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St Catherine's Convent

GRADE 12 LIFE SCIENCES

SUPPLEMENTARY PRELIMINARY EXAMINATION 2023

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.

1. Galapagos Finch Evolution

Our planet has millions of species, over 300,000 beetles alone. 17,000 butterflies, thousands of mammals, fish, and birds, all astonishingly different. How did so many species come to be? To seek insights into that question, researchers are focusing on places where species recently arose, such as the remote Galápagos Islands.

Scientists are making observations and conducting experiments that would have surprised Charles Darwin. And they're discovering new insights into what the great naturalist called the "Mystery of Mysteries": How New Species Form.

The Galápagos Islands are one of the most spectacular landscapes in the world, home to a variety of species that live nowhere else. Biologists Peter and Rosemary Grant have been seeking answers to how species arise by focusing on one of the smaller islands, called Daphne Major. When the biologists started out, they had no plan for the long term. In fact, they thought it was just going to be just a few years, maybe two years. Two years have turned into a 40-year odyssey. The Grants have returned every summer since 1973.

Here, they've made some of the most remarkable observations in the history of field research as they studied the famed Galápagos finches. The finches were first brought to scientists' attention by Charles Darwin, when his voyage around South America brought him to this cluster of islands 600 miles from mainland Ecuador. These volcanic islands are geologically young. They began rising from the ocean floor less than five million years ago. At first devoid of life, they now support a modest number of species. Among them, 13 species of finches found in various combinations on the different islands. The birds live in diverse habitats.

The islands are very different from each other. They differ in size. They differ in topography and in height. Larger trees grow at higher elevations while low islands have mostly cactus, grasses and shrubs. In these diverse habitats, the finches have evolved many ways to survive.

So, what's the important difference between these birds? The little warbler finch with its very fine needle like beak is perfect for picking off insects. The woodpecker finch with a rather more robust beak concentrates on beetle larvae and termite larvae. Then the cactus finch with a much longer sharp pointed beak probes into cactus flowers. The finches look so different that Darwin first mistook them for entirely unrelated kinds of birds.

In terms of the actual history of the finches of the Galápagos, there were many different possibilities. Different kinds of finches could have all come from the mainland separately or the finches could have all evolved out there on the islands. DNA evidence shows that all of the finches are more related to each other than anyone is to a species on the mainland. And that tells us only one species arrived on the Galápagos and diversified into the 13 species that we see nowadays. They've all come from a single common ancestor.

The question then becomes how one ancestral population gave rise to many different species, each adapted to a different lifestyle. A crucial insight into how adaptation occurs came when the Grants focused on one species on the island of Daphne Major. The small size of the island meant that they could walk all over the place and follow every individual or almost every individual. They rose at 5:30 each morning to net the island's medium ground finches. They measured the size and shape of each bird's beak; the bird's weight and they tagged them for identification. Year after year they returned, at times tracking over 1,000 finches.

Over the first four years, little seemed to change. Then in 1977 a terrible drought began. Virtually no rain fell for the next 18 months. The vegetation practically disappeared apart from a few trees without any leaves. And, of course, the cactus bushes were still there. Now the medium ground finches had to compete for scarce food. They started off with a big food supply of small seeds, medium seeds, large seeds. As these small seeds became very scarce, they had to turn increasingly to the large and hard seeds. Only birds with large beaks could crack open these woody, spiny fruits. The birds with the smallest beaks had the most trouble. That year, over 80 percent of the medium ground finches died. When they inventoried the surviving medium ground finches, they discovered that one trait had made the greatest difference between life and death. The larger the beak, the higher the likelihood of surviving through the drought of 1977.

When they looked at the offspring, they found an even greater surprise. The average beak depth was more than four percent larger than the previous generation. Natural selection had changed the average beak size. They could never have imagined measuring and observing something like this on such a short time scale. But was this a fluke? Or are changes like this happening all the time? Five years later in 1983, an unusually strong El Nino brought ten times more rain than normal. And the island was overrun by vines that covered even the cactus. The rains changed the vegetation on the island, such that two years later, when drought struck, larger seeds became scarce. The birds with larger beaks now had difficulty picking up the more abundant food: the small seeds produced by the vines. That year many more finches with small beaks survived, and their offspring inherited smaller beaks. So, the selection had swung in the opposite direction, and evolution had occurred as a result.

