed on to the next generation, and so the population will change. Genetic drift doesn't need any selection pressures, and it is still happening today.

As our environment is always changing, natural selection is always happening. And even if our environment was 'just right' for us, we would evolve anyway!

Dr Alywyn Scally, an expert in evolution and genetics from the University of Cambridge: "As long as human reproduction involves randomness and genetic mutation there will continue to be differences from one generation to the next, meaning that the process of evolution can never be truly halted."

E. Hamrud (2020) Are humans still evolving? <https://www.sciencealert.com/>

SOURCE C: Un-natural selection

Recent research is revealing that many of our activities exert significant unintentional selection on organisms. Such "unnatural selection", as it has been termed, is causing evolution in those populations.

Some well understood examples of unnatural selection and evolution come from commercial fisheries. It is the larger fish that are usually targeted and those that remain are consequently smaller. Dr Eric Palkovacs from the University of California Santa Cruz explains: "We have removed the large fish and that has a direct effect on the size structure of a population. Subsequent populations will feel that impact because those smaller fish contribute more genes to the population."

Not only are the fish evolving to be smaller but they also are evolving to become sexually mature at a younger age. This is because those fish that have genes causing later maturity are likely to be harvested before they have the chance to breed, removing those genes from the population.

Trophy hunters pay large sums to hunt big horn sheep animals and they are after the biggest and most impressive males. Big males with big horns can fight successfully against other males and thereby mate with far more females than smaller males with less impressive horns. Professor David Coltman, at the University of Alberta, and colleagues have been studying the sheep on Ram Mountain for over 40 years, following individuals throughout their lives. The males grow their horns quite quickly when they're young, but a successful ram has to live long enough to become socially dominant. Once he does, those big horns pay off and he can have a lot of offspring.



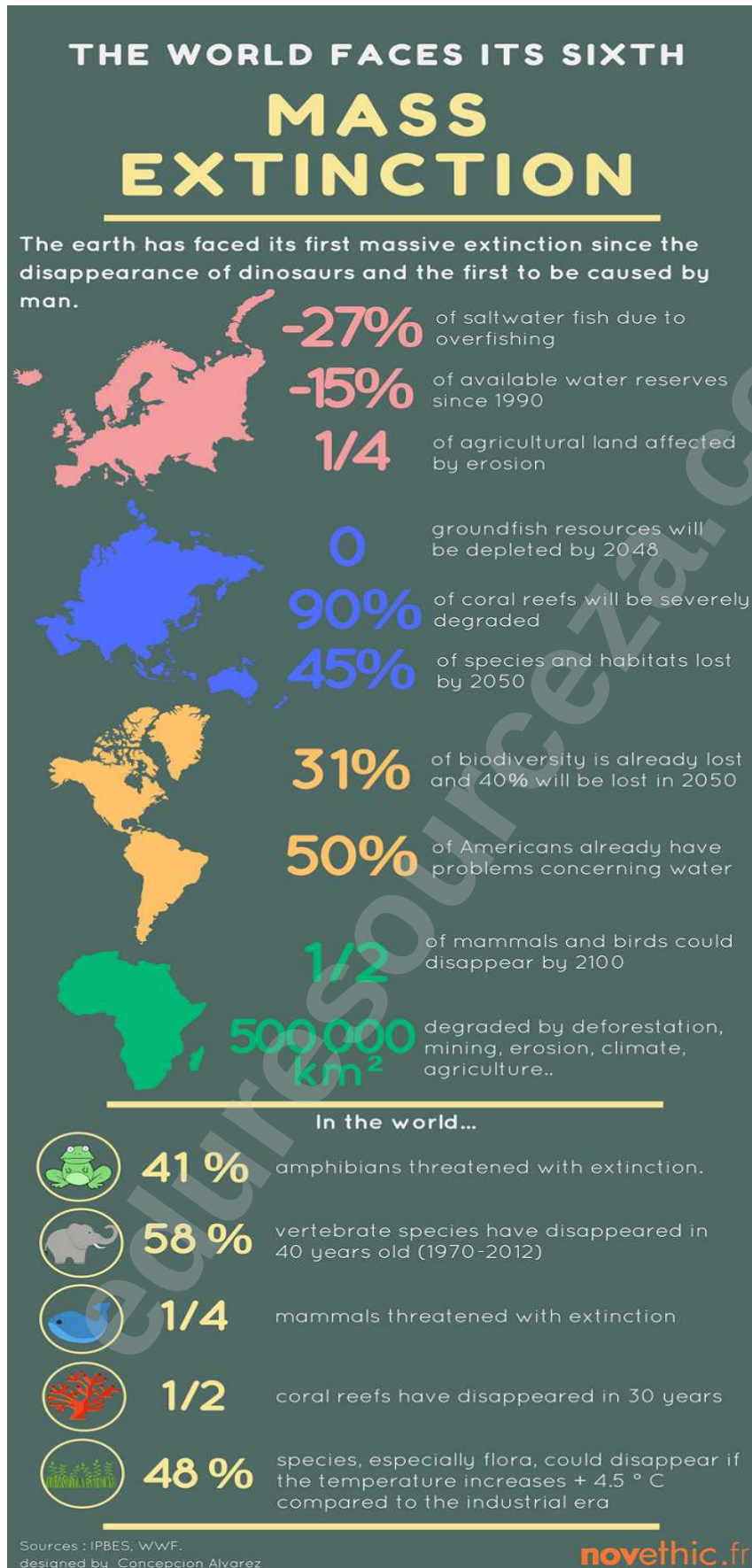
Hunting has exerted a strong selection pressure on big horn sheep. This pressure is leading to smaller horns but it's not just that there are more smaller-horned males around because the larger-horned males are being removed. As in fisheries, hunting is causing evolutionary changes in the genetic make-up of the population, in this case resetting the baseline of horn size to a lower level.

