SURVIVAL STORIES

FROM THE MOUNTAIN TOPS TO THE OCEAN FLOOR

IT IS NOT THE STRONGEST OF THE SPECIES THAT SURVIVES, NOR THE MOST INTELLIGENT THAT SURVIVES. IT IS THE ONE THAT IS MOST ADAPTABLE TO CHANGE.

-CHARLES DARWIN

Foreword

Ashoka is proud to present this compendium of excellent essays on survival strategies written by our undergraduate students. These were commissioned as assignments in a critical thinking course on “Survival Strategies”. The quality of the writing, scientific accuracy, critical analysis of evolutionary processes leading to the emergence of these fascinating behavioral manifestations etc motivated us to publish these assignments in the form of a booklet for general readership.

Ashoka is a liberal arts research University. The education at Ashoka has strong emphasis on foundational knowledge, academic research on pedagogy, and hands-on experience with real-world challenges. The aim of Ashoka is to help students think critically about issues from multiple perspectives, communicate effectively and become leaders with a commitment to public service. Each one of the essays in this compendium is an example of what Ashoka has been able to achieve in its short period of existence. The credit mainly goes to the students for showing confidence in the liberal arts curriculum, investing time and efforts in developing critical thinking and self-learning abilities and to Prof Alok Bhattacharya, the course teacher for motivating and nudging students to think differently and critically. Special thanks to Dr. Anusha Krishnan for reviewing and editing these essays.

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Editor's note

Nature has an abundance of species—each with its own story of survival. Over millions of years, countless species have evolved and survived, while others went extinct. In this book, our aim is to explore the evolutionary strategies of those species whose struggle for existence provides us with an insight into the marvelous workings of nature. In addition, we also explore the evolutionary strategies of some extinct species and why these strategies failed.

This book is published as a collection of papers written by the students who undertook the critical thinking course 'Survival Strategies' offered by Prof. Alok Bhattacharya. Throughout the course, students explored the physiological, morphological, and behavioral adaptations of different organisms—from unicellular microbes to highly developed mammals—that help them to survive in nature. In Prof. Bhattacharya's course, students are encouraged to observe the physiologies, anatomies, and behaviors of different organisms and critically analyze the ways in which those adaptations may aid the organism in survival. As a final research project for this course, students must choose a species of interest to them and present a paper on their peculiar survival strategies. This book is a collection of such papers presented by the students from three undergraduate years at Ashoka University.

We would like to express our deepest gratitude to Prof. Alok Bhattacharya who encouraged and guided us to collect and edit the papers for this collection. We would also like to acknowledge all the students who worked with us in editing and polishing their papers for this publication. We are grateful to Dr. Anusha Krishnan, who further edited these papers for language and originality. In addition, we would also like to thank Prof. L.S. Shashidhara and all the faculty members of the Department of Biology who provided valuable inputs and suggestions for these papers. We highly appreciate the time and effort you spent in helping us with this project.

Ankit Wenju Shrestha and Jenish Raj Bajracharya
Editors

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The Complicated Relationship between Bats and Viruses

Chiropterans or bats belong to the most abundant and second most species-rich order in class Mammalia. This paper explores the different characteristics of bats, which make them highly susceptible to viral infections. In addition, it also examines bats' survival strategies against these pseudo-microorganisms, focusing particularly on their immune systems.

ANKIT WENJU SHRESTHA
UG 22

Introduction

Bats are classified under class Mammalia and order Chiroptera in the animal kingdom. They are some of the most abundant, diverse, and geographically widespread vertebrates, which are found in every continent except Antarctica [1]. Amongst the mammals, bats are unique as they have wing-shaped forelimbs that allow them to fly.

Bats can feed on insects, other small mammals, fish, fruit, pollen, and even blood, depending on their species and food availability. In the temperate regions, bats usually migrate or hibernate to survive the cold of winter months, whereas, in the tropical regions, bat migration follows the movement of ephemeral food resources [1].

Bats are known to be reservoirs and transmitters of many viral diseases; it is believed that several characteristics of bats, such as their propensity for roosting in large numbers, hibernation, migration, and echolocation make them excellent transmitters and hosts for a large variety of viruses. Recent studies show that bats are one of the main sources of zoonotic spill-over events, where pathogenic viruses jump from wild animal hosts to domestic animals and/or humans [1]. However, despite being hosts to a large variety of pathogenic viruses, bats rarely develop clinical symptoms of the deadly diseases that these viruses can cause. This paper will analyze the selection pressures on bats caused by pathogenic viruses and the survival strategies adopted by bats against these viruses.

Complicated relationship between Bats and Viruses

Recent studies on bat ecology have shown that numerous bat species are primary reservoirs and transmitters of zoonotic viral pathogens [2]. However, this is a relatively new discovery. Although bats were known to be both victims and vectors of the rabies virus [2], scientists have only recently begun to study the associations between bats and viral diseases after several zoonotic spillovers to humans. In the 1990s, two novel paramyxoviruses, namely, the Hendra and Nipah viruses, caused outbreaks of fatal diseases in Australia and Malaysia, respectively. Studies following the outbreaks showed that pteropid bats were hosts for both viruses [3].

Similarly, the coronavirus that caused an outbreak of severe acute respiratory disease (SARS) in China and Hong Kong in the early 2000s [4], was also found to use bats as a reservoir host. However, no records of epidemic viral infections amongst bats, even in densely populated roosts were either observed or reported. Furthermore, although more than 100 viruses fatal to humans have been detected in different species of bats, these bats displayed no clinical symptoms of the diseases usually caused by these viral infections [5].

Bats as excellent reservoir for viruses

Although there is not enough scientific evidence to trace the origins of co-existence between bats and pathogenic viruses, some fundamental characteristics of bats, such as their food choices, colonial nature, population structures, locomotion (ability to fly, seasonal migration, daily movement patterns, etc.), hibernation, lifespan, roosting behaviors, and ability to echolocate, have been proposed as reasons that make these mammals uniquely suitable hosts and vectors for viruses [1].