In an amazingly short period of time, the Grants had measured evolution of beak size, not once, but twice, demonstrating that when birds encounter different environments they will change over a very short amount of time. Over millions of years, changes like these occurring throughout the Galápagos generated all sorts of beak sizes and shapes. But that's only part of the story. How did finches with different beaks become distinct species? Species are defined as populations whose members don't interbreed.

So, in the Galápagos, the Grants asked what keeps different species of finches from mating? The Grants were very conscious that on any given island, the different species sing very different songs. So, to see if songs keep the species apart, the Grants, played each species' songs through a loudspeaker. When they played back the cactus finch song, cactus finch came to the loudspeaker and the medium ground finch completely ignored it. The males only responded to songs of their own species.

The Grants looked at whether finches might also choose mates based on appearance. They put out stuffed female specimens to see if males would respond. The male vigorously courted a female of his own species and completely ignored the other one. The males only courted females that had a similar size and similar beak. Song and appearance both played a role in keeping different species from mating. The Grants have shown that both geography and ecology are keys to the evolution of the Galápagos finches.

While unique to the remote Galápagos Islands, the history of the Galápagos finches offers a general insight into why the world is populated with so many species. The more diverse the environment, the more opportunities for evolutionary change to produce those new species. Over 150 years after Darwin first recognised their significance, these unassuming birds still illuminate how the great diversity of life arose and continues to evolve.

[Adapted: <<https://www.amnh.org/exhibitions/lonesome-george/galapagos-tortoises-and-evolution>>]

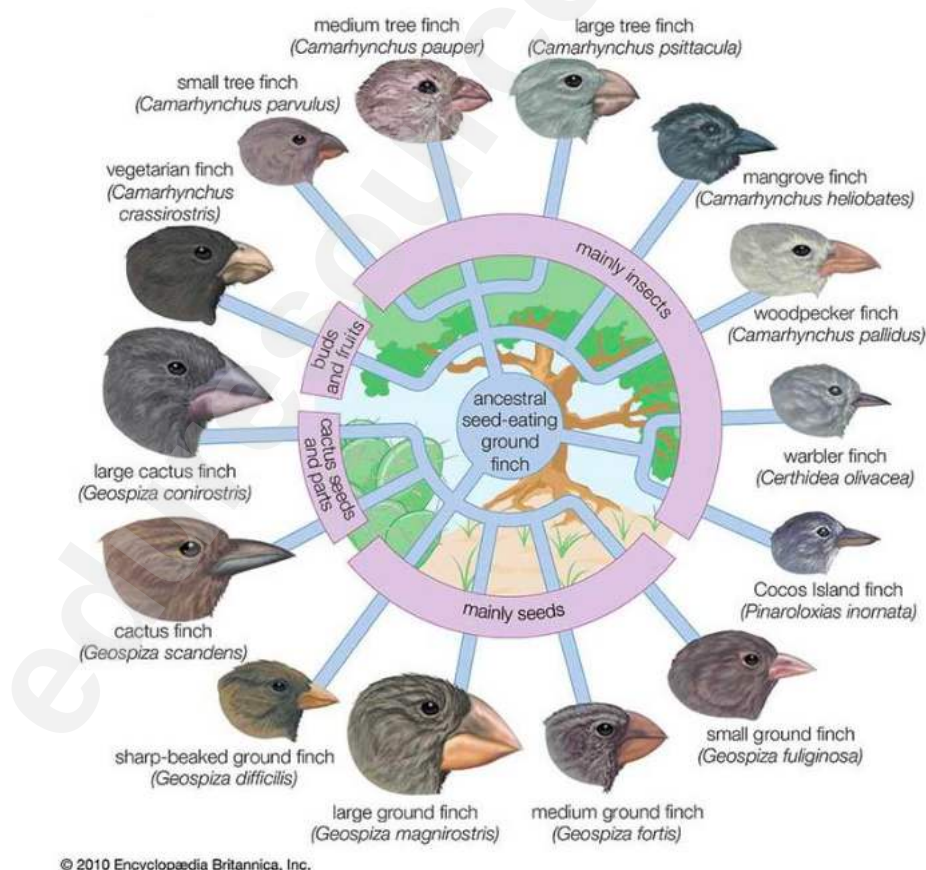


Figure 1.1: Darwin's finches

[Adapted: <<https://www.britannica.com/science/evolution-scientific-theory/>>]