Prof Coltman explains: "The crux here is that the horns develop to the length where they can be legally harvested several years before they achieve social dominance. So in effect they're being harvested from the population before they can reproduce and pass their genes on."

As a consequence, big horn sheep horns have evolved to be as much as 25% smaller.

Adapted: <https://www.bbc.com/news/science> (2016)

SOURCE D:



SOURCE E:

One of the key mechanisms of evolution, natural selection, causes organisms to evolve in response to the changing environment caused by global warming.

In many cases, these changes are simply non-evolutionary examples of phenotypic plasticity, where an organism expresses different traits depending on environmental conditions. For example, many organisms respond to warmer weather by reproducing earlier and taking advantage of an earlier spring — but this early reproduction is not caused by genetic changes in the population and so is not an example of evolutionary change. Similarly, many species have shifted their ranges in response to this tiny temperature difference, spreading towards the poles, as those habitats warm — but this change in range cannot be traced to a genetic shift in the population and so is not an example of evolution. And still other species simply seem to be on the path to endangerment or extinction as their habitats (like coral reefs) are degraded and their population sizes drop.

However, in a few cases, we know that species have actually evolved — experienced a change in gene frequency in the population — in response to global warming. Interestingly, in those cases, the species are not necessarily becoming more heat tolerant, but are adapting to changes in seasonal timing:



Canadian squirrels are evolving to take advantage of an earlier spring and are breeding sooner, which allows them to hoard more pinecones for winter survival and next year's reproduction. Squirrels with genes for earlier breeding are more successful than squirrels with genes for later breeding.



European great tits (a type of bird) are also evolving different breeding times. Birds that are able to adjust egg-laying to earlier in the spring can time hatching so that it coincides with greater food (caterpillar) abundance — and with recent climatic changes, the caterpillars have been maturing earlier in the spring. Birds with genes for more flexible egg-laying times are more successful than birds with less flexibility in their egg-laying.