It is likely that these properties of bats make them highly susceptible to viral infections. For instance, bats travel fairly long distances during seasonal migration events; those belonging to the Myotis spp. may fly up to 200–400 miles between their winter hibernation sites and summer ranges [6]. During migration, they are exposed to various habitats that may be potential sources of viral infection. In colonial bat species, such viral infections can quickly spread to thousands of individuals due to the high population densities and behavioral crowding that occurs in roosts.

Echolocation is another possible reason for the wide transmission of viral particles by bats. During echolocation, a bat generates loud sounds through its larynx and emits them through its mouth or nostrils; the echo of these sounds allows the bat to sense its surroundings. During this process, bats likely produce droplets and aerosols loaded with viruses [7]. As the density of bats in a typical roost can be as high as 300 bats per square foot [8], droplets and aerosols can easily transmit viruses to large numbers of bats. In addition, during torpor and hibernation, which set in at low temperatures (in tropical and temperate regions, respectively), the activities of the bats' immune systems are temporarily limited to optimize limited energy reserves [9]. As a result, viruses can easily survive in their bat hosts during these periods. The high probabilities of infections occurring during migration, coupled with the high probabilities of transmission during echolocation, and viral survival during hibernation, likely make bats good hosts and reservoirs for many viruses.

Paradoxically, the different survival strategies that bats have developed to counter environmental pressures make them susceptible to exploitation by viruses. Generally, migration is one of the best strategies to avoid freezing temperatures and ensure an adequate supply of food in winter. However, the migratory movement makes bats more susceptible to viral infections. Similarly, hibernation is also an effective strategy for surviving in extremely cold temperatures. However, hibernation also allows viruses to evade their sleeping hosts' dormant immune systems and survive. Since the same characteristics that ensure the bats' survival in unfavorable environmental conditions make these animals more susceptible to viruses, viral infections can threaten the survival of the Chiropteran family.

Threats to bats: Problems caused by viruses

Hosting a virus usually comes at a cost, even if primary observations in bats indicate no record of clinically symptomatic diseases. However, viruses such as Ebola, rabies, and Lyssavirus impose fairly high costs on their bat hosts by causing fatal outbreaks in bat populations across the world. For instance, the bat Lyssavirus affects the peripheral nervous system of certain species of bats, causing them to display serious clinical symptoms like difficulty in flying, uncontrolled movements, agitated and aggressive behavior, and eventually paralysis [2]. Outbreaks of such diseases prove that the inactivity of viruses in bats cannot always be guaranteed, and that despite having several survival strategies against viruses, these mammals do sometimes fail to neutralize the deadly parasites.

Survival Strategies of Bats: How they fight against viruses?

On the face of it, it seems almost impossible for bats to host so many viruses without showing any clinical symptoms of viral infections. As of now, our current limited knowledge is not enough to provide a complete description of the complex host–pathogen relationship between bats and viruses. However, recent studies on the immunology of bats may explain some of the counter-intuitive patterns observed in bat–virus relationships.

Recent studies indicate that bats' immune systems are very similar to those of other mammals such as humans and rodents. Researchers have identified immune cells that behave similar to macrophages, B-cells, T-cells, lymphocytes, neutrophils, eosinophils, basophils, and macrophages in at least two species of bats [10,11]. Although more studies are required to draw solid conclusions on bat immunity, these studies indicate that the key survival strategy employed by bats against viruses, likely lies in the advanced immune system of mammals.

A promising hypothesis for how bats can host so many viruses without developing diseases suggests that these mammals control viral replication in the early stages of infection [12]. Support for this hypothesis comes from several studies that demonstrate bats' advanced innate immunity, that stops viruses from invading their hosts by blocking the viral replication process. Bats have pattern recognition receptors, including toll-like receptors and inducible gene-like helicases, which help them to very quickly recognize and mount immune responses against different pathogens such as viruses, bacteria, and fungi [13]. In addition, bats have different signaling molecules and receptors to initiate an interferon (IFN) response that induces an 'antiviral state' in their body [14]. Once a virus is detected by pattern recognition receptors, IFN molecules initiate an antiviral response by binding to immune cell surface receptors. These receptors, in turn, activate a series of enzyme-regulated cascades to transmit information to the nucleus, which then switches cells into an 'antiviral state' that directs the production of enzymes that can block viral replication [15].

Apart from their highly responsive innate immune systems, bats also rely on their adaptive immune systems to survive viral infections. Recent studies on bat adaptive immunity indicates that bats can produce antibodies and activate cell-mediated immunity [12]. The mechanisms by which antibody-mediated immune responses in bats function, are similar to those observed in other mammals. Antibodies are used to neutralize, precipitate, and agglutinate invading viruses; these events further trigger the complement system that stimulates immune cells such as macrophages and cytotoxic T-cells to engulf antibody-bound viruses and kill infected cells, respectively [12,16].

Further studies on the innate and adaptive immunity of bats indicate that they possess various specialized gene sequences, proteins, and enzymes against specific viruses. A recent transcriptomic study indicates the presence of myxovirus resistance (Mx) proteins in different species of bats. The Mx proteins are specialized enzymes that suppress the invasive actions of several viruses including orthomyxoviruses, rhabdoviruses, and the human immunodeficiency virus (HIV). This study also indicates that Mx proteins in bats are highly effective in controlling the replication of the influenza A-like (H17N10) virus. The effectiveness of the Mx1 protein in bats is comparable to the inhibitory actions of the highly complicated human MxA protein [17].

Although the mechanisms by which the bat immune system battles viruses is very similar to those of other mammals, it does show some differences in certain quantitative and qualitative immune responses. A recent study on the antigen-binding capacity and specificity of bat antibodies demonstrates that bats have very high diversities in their antibody repertoires, even exceeding those of humans and rodents [18]. This high diversity in antibody repertoires indicates that bats can recognize and neutralize viruses which may not be recognized by the human immune system. Similarly, another study on the interferon regulatory transcription factor 3 (IRF3) gene sequence of bats indicates that there is positive selection for characters that promote antiviral responses. A serine residue (serine185) within this protein is positively selected in the bat population, as it promotes a strong innate antiviral response; phosphorylation of this serine residue in IRF3 plays a vital role in the activation of IRF3 and the induction of a strong antiviral immune response. When researchers replaced serine185 in bat IRF3 with the leucine residue usually found in humans, they found that the antiviral response is severely diminished [5].