2. More in Lonesome George

Lonesome George lived in the Galápagos, a chain of volcanic islands off the coast of Ecuador, in South America. Islands that forever changed our understanding of the natural world. While visiting the Galápagos in 1835, British naturalist Charles Darwin observed local plants and animals. He became fascinated by species that seemed related to ones found on the mainland—but that also had many physical variations unique to different islands.

Over time, Darwin began to wonder if species from South America had reached the Galápagos and then changed as they adapted to new environments. The idea that species could change over time eventually leading to Darwin's most well-known theory of evolution.

Galápagos tortoises have two very different shapes, each adapted for different feeding habits needed on low, arid islands versus high, lush islands.

Some tortoises, including Lonesome George, have shells that rise in front, like a saddle (saddle-back tortoises). This adaptation makes it easier for them to lift their heads high to eat tree cactus and to resolve disputes over limited food resources, which they do through raising their heads as high as possible during social interactions. Whereas tortoises with the dome-shaped shells are not able to lift their heads as much.

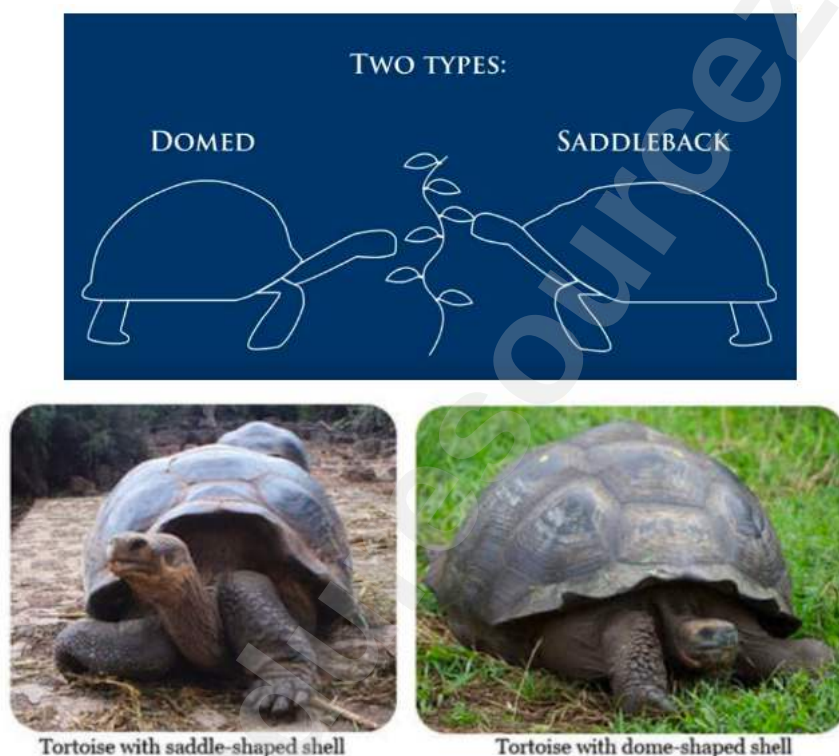


Figure 1.2: The two types of tortoises

[Adapted: <<https://www.britannica.com/science/evolution-scientific-theory/>>]

QUESTION 2

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

1. **Child of Darkness: A 240000-year-old *Homo naledi* child is discovered.**

Homo naledi is known from the Rising Star cave system, South Africa, where its remains have previously been reported from two localities: the Dinaledi Chamber and Lesedi Chamber. Continued exploration of the cave system has expanded our knowledge of the Dinaledi Chamber and its surrounding passageways, leading to the discovery of new fossil localities.