Another European bird, the blackcap, has been evolving due to changes in its migration patterns. Some blackcaps have begun to overwinter in the now slightly warmer Britain instead of in Spain, Portugal, and North Africa, as they historically did. The British sub-population has evolved genetic differences from the other birds and is more successful at reproducing since its members arrive at the nesting grounds earlier and have first choice of territories and mates.



One North American mosquito species has evolved to take advantage of longer summers to gather resources while the weather is good. Mosquitoes with genes that allow them to wait longer before going dormant for the winter are more successful than mosquitoes that go dormant earlier.

In a sense, these populations are the lucky ones. Small animals (like the birds, squirrels and mosquitoes described above) tend to have large population sizes and short generation times — and that bodes well for their ability to evolve along with a changing environment. Large population size means that the species is more likely to have the genetic variation necessary for evolution, and having a short generation time means that their rate of evolutionary change may be able to keep pace with environmental change. However, other species may not be so lucky: larger animals tend to have longer generation times and so evolve more slowly — and larger animals also tend to have smaller population sizes, which means that their populations

are simply less likely to contain the gene versions that would allow the population to adapt to warmer climates. If global warming continues, such species may come face to face with extinction, as the environments to which they have been adapted over the course of thousands or millions of years change right out from underneath them in the course of a few decades.



University of California, Berkley (2008), *Understanding evolution – Warming to Evolution*, <https://evolution.berkeley.edu/evo-news/warming-to-evolution/#warming>

SOURCE F:

Typically, members of two different species can't mate with one another — and if they do, the offspring they produce are often infertile or so weak they die before they can produce any babies. Occasionally though, horizontal gene transfer between species is successful:

(1) Clepto sea slugs:

When food runs scarce, the bright green sea slug snatches chunks of DNA from the algae they eat. Coupled with tiny energy-producing powerhouses called chloroplasts (which the sneaky slugs also pilfer from their algal meals), the stolen genes are enough to allow the slugs to survive on nothing but sunshine for days. The genes are also passed to offspring.

(2) Coywolf:

A new hybrid of the coyote and the wolf that first emerged in the last few decades is now coming out in droves in the Northeastern US. About two-thirds of the coywolves' DNA is from wolves, while another quarter is from coyotes. The coywolf's unique genetic makeup appears to be particularly appropriate for its northern habitat — more so, even, than either of its parent species, meaning the hybrid genes will likely keep getting passed down to future generations. While the DNA from the wolf appears to allow the coywolf to hunt larger prey, the coyote DNA helps it adapt rapidly to urban areas.

(3) Bacteria:

Gene transfer between different species of bacteria is leading to spread of antibiotic resistance.

(4) Corn snake/King snake cross:

Corn snakes are *Pantherophis guttatus*, and eastern king snakes are *Lampropeltis getula*. These two snakes are NOT IN THE SAME GENUS. Yet they can hybridize and produce fertile offspring.

Business Insider (2023) <https://www.businessinsider.com/examples-of-evolution-happening-right-now>
Donna Fernstrom, Former Reptile Breeder; <https://www.quora.com/At-what-point-will-crossbreeding-hybrids-animals-not-work>



University of Adelaide scientists have shown that widespread transfer of genes between species has radically changed the genomes of today's mammals, and has been an important driver of evolution. They have found that cross-species transfers, even between plants and animals, have occurred frequently throughout evolution. They showed that “jumping genes” crossed 759 species of plants, animals and fungi. 25% of the genome of cows and sheep are derived from such genes.

University of Adelaide. "Jumping genes: Cross species transfer of genes has driven evolution." *ScienceDaily*. ScienceDaily, 9 July 2018. <www.sciencedaily.com/releases/2018/07/180709101216.htm>.