Conclusion

Bats are one of the most adaptive, diverse, and abundant species in the animal kingdom. Despite their abundance in nature, the ecology and biology of bats was not well-known due to difficulties in studying them, and researchers' lack of interest. However, recent zoonotic spill-over events involving deadly viruses have sparked interest in bat biology and ecology, as these events were often connected to bats; subsequent research has uncovered the complicated relationship between bats and viruses. Studies have found out that bats are highly susceptible to several viral infections which are fatal to humans and other animals; however, although infected bats carry such viruses, often, they themselves do not show any clinical symptoms of the viral disease. Further studies on bat behavior have revealed that several of the bats' key survival characteristics, including migration, hibernation, and echolocation, render them uniquely susceptible to viral infections, and make them suitable hosts and transmission agents for viruses.

Although bats seem to be able to coexist with many deadly viruses, several viruses such as the rabies virus, Ebola virus, and Lyssavirus cause fatal infections in different bat populations. This indicates that the 'general neutrality' or perceived 'peacefulness' of the bat–virus relationship may be the result of various survival strategies that bats use to fend off fatal viral infections. Though further research is required to gain a more complete understanding of such survival strategies, studies on bats' immune systems have given us some insights into the bat–virus host–parasite relationship. Recent studies indicate that the immune systems of bats have complex defense systems to inhibit viral replication at an early stage. Bats are well equipped with complex immune defenses which include pattern recognition receptors, antigen-specific antibodies, and Mx proteins to fight against viruses. In addition, the high diversity of antibodies in bats (higher than those found in humans and rodents) and active selection for more responsive immune reactions (as evidenced by the selection for serine185 in the IRF3 gene) indicates the presence of an ongoing arms-race between bats and viruses. Although initial work indicates that bats' survival strategies against viruses may depend mostly on a classical immune response, further studies are needed to confirm this and explore other possible mechanisms by which bats survive viral infections. It is in our best interests to better understand the complex relationship between bats and viruses in order to prevent future zoonotic spill-over events like the current COVID-19 pandemic.

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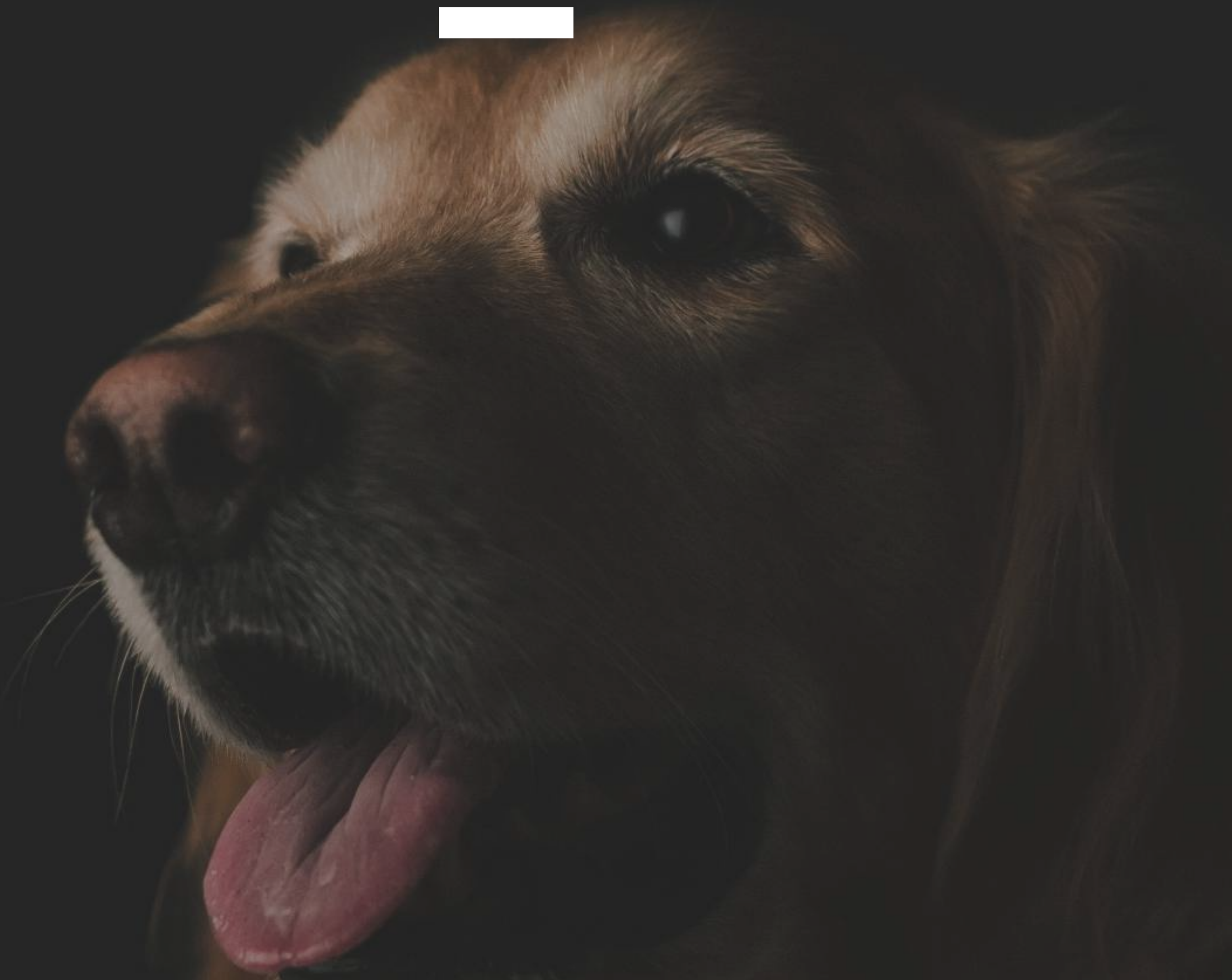
Ethics: A Survival Strategy?



This paper aims to investigate animal behavior and examine whether the human idea of morality is in conflict with evolution, or whether morality as a survival strategy. It will explore behaviors and survival strategies spanning a range of species and kingdoms to test whether ethical codes are prevalent enough to be generalized for the animal kingdom at large.