Figure 2.1: The reconstructed skull of "Leti" fits into the palm of a modern human hand. (Image credit: Wits University)

[Adapted: Brophy, J. K. et al. 2021 *PaleoAnthropology* 2021:1: 1–14. Available at: <<https://doi.org/10.48738/2021.iss1.64>>]

Deep within South Africa's Rising Star cave system, in a dark passageway barely 15 centimetres wide, scientists have discovered the fragmented skull of a *Homo naledi* child they're calling "Leti." How the little skull ended up in such a remote part of the cave is a mystery, though the discoverers suspect it could be evidence of an intentional burial.

"Leti," short for "Letimela," or "Lost One" in the Setswana language of South Africa, probably lived between 335,000 and 241,000 years ago. Fossil fragments belonging to about 24 *Homo naledi* individuals have been found in the cave system since 2013, when the first fossils from this human ancestor were discovered in what's now known as the Dinaledi Chamber. The presence of so many individuals from a single species in the cave is mysterious. The only way in is a 12-meter vertical fracture known as "The Chute," and geologists and spelunkers (people who explore caves) have so far found no evidence of alternative entrances into the passageways. Leti's small skull was found scattered in pieces on a limestone shelf about 80 cm above the cave floor.

The area is barely navigable for experienced spelunkers with modern equipment. There is no evidence that animals carried the *H. naledi* bones into the cave. There are no gnaw marks or evidence of predation. The bones also appear to have been placed in the cave, not washed in, as they were not found mixed with sediment or other debris. That leaves open the possibility that more than 240,000 years ago, human ancestors with orange-size brains deliberately entered a dark, maze-like cave, perhaps through a vertical chute that narrows to 18 cm in places and placed their dead inside.

No tools or artifacts have been found alongside the Rising Star cave system fossils. There are few signs of other animals entering the caves, beyond two specimens of juvenile baboons, at least one of which may be much older than the *Homo naledi* remains.

According to John Hawks, an anthropologist at the University of Wisconsin-Madison who studies the remains of hominin fossils, this human ancestor lived at the same time as early *Homo sapiens*. Their apparent forays into the cave suggest that they were among modern humans' smarter ancestors, and that they had mastered the use of fire to light their explorations. According to the Smithsonian National Museum of Natural History, *H. naledi* walked upright, stood about 1.44 m tall and weighed between 40 and 56 kilograms.

While a few jaw fragments from juveniles have been found in the cave, this is the first-time researchers have discovered bones from the skull case, or cranium. They also discovered six teeth. The bones and teeth were found during an exploration of the narrow, twisting passageways around Dinaledi Chamber.

Researchers mapped 316 m of these passageways, looking for evidence of another way into that chamber and several others nearby where remains have been found. They saw no evidence of another route.

The teeth consisted of four unworn permanent teeth and two worn baby teeth. Their development and wear indicate that the child was at the age where the first permanent molars were breaking through the gum. The size of the skull indicates that Leti's brain had a volume of around 500 cubic cm, about 92% of the brain volume of adults of her species.



Figure 2.2: Teeth from the Homo naledi child "Leti." The teeth indicate that Leti died around the time of the eruption of the first permanent molars.

(Image credit: Wits University)

[Adapted: Pappas, S. 2021 <<https://www.livescience.com/child-of-darkness-homo-naledi-discovered.html>>]

2. Newly named human species maybe the direct ancestor of modern humans

Scientists have named a new species that may have been the direct ancestor of modern humans.

The newly proposed species, *Homo bodoensis*, which lived more than half a million years ago in Africa, may help to untangle how human lineages moved and interacted across the globe.

Although modern humans, *Homo sapiens*, are the only surviving human lineage, other human species once roamed Earth. Deciding whether a set of ancient human fossils belongs to one species, or another is often a challenging problem open to heated debate. For instance, some researchers suggest that skeletal differences between modern humans and Neanderthals mean they were different species. However, other scientists argue that because there is recent abundant genetic evidence that modern humans and Neanderthals once interbred and had fertile, viable offspring, Neanderthals should not be considered a single species. Some have suggested that they may be a sub-species of modern humans.