Atma M. Ivancevic, R. Daniel Kortschak, Terry Bertozzi, David L. Adelson. Horizontal transfer of *BovB* and *L1* retrotransposons in eukaryotes. *Genome Biology*, 2018; 19 (1) DOI: 10.1186/s13059-018-1456-7

Scientists have recognised hybrids in plants since the mid-1900's. Now evidence is suggesting hybrid animals are more common than we thought and may have a critical role in evolution. Focusing on animals in what scientists call hybrid zones—geographical regions in which two species interbreed to produce offspring of mixed ancestry—researchers in the late 1980s and early 1990s began to show that, contrary to the prevailing viewpoint, hybridization was a valid mechanism of evolutionary change—one that could radically influence an animal's ability to adapt to its environment.

A genetic analysis of a rare skull found at the Natural History Museum of Denmark showed that in the past few decades a male beluga (*Delphinapterus leucas*) and a female narwhal (*Monodon monoceros*) mated, creating a hybrid called a narluga that looked a bit like both. The animal's 18 teeth were small, like a beluga's, and twisted, like a narwhal's tusk. Those teeth may have changed the way the narluga fed, not hunting on cod, squid, and shrimp in the water column as both of its parents did, but instead feeding off the bottom. Its teeth may have allowed it and others like it to occupy a different ecological niche than its parents. Because several narlugas have been spotted before, researchers suspect that the creatures may be fertile, and that some narlugas may be the product of two narluga parents rather than one beluga and one narwhal.

At some point in the past, black-tailed jackrabbits (*Lepus californicus*) and snowshoe hares (*L. americanus*) crossbred, with the hybrids mating again with snowshoe hares. A combination of whole-genome and whole-exome sequencing revealed that the resultant hares retained a variation of the *Agouti* gene that led to brown, rather than white, coat color in hare populations experiencing mild, less snowy winters, allowing them to better blend into the drab surroundings of dirt and dead leaves.

"We're beginning to realize that hybridization exists in the evolutionary history of many organisms we didn't expect it to, including *Homo sapiens*," Scott Taylor, an evolutionary ecologist at the University of Colorado, Boulder.

Researchers suspect that hybridization events are perhaps becoming more common, as human disturbances shift species ranges in ways that promote breeding across similar species. In Colorado, for example, two species of small, nonmigratory birds—black-capped chickadees and mountain chickadees—have recently hybridized in areas being heavily developed by humans.

Evolutionary biologists have seen pulses of cross-breeding as species shift where they live to higher or lower latitudes or altitudes to find cooler temperatures. When they move into those regions, the barriers to hybridization, such as differences in mate choice or other factors, might disappear. Adapted: A. Yeager (2021) Hybrid animals are not nature's misfits; <https://www.the-scientist.com/features/hybrid-animals-are-not-nature-s-misfits-68691>

SOURCE G:

While hybridisation in plants is known to be successful, hybridisation between animal species is rare and relies a lot on chance. The less closely related animals are, the less likely that their chromosomes will pair up correctly to make viable offspring.

As climates change, the chance increases that species that were separated will come into contact with each other and perhaps breed. But not between species that are very far apart genetically such as giraffe and zebra, or elephant and giraffe. In these cases the likelihood of being able to interbreed is close to zero.