RUTHU ROOPARAGHUNATH
UG 21

Introduction

Survival strategies are an essential component of evolution ever since life began after the oceans formed 4.41 billion years ago [1]. Although the patterns that emerge in the most diverse and efficient methods of survival are termed 'survival strategies', organisms do not consciously plan or create these strategies for survival. This paper examines various behaviors of different life forms to question whether ethics is a survival strategy on an evolutionary scale.

Ethics has had several definitions and approaches; however, this paper will only analyze ethics from a behavioral perspective and defines it as a broad distinction between 'good' or 'bad.'

Ethics in animals

Charles Darwin, widely known for his contributions to evolutionary theory, believed that social animals would inevitably act ethically. A common objection to the application of the term 'ethics' for animal behaviors, is that animal interactions are usually aggressive, and are driven by the urges to mate and hunt. However, only 0.3% of animal interactions are actually extremely violent [3].

Research has also shown that 'fairness, empathy, forgiveness, trust, altruism, social tolerance, integrity, and reciprocity' are all values that animals have displayed [2]. These characteristics are essential for the performance of defined ethical actions. The behaviors discussed in the sections below illustrate animals displaying these qualities.

Soliciting Play

Similar to human play, animal play is challenging to define; in addition, play does not always serve the same functions in all species. Social play can be defined as all motor activities that appear purposeless, involve the use of activities modified from other contexts, and are directed at another being [4]. Social play requires well-defined social rules, because the partners in play must not misinterpret play with behavior usually used for aggression, hunting, and mating. Therefore, animals must communicate their intent to play beforehand, in a series of behaviors known as soliciting play. There must also be general forms of apology if play gets out of hand.

Coyotes, beagles, and wolves use motions called bows to signify their intent before play. In grasshopper mice, play develops their predatory behavior and thus includes boxing, wrestling, pouncing, chasing, and pinning each other down. To ensure that another mouse interprets these behaviors as play, one mouse approaches it nose-to-nose, flips to its back, and wriggles. A similar practice is also found in rats [5]. Several bird species, such as parrots, display play invitations by distinctly hopping while approaching a partner, rolling onto their backs or cocking heads [6]. Researchers have also observed play behavior in turtles [7]. There is usually no difference in play soliciting behavior between males and females.

In humans, play is the means by which children learn to make ethical decisions, follow rules, regulate emotions, express happiness, and act fairly.

Below is a table (from Bond and Diamond, 2003) [6] showing play types in relation to level of social interaction and brain size in birds may indicate that with increased social interaction and brain size, characteristics of fairness, forgiveness, empathy, trust, and a sense of ethics are more common.

Taxonomic level	Life history variable	Occurrence/ Type of play
Order/ Family	Large brain size/ Altriciality	Enables evolution of play
Family/ Genus	Sociality/ Cooperative breeding	Promotes social play
Genus/ Species	Delayed reproduction/ Persistent association of juveniles with adults	Selects for complex social play in taxa in which social play is relatively common

Fairness through Self-handicapping and Role reversing

Animals demonstrate empathy, trust, and fairness through self-handicapping and role-reversing. Animals self-handicap or restrict themselves in their actions during play to avoid harming their partners. Researchers have observed such behavior in pigs [8].

Most organisms display forms of role reversal during play, in which the dominant animal enacts roles with a less dominant partner that would not occur during truly aggressive mating or hunting contexts. Such behavior indicates the presence of a critical characteristic in the development of ethics—empathy. Empathy is ‘an emotional situation which one animal is in that calls up a reciprocal state of feeling in another animal. It is the identification by one animal with the feelings of another’ [9].

In human children, actions judged as unethical, such as unprovoked violence, gradually decrease in most cases after the ability to empathize is developed [10].

Animals can also demonstrate strong integrity in these principles. They do not falsely use play solicitation cues to initiate genuine mating and aggressive behavior. If they are found guilty of violating these implicit rules of trust and fairness, the offending animal is usually shunned by the rest of the group and often exiled from the group [11]. In canids and black bears, play which involves play fighting, has a fairly strict rule system; animals who consistently bite too hard and refuse to play by the rules are ignored by others and receive fewer invitations to play [12]. Such exiled animals develop less refined hunting and communication strategies, and sometimes have higher mortality rates than the rest of the group.

Aversion to Inequity

Humans, especially human children, frequently resist inequity. Its most common forms are observed in sibling rivalry and proceed to manifest in more complex forms of protest against racism, gender inequality, and other such issues. Interestingly, animals such as chimpanzees, gorillas, macaques, capuchins, and canids demonstrate a similar aversion to inequity, comparable to a human preference for justice.

Macaques and chimpanzees that have a high social ranking intervene on behalf of losing parties in fights [13]. Primates refuse to take part in cooperative tasks if they see others acquiring more or better-quality rewards than themselves for the same effort. Dogs also respond when they do not gain rewards of food for the same task that rewards their partners. However, they do not respond to the quality of food or task effort, unlike primates [14].

These situations indicate that animals do have an ability to recognize inequality and a desire to decrease it. In addition, all species that are known to exhibit inequity aversion are cooperative. Furthermore, the trend seems to be for dominant actors to intervene on behalf of those with less power in terms of hierarchy, fitness, etc. [15].

Conclusion

On a final note, we can ask, do ethics exist in more primitive organisms? The bacterium Bacillus subtilis uses electrical signals to communicate with other members of its own species to coordinate community growth in biofilms so that the innermost cells do not starve [16]. Aleochara bilineata larvae can recognize relatives and display altruism towards them [17]. In experiments with rats, when a rat observed its partner receive an electrical shock and display distress, that rat would often learn to press specific buttons to relieve its partner’s suffering [18].

Thus, we see that ethics are not in conflict with animal behavior and survival. Ethics are, in fact, integral to animal survival. Social animals that do not follow the rules of ethics are often isolated, and have higher rates of mortality than the rest of the group. The evolution of more complex ethical systems is seen in more advanced species, suggesting that ethics is a successful evolutionary survival strategy for animals and animal societies. Perhaps understanding the evolution of ethics in animals will help humans refine our own understanding of ethics.