In the new study, researchers analysed human fossils dating from about 774,000 to 129,000 years ago. Previous work suggested modern humans arose during this time in Africa, while Neanderthals emerged in Eurasia. Chibanian-era human fossils from Africa and Eurasia are often assigned to one of two species: *Homo heidelbergensis* or *Homo rhodesiensis*. Recent DNA evidence has revealed that some fossils in Europe dubbed *H. heidelbergensis* were actually from early Neanderthals. As such, *H. heidelbergensis* was a redundant name in those cases, the scientists noted. Similarly, recent analyses of many fossils in East Asia now suggest they should no longer be called *H. heidelbergensis*, the researchers added. For instance, many facial and other features seen in Chibanian East Asian human fossils differ from those seen in European and African fossils of the same age.

To help deal with all this confusion, the researchers now propose the existence of a new species, *H. bodoensis*. This new name would encompass many fossils previously identified as either *H. heidelbergensis* or *H. rhodesiensis*. The researchers suggest that *H. bodoensis* was the direct ancestor of *H. sapiens*, together forming a different branch of the human family tree than the one that gave rise to the Neanderthals and the Denisovans, which lived about the same time as their Neanderthal cousins.

In this new classification, *H. bodoensis* will describe most Chibanian human fossils from Africa and the Eastern Mediterranean. Many Chibanian human fossils from Europe would get reclassified as Neanderthals. The names *H. heidelbergensis* and *H. rhodesiensis* would then disappear. Chibanian human fossils from East Asia may get their own names with more research.

[Adapted: Choi, C.O. 2021 from <https://www.livescience.com/new-human-species-named-bodoensis?utm_source=notification>]

It is now known from a growing body of genetic data that the co-existence of *Homo neanderthalensis* and *Homo sapiens* was accompanied by bouts of interbreeding between the two species. It is suggested that a continuing absorption of Neanderthal individuals into *H. sapiens* groups could have been one of the factors that led to the demise of the Neanderthals. It wasn't fighting or a ferocious animal that preyed on Neanderthals. It was sex with *Homo sapiens*.

How the species met each other and communicated

While fossils of Neanderthals have been found across Europe and Asia, the ancestors of our species evolved in Africa, all around 600,000 years ago. Researchers believe that Neanderthals spent around 400,000 years evolving in their environment. According to genetic data, the two species first came across each other when *Homo sapiens* began traveling out of Africa about 250,000 years ago.

We do not know how the two groups communicated. The language differences would probably have been greater than we could imagine. Body language could have caused problems with communication as well. For example, Neanderthals had a prominent brow ridge that could have been used for communication, but it was likely that these signals were lost to our ancestors. As reduced brow ridges would have allowed *Homo sapiens* rather use eyebrows to convey a range of subtler, temporary signals.

Even though we know that our species interbred with Neanderthals, as we have Neanderthal DNA in us today, there is no evidence of *Homo sapiens* genetics in Neanderthal genomes from 40-60,000 years ago. We don't know if the apparent one-way gene flow is because it simply wasn't happening, that the breeding was taking place but was unsuccessful, or if the Neanderthal genomes we have are unrepresentative. As more Neanderthal genomes are sequenced, we should be able to see whether any nuclear DNA from *Homo sapiens* was passed on to Neanderthals.

[Adapted: Theresa, D. 2022. Available at: <<https://interestingengineering.com/science/neanderthals-went-extinct-because-of-sex-not-war>>]

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 **Darwin's view on sexual selection**

Darwin's second major contribution to evolutionary theory was the concept of sexual selection. He defined sexual selection as the advantage certain individuals have over others of the same species and sex in terms of reproduction. It encompasses the competition among individuals within a species for reproductive opportunities.

While there are those who argue that differentiating between sexual and natural selection is insignificant, Darwin made a clear distinction between the two for valid reasons. He aimed to explain the presence of traits that seemed to be unaffected by natural selection. Darwin specifically highlighted that sexual selection is not the same as natural selection because it primarily involves the struggle between males to secure mates, rather than the struggle for survival. Sexual selection is not a mere subset of natural selection because it arises from variations in mating success, whereas natural selection is driven by variations in all other aspects of fitness.