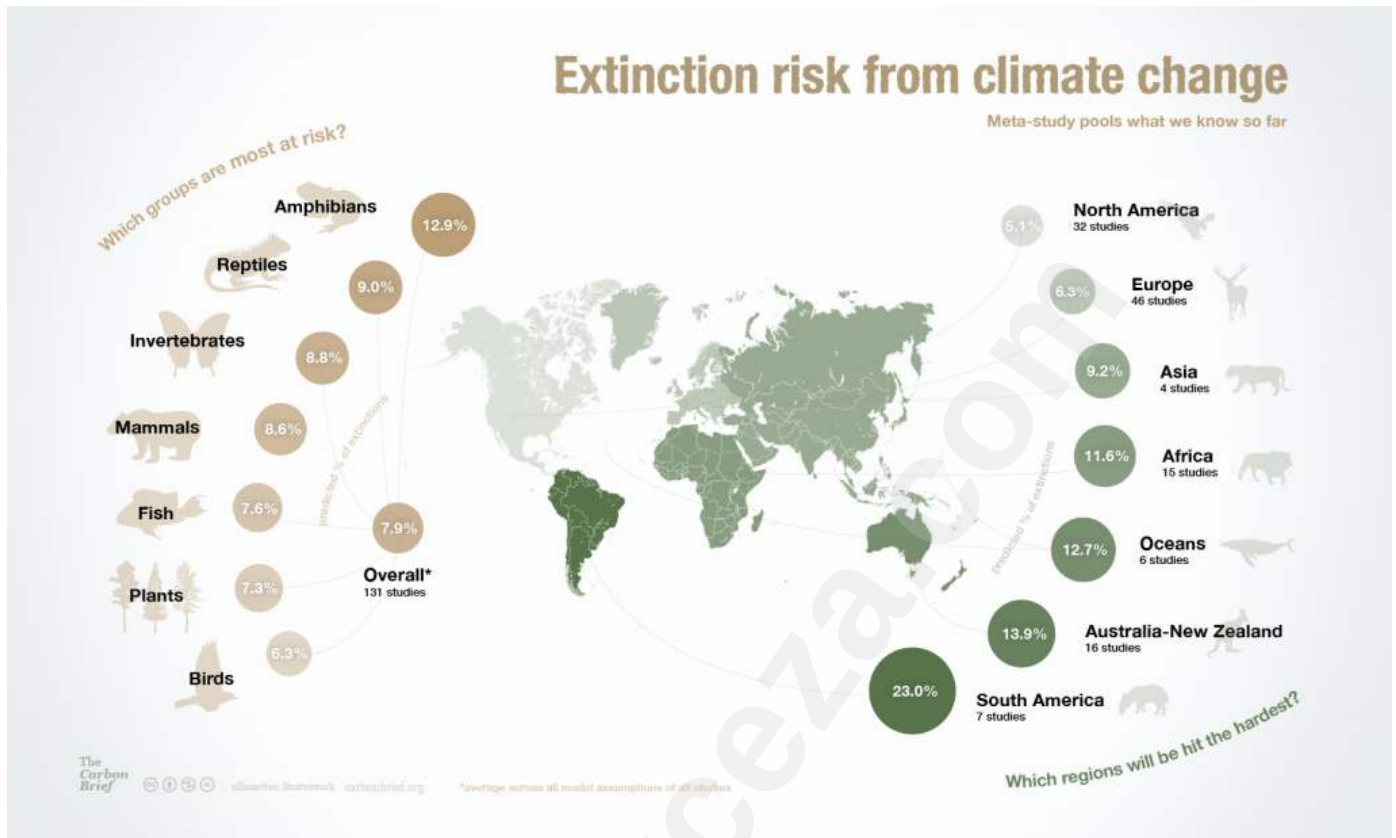
Natural selection is a primary mechanism that drives the adaptation of species to changing environmental conditions, including climate change. It operates over generations, favouring traits that enhance an organism's ability to survive and reproduce in its specific environment. Natural selection can lead to the evolution of traits that enable animals to better cope with changing climate conditions, such as changes in temperature, habitat availability, or food sources.

Hybridization between different species and genera, on the other hand, is relatively rare and typically occurs when species are closely related. Hybridization between more distantly related species or genera is less common due to genetic and physiological barriers. While hybridization can introduce new genetic diversity and potentially lead to novel traits, it is not a primary mechanism for adapting to climate change.

In the context of climate change survival in animals, natural selection is a much more significant factor. Over time, individuals within populations that possess traits that provide an advantage in the changing climate are more likely to survive, reproduce, and pass those advantageous traits to their offspring. This process gradually shapes populations to be better suited to their changing environment, though the rapid change needed may not be possible – leading to extinction.

Adapted: ChatGpT

SOURCE H:



Credit: Rosamund Pearce, Carbon Brief, based on data from Urban (2015).