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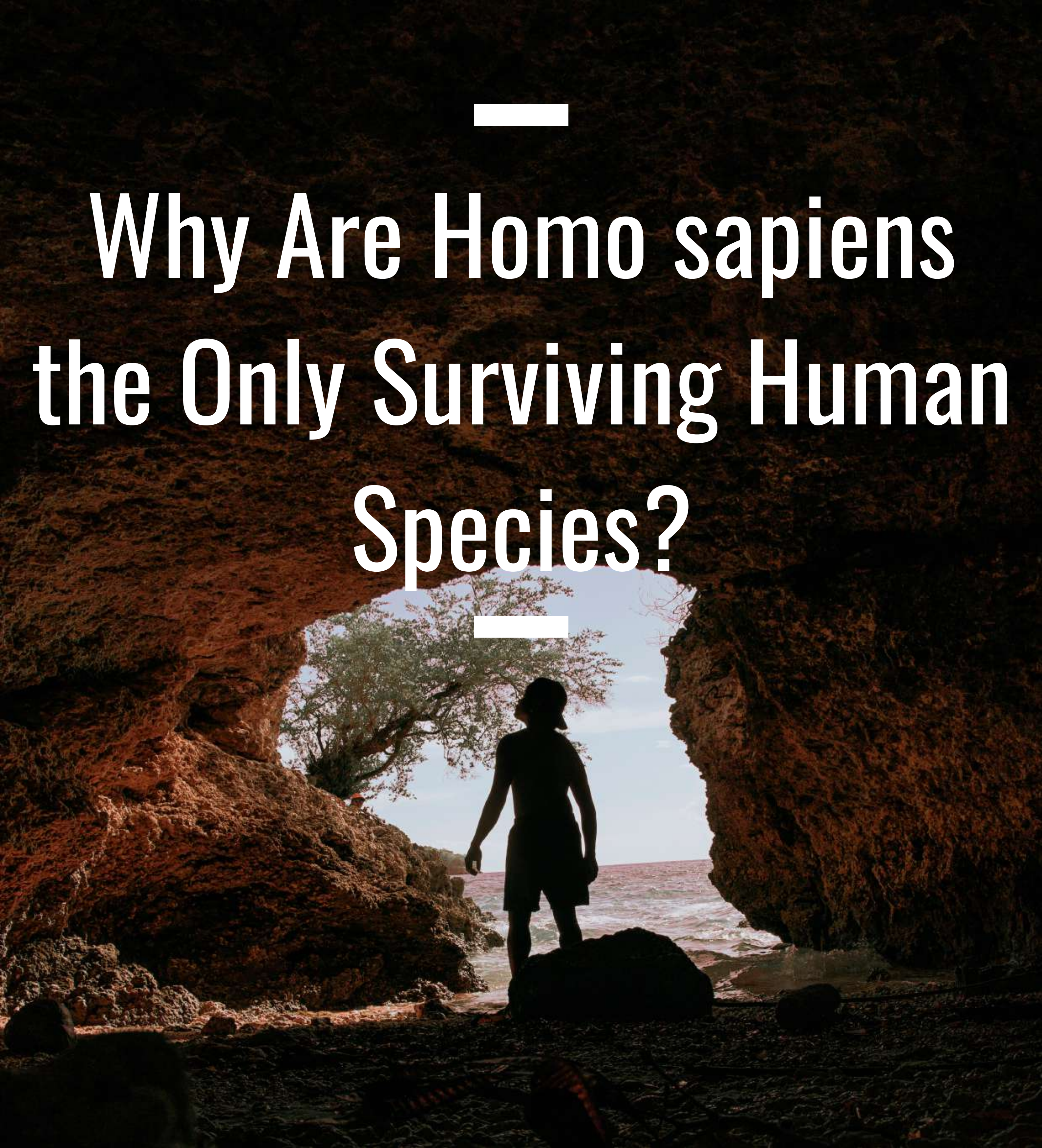
Why Are Homo sapiens the Only Surviving Human Species?



Homo sapiens is the only human species to survive today. This paper analyzes the physiological, morphological, and behavioral adaptations of *H. sapiens* that helped them survive and describes the role of brain development and the cognitive revolution in the evolutionary path of human survival.

SAUMYA SHARMA
UG 21

Introduction

Over millennia, as the environmental conditions on Earth have been through a number of drastic changes, so have the species that inhabit our planet. Every species has had to evolve, sometimes rapidly, to survive in these changing environments; those who failed to do so, have ceased to exist. In accordance with Darwin's theory of natural selection, we have witnessed several species of plants and animals go extinct, while several others, who adapted, have survived. *Homo sapiens*, or the current-day modern humans, have also undergone several adaptations to which they owe their current success and flourishing populations. However, *H. sapiens* was not the only human species to walk the earth. There were several other species of humans, falling under the genus Homo, that came before *H. sapiens*. The question here then arises, why did none of them except *H. sapiens* survive?

Scientists believe that all humans and apes are descendants of the CHLCA (chimpanzee–human last common ancestor) that can be traced back to 6 million years ago. From this ancestor emerged two branches—the apes and the humans. Currently, we are aware of seven different species of humans that existed, out of which only *H. sapiens* still survive today.

- *Homo erectus* lived from about 1.9 million years ago (mya) to about 0.143 mya [1]. Examinations of the H. erectus fossils proved that H. erectus first originated in Africa and spread through India, China, Georgia, and Java. In general, H. erectus were ranged in height from 4 feet 9 inches to 6 feet 1 inch and weighed around 40–68 Kgs. Their heights and weights varied quite widely based on where the fossils were found; for example, fossils from Africa indicated that H. erectus from this area had larger body sizes than those from Indonesia, China, and Georgia [2].

- *Homo heidelbergensis*, believed to be a derived species from H. erectus, lived between 0.7–0.2 mya [1]. Emerging from Africa, this species had a larger braincase with a flatter face than today's humans. They were the first human species to adapt to colder climates and build shelters, besides which, they were also widely known for their ability to hunt large animals [2].