[Adapted: < <https://www.sciencedirect.com/science/article>>]



Adapted: <<https://www.pinterest.ca/pin467530005042589595>>

SOURCE B

The concept of sexual selection as a special form of natural selection is easily explained. Other things being equal, organisms more proficient in securing mates have higher fitness. There are two general circumstances leading to sexual selection. One is the preference shown by one sex (often the females) for individuals of the other sex that exhibit certain traits. The other is increased strength (usually among the males) that yields greater success in securing mates.

The presence of a particular trait among the members of one sex can make them somehow more attractive to the opposite sex. This type of “sex appeal” has been experimentally demonstrated in all sorts of animals, from vinegar flies (*Drosophila*) to pigeons, mice and dogs (*Canis lupus familiaris*). When, for example, *Drosophila* flies, some with yellow bodies as a result of spontaneous mutation and others with the normal yellowish grey pigmentation, are placed together, normal males are preferred over yellow males by females with either body colour.

Sexual selection can also come about because a trait—the antlers of a stag (deer), for example—increases prowess in competition with members of the same sex. Stags use antlers or horns in contests of strength; a winning male usually secures more female mates. Therefore, sexual selection may lead to increased size and aggressiveness in males. Among many mammals that live in packs, troops, or herds—such as wolves, horses, and buffaloes—there usually is a hierarchy of dominance based on age and strength, with males that rank high in the hierarchy doing most of the mating.



[Adapted: < <https://www.britannica.com/science/sexual-selection>>]

SOURCE C **Definitions/explanations of sexual selection from Darwin onwards**

Darwin 1871, We are, however, here concerned only with that kind of selection, which I have called sexual selection. This depends on the advantage which certain individuals have over other individuals of the same sex and species, in exclusive relation to reproduction."

Andersson 1994, "Sexual selection of a trait can therefore be viewed as a shorthand phrase for differences in reproductive success, caused by competition over mates, and related to the expression of the traits"; "In spite of many suggestions to the contrary by leading biologists [...] the term sexual selection is here restricted to competition over mates."

Ritchie 2007, "Sexual selection: the component of natural selection arising owing to variation in mating or fertilisation success".

Kuijper et al. 2012, "Sexual selection is the process by which individuals compete for access to mates and fertilisation opportunities."

Rosenthal 2017, "Sexual selection. A special case of natural selection: differential reproductive success due to the ability to secure mating and/or fertilisation."

[Adapted: < <https://www.researchgate.net/publication/353766232>>]

SOURCE D **Male Ornaments**

Sexual selection acts to refine secondary sexual characters of the phenotype such as morphological differences between males and females, or differences between male types.

Darwin viewed male sexual ornaments as a curious evolutionary puzzle that begged explanation. Natural selection tends to produce individuals that are well adapted to their environment. However, sexual selection does not adapt the individual to the environment but does enhance traits involved in mate acquisition. Moreover, sexual selection can produce individuals with such elaborate ornaments that they must be either energetically costly to develop, costly to maintain, or even lead to a direct survival cost for the individual that bears the ornament. In this sense, sexual selection has the capacity to evolve maladaptive traits.

Darwin's theory of sexual selection gave a plausible explanation for the origin of many splendid if not bizarre ornaments. Females are the limiting sex and invest more in offspring than males.

Sexual selection can arise when in which females choose males based upon elaborate ornamentation or male behaviours. Female choice is a striking example of maladaptive evolution when a trait develops that is (or has become) more harmful than helpful.

[Adapted: <<https://bio.research.ucsc.edu>>]

SOURCE E Sexual selection in Widowbirds

Selection makes many organisms go to extreme lengths for sex and develop traits that are in fact useless for survival.

Sexual selection is often powerful enough to produce features that are harmful to the individual's survival. For example, extravagant and colourful tail feathers of the male Long-tailed Widowbirds. The tails are prominently exhibited as the male flies slowly in aerial display over his territory. This can be seen from more than half a mile away. The females, in contrast, have short tails and are inconspicuous. These tails can also result in the male bird losing balance.