- *Homo rudolfensis* is another extinct species that fall within the hominid category. They lived around 1.9–1.8 mya [1]. Their physical features are still unknown due to the scarcity of cranial fossils. Many scientists believe that H. rudolfensis should be reclassified under the Australopithecus genus; Australopithecus is a genus of apes from which the genus Homo evolved. However, due to the lack of fossils, this relationship and classification remains unclear [2].

- *Homo habilis* lived 2.4–1.4 mya [1]. They possessed some ape-like features such as long arms and a moderately prognathic face. Although they had large braincases (550–687 cm), they had smaller faces and teeth than other hominids. There has been some debate as to whether Homo habilis should be classified under the genus Homo as they share very few characteristics with the other species in this genus. However, scientists have discovered that H. habilis had the capacity to use stone tools for various purposes, and so these hominids have been retained in the genus Homo [2].

- *Homo floresiensis* lived from 95,000–17,000 years ago in Indonesia [1]. One of the most recently discovered species, they stood at about 3.5 feet tall, had tiny brains, large teeth for their size, shrugged forward shoulders, no chins, receding foreheads and large feet. Despite their diminutive brain size, H. floresiensis made and used stone tools, hunted small elephants and large rodents, and dealt with predators such as the Komodo dragons. So far, fossils of these early humans have only been found on the island of Flores (Indonesia) [2].

- Homo neanderthalensis is an extinct species of human with the highest similarity to modern humans. Only 0.12% of their DNA differs from that of modern humans. These hominids possessed most of the features of modern humans, used various tools for hunting, and even wore symbolic ornamental items. Some evidence suggests that they used to bury their dead with offerings such as flowers, thus engaging in symbolic behavior much like H. sapiens. The Neanderthals were believed to have existed from about 600,000–30,000 years ago and lived throughout Europe and in southwest and central Asia [2].

- Homo sapiens are the only species of humans that currently exist. They are said to have diverged from an ancestral species—perhaps H. erectus—around 200,000 years ago in eastern Africa (present-day Ethiopia). However, there have been discoveries of fossils dating much farther back, all the way across the African continent in Morocco, that are believed to be ancestral human remains [2].

Survival of hominids and modern human

Through several studies, we know that the other hominids were equally (if not more) equipped than *H. sapiens* to cope with their surroundings. Neanderthals, with whom we share a significant amount of DNA, were much stronger and had larger limbs (with males standing at 164–168cm in height and females at 156–158 cm) than *H. sapiens*. A study has also shown that Neanderthal and modern human brains were similar at birth; however, as they grew older, Neanderthal brains increased in size. The elongated legs and short arms of *H. erectus* allowed them to climb trees easily and run faster than the *H. sapiens*. The small build of the *H. floresiensis* enabled them to survive on an island. Yet, none of these adaptations kept these hominids from going extinct.

Most hominids engaged in hunting and gathering plants, fruits, and other edible items each day. Several species fashioned simple tools such as wooden spears (reportedly made by *H. heidelbergensis*) and stone hammers to aid in their food collection. However, some species like *H. sapiens* and *H. neanderthalensis* learned to make more complex, task-specific tools such as sharp hand axes, using bones, antlers, wood, and flintstone; there is also evidence to indicate that these species had begun to use fire for various purposes as well. In addition, prehistoric *H. sapiens* also made a variety of smaller, more complex, and refined tools like fishhooks, harpoons, bows and arrows, and sewing needles. Thus, it is possible that *H. sapiens* were set apart from the rest of their species owing to their dexterity with toolmaking. This advancement, like most things that set *H. sapiens* apart from other hominids, is likely due to the several unique aspects of their brains [3].

The *H. sapiens* brain is the largest one relative to body size amongst all the hominid species. Although a larger brain may be associated with an increased chance of survival, it does come with some caveats; a larger brain at birth would require a wider birth canal for the infant to pass through. However, if a female's birth canal were too wide, it would widen her pelvis, thus hampering her ability to run, which was a vital survival skill also.

Nonetheless, the larger brain-to-relative-body-size ratio in *H. sapiens* may have paved the way for a cognitive revolution, leading to a social and agricultural revolution, thus boosting survival. To cope with the problem of large head-sizes during birth, another adaptation allowed the brain to continue its development with age;

the capacity of the *H. sapiens* brain to continue learning with age is far beyond that seen in most organisms. This adaptation brought about changes in the anatomy of the prehistoric humans, particularly in the cranial region, and the advanced brain development allowed them to travel across and inhabit varied climates. From the harsh dry environments of Africa, *H. sapiens* eventually spread out into the colder, wetter regions of Europe and Asia. Most other hominid species settled in only comfort zone regions consisting of grasslands and woodlands. Thus, when extreme climatic changes swept the planet after the Toba catastrophe, they became casualties of genetic bottlenecks. The Toba catastrophe occurred as a result of a super-eruption in Lake Toba in present-day Sumatra, Indonesia, around 75,000 years ago. The Toba catastrophe theory holds that the eruption caused a volcanic winter for 6–10 years and a 1000-year cooling period after that. Due to their exploratory nature, some populations of *H. sapiens* had become accustomed to colder conditions and were able to cope with these climatic changes while most other hominids were not [4].

It is also possible that a combination of behavioral and physical characteristics—many of which other species of early humans also possessed, but not to the same degree as *H. sapiens*—contributed to this species' survival. No other animal on the planet functions in networks as large as those maintained by *H. sapiens*. This communication among large numbers of individuals is unique to humans and functioned in communicating vital information about danger, detailed maps of surroundings, and strategies to hunt and forage for food. The complex brains of *H. sapiens* enabled them to interact with each other and with their surroundings in new and different ways. As the environment became more unpredictable, bigger brains probably helped them to survive. sometimes included people they'd never met before.

The large networks that *H. sapiens* maintained with different populations of their species led to the creation of art, music, ornaments, rituals, and complex symbolic practices. The time from around 70,000 years ago to 30,000 years ago witnessed the invention of boats, oil lamps, better versions of bows and arrows, and finer sewing needles to make warm clothes. The first objects of art date back to this era, as does the first clear evidence of religion, commerce, and social stratification. Scientists still unsure about which changes in the brains of *H. sapiens* triggered these advances but agree that these are all products of a cognitive revolution. The most commonly believed theory is that genetic mutations over time changed the wiring of the *H. sapiens* brain, enabling this species to think in unprecedented ways and communicate using new types of languages [3].

This cognitive development even allowed *H. sapiens* to make the transition from a hunting and gathering lifestyle to one producing food; it further led to *H. sapiens* altering their surroundings to control the growth and breeding of desirable plants and animals. These practices of farming and herding began to physically change the landscape of the earth, allowing *H. sapiens* to settle down and form communities, which grew into small villages and provided *H. sapiens* with the resources required to flourish. With the increased and easy availability of food, and an extensive network of individuals, a sense of security prevailed, and populations began to increase dramatically. These advances aided in the development of complex systems of social existence and bartering, along with rituals and practices that were passed down over generations.

Conclusion

Due to their unique brains, *H. sapiens* have created and sustained networks of interconnected populations that have allowed this species to protect and provide for themselves, and even flourish under conditions that other species of hominids were unable to survive. The *H. sapiens*' versatile use of language, tendency to explore and adapt to new climates and landscapes, innovative hunting strategies, and overall social connectivity has gained them the upper hand in survival and brought us to our current state of dominant existence on the Earth.

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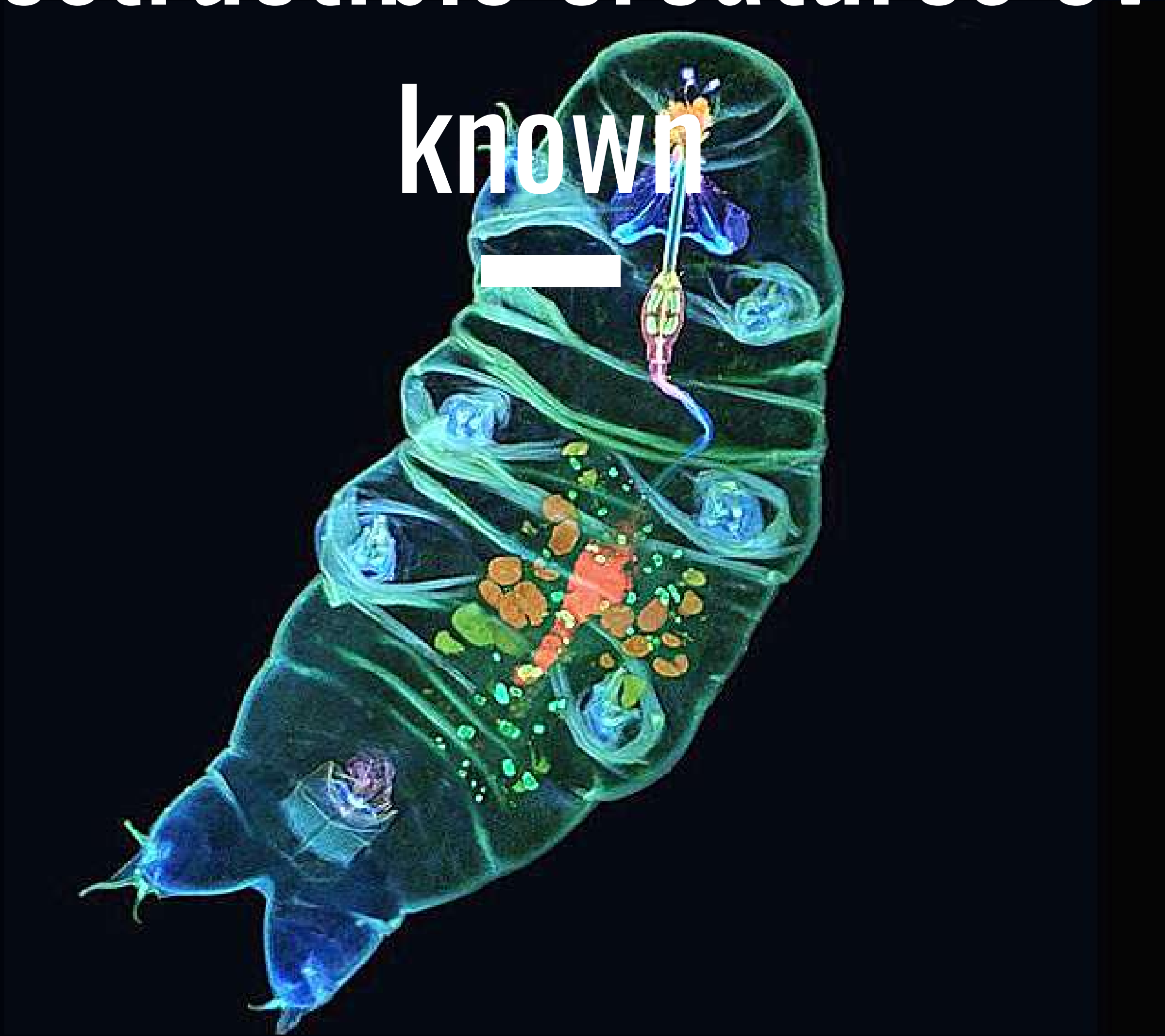
Tardigrades: one of the most indestructible creatures ever known



Tardigrades use diverse mechanisms to survive in different environments and have unique taxonomic and biological features. This paper discusses the different survival strategies and overall effectiveness of these strategies in the survival of tardigrades.

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Introduction

Tardigrades (slow walkers, from tardus = slow and gradus = step), also known as water bears or moss piglets, are a phylum of small multicellular invertebrates of size 0.1mm–1.5mm. Since the discovery of the first tardigrade in 1773 by the German zoologist Goeze, approximately 1000 known species of tardigrades have been discovered till now [1]. Tardigrades can be found abundantly in nature from the depths of the ocean to the tops of mountains. Terrestrial tardigrades live in association with bryophytes and lichens, while in aquatic environments, they are found in algae and bryophytes. Terrestrial tardigrades are limnoterrestrial, requiring moist environments to survive and grow in; therefore, they are found in mosses and liverworts, which generally have adherent water drops that provide an ideal environment for these organisms [2]. These terrestrial tardigrades usually have a lifespan of about 3-7 months [3].