[Adapted: <<https://www.nature.com/scitable/blog/accumulating-glitches>>]

SOURCE F Human Traits

Throughout human evolution, certain traits that underwent natural selection are believed to have also been influenced by sexual selection. Here are a few examples:

1. Physical attractiveness: Humans have consistently shown an interest in physical attractiveness, which is likely shaped by sexual selection. Traits like facial symmetry, clear skin, healthy hair, and proportional body features are often considered attractive and may have been preferred by potential mates.
2. Breast development: Unlike other primate species, human females possess enlarged and prominent breasts. Since this additional fatty tissue does not contribute significantly to milk production, it has been proposed that breast development in humans evolved as a courtship signal.
3. Absence of penis bone: Human males lack a penis bone, unlike other primates. Instead, they achieve and maintain an erection by pumping blood into the penis. Additionally, humans possess a relatively larger penis size compared to our primate relatives, such as gorillas and chimpanzees.

The presence of rounded breasts and larger penises in humans may have served as courtship signals, indicating health and fertility. These traits might have been favoured by sexual selection as indicators of reproductive fitness.

[<<https://evolution.berkeley.edu>>]

Adapted from an article written by Rex Graham, owner of Top Birding Tours and Understanding Evolution

SOURCE G Dangers of Sexual Selection

The male redback spider is much smaller than the female and is likely to be eaten after copulation.



Elephant seals fight over territories with breeding females.

Features chosen by sexual selection are not necessarily suited for survival.

[Adapted from NSC Life Sciences Supplementary Examination 2015]

SOURCE H **Peacock's train**

A male peafowl (peacock) spreads its feathers to attract a mate during mating season. When a peahen notices a peacock and looks at the potential mate, the peacock will angle his tail feathers to the sun in order to show off its brightest radiance to the peahen as their feathers change colours with the angle of viewing. The male will continue to show off at different angles until the female is satisfied and comes in closer.

But a peacock's train does more than just attract a mate. It's quite a sight to see when you're a predator and suddenly your prey becomes twice the size you originally thought they were. Fanning their trains can make many predators think twice. Being ground feeding birds, peafowl are easy prey. However, there is a downside of having such stunning feathers for the male peacock. They might be very visible to their predators.

[Adapted from: <<https://beautyofbirds.com/why-do-peacocks-spread-their-feathers>>]

According to new research, peacock's multi-coloured tail feathers may also help to keep them hidden from predators in the wild.

While it might seem that these feathers would attract the attention of other animals, experts say their native threats, including big cats and stray dogs, lack the colour receptors needed to distinguish a peacock's tail from its surroundings.



[Adapted: <<https://www.dailymail.co.uk/sciencetech/article-6608667>>]

SOURCE 1 Natural and sexual selection in action.

In 1972, a pet shop owner on the island of Oahu, in Hawaii, ordered a few dozen Jackson's chameleons from Kenya to sell. After leaving them in his backyard after a long journey they all escaped and thus inadvertently causing the colonisation of Oahu by invasive chameleons. With no predators they thrived, and researchers could observe natural selection occurring.

Male Jackson's chameleons are normally bright green, but they change colour to become lemon yellow when trying to attract females. According to a paper in *Science Advances*, this shade of yellow has become brighter in Hawaii.

"Jackson's chameleons are native to East Africa, where they are preyed upon by a wide range of mostly bird and snake predators," says lead author Professor Martin Whiting, a researcher at Macquarie University's School of Natural Sciences. "In Hawaii, however, there are virtually no bird or snake predators to worry about."

Without this selection pressure, the chameleons have no need to getting brighter. But becoming brighter does give them a couple of advantages in sexual selection.

"If you're a brighter, higher quality individual, you might be doing better in contests and you might also be more attractive to females," says Whiting. He also mentioned that this colour change only took 50-60 generations and it is an example of a rapid case of natural selection.



[Adapted: <<https://www.canberratimes.com.au>>]

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