Tardigrades have a head, a three-segmented body with one pair of legs per segment, and a tail with another pair of legs. Tardigrades have sharp little teeth that help them to pierce plant parts and capture small invertebrates upon which they feed. Tardigrades have flexible cuticles on their bodies which help them sense surrounding vibrations. The legs have claw-like endings, which help in grabbing onto food and surfaces. Despite their tiny size, several species of tardigrades boast complete digestive systems and well-developed nervous systems. Tardigrades can either be dioecious or bisexual.

Physiological Adaptations

Aquatic tardigrades usually do not undergo dehydration, extreme temperatures, and desiccation, due to which they have not developed strategies to survive such conditions. However, limnoterrestrial tardigrades have developed some remarkable survival strategies to adapt to these terrestrial dangers. Terrestrial tardigrades obtain nutrition from bryophytes by using their stylets to suck the contents of bryophyte cells. In exchange for these nutrients, the tardigrades protect their host bryophytes from parasites such as nematodes and protozoa by feeding on these organisms.

Terrestrial tardigrades have several physiological adaptations that help prevent desiccation and maintain a water film around their bodies. These tardigrades have chitin in the innermost layers of their cuticles; this chitin-based armor of some limnoterrestrial tardigrades (Heterotardigrades) slows the process of drying and protects against dehydration. The ability of limnoterrestrial tardigrades to dry slowly allows them time to enter a dormant mode, called a ‘tun’ to tide over dry conditions. This also prolongs their life spans as tardigrade cells do not age during dormancy.

Due to their small size, tardigrades are well-suited to their lives in the miniature world of bryophytes. Their claws permit them to clamber about easily among the leaves and branches of bryophytes. The small chambers among bryophyte branches within which tardigrades are found, protect these organisms from larger predators; in addition, the spines and hairs on limnoterrestrial tardigrades help them avoid predators. Furthermore, bryophytes carry the tardigrades with them when they disperse. The interstitial water in the leaf sheaths of bryophytes also provides a suitable habitat for tardigrades [4].

Limnoterrestrial tardigrades have eyes that allow them to respond to light. In one species, *Macrobiotus hufelandi*, the response to light changes with size and age [5]. The smaller (younger) *M. hufelandi* move away from light. Beasley (2001) hypothesized that this adaptation helps the smaller tardigrades conserve body moisture as they have a larger surface area to volume ratio than larger tardigrades. This response is not phototaxis (directional response to light), but photo kinesis (non-directed, random movement), where the tardigrades change directions when exposed to light, and move faster to get away from light.

Adaptations to extreme conditions: cryptobiosis and tun formation

Tardigrades are well known for their ability to survive in extreme conditions. They have adopted various physiological and morphological strategies to survive in extremely dry, highly saline conditions, as well as under high pressure and low oxygen conditions; tardigrades are also known to be able to survive nuclear radiation. Tardigrades can survive such conditions in a state known as 'cryptobiosis'.

Cryptobiosis is a reversible ametabolic state induced as a result of several stresses including dehydration, cooling, osmotic stress, and low oxygen concentrations. Before entering the cryptobiotic state, tardigrades synthesize glycerol, sucrose, and trehalose from their glycogen reserves [6]. Cryptobiosis in tardigrades occurs in different forms:

- anhydrobiosis: induced by loss of water
- cryobiosis: induced by low temperature
- osmobiosis: induced by high salinity
- anoxybiosis: induced by low concentrations of O_2

Cryptobiosis is followed by the formation of a tun, which can be described as a ball-shaped dormant tardigrade. Usually, tun formation occurs during anhydrobiosis, osmobiosis, and cryobiosis, but not in anoxybiosis. Tardigrades can survive 0% relative humidity as a tun. Tun formation is usually triggered when relative humidity levels fall by 70-95% [7] . During tun formation, tardigrades lose almost 95% of the free and bound water in their bodies [8]. ax is also extruded onto the surface of the tun to prevent further water loss in this stage [9].

Tun formation stalls aging and can increase the life span of a tardigrade to years or even decades. In the presence of abundant water, tuns can revive in as little as four minutes, though in most cases, the process takes several hours; the length of time take for revival also depends on how long the tardigrade has been in the tun form [10]. The presence of cell protectants such as trehalose, glycerol, and heat shock proteins contribute to successful recovery from the tun state [11]. Long periods of dormancy, even in the tun state can cause cell degradation and DNA damage in tardigrades [12].

Anhydrobiosis

The most common cryptobiotic state is anhydrobiosis (a state of dormancy brought on by dehydration). In a state of anhydrobiosis, tardigrades can tide over conditions of prolonged dryness [13].

Tardigrades must dry very slowly to enter the anhydrobiosis stage [2]. During this process, they retract their head, legs, and hind ends to form a rounded tun to reduce surface area. The small spaces among mosses hold static air that can slow the dispersion of water vapor; this allows tardigrades to undergo slow drying which is necessary for the tardigrade to form tuns to survive in the desiccated state. Typically, tardigrades desiccate in 75% relative humidity;[6] during this process, they dehydrate rapidly, following which there is an abrupt reduction in water loss, called the permeability slump. This slump occurs in live animals before tun formation, as well as in dead animals, and so is known to be a non-physiological phenomenon.

Like nematodes and rotifers, tardigrades prepare for desiccation by producing glycerol and disaccharide sugars including trehalose from glycogen reserves. Trehalose, sucrose, and glycerol are used as membrane protectants (the water in the cell membranes are replaced by these sugars) [1]4. The accumulation of trehalose to 0.1–2.3% of dry weight occurs within 5–7 hours of onset of desiccation in *Richtersius coronifer* [1]5.However, they can reverse this accumulation within 6 hours of rehydration. Trehalose has multiple properties that help to stabilize desiccated cells.

The reduction in surface area during tun formation also helps in slowing the process of dessication [6]. Tardigrades with the highest tolerance towards desiccation have tuns with the greatest infolding.

In the tun stage, tardigrades can also survive extremely high temperatures. Experiments performed on the eutardigrade *R. Coronifer*, also known as the yellow water bear, show that during this anhydrobiotic state they can survive temperatures of 70^{o}C for 1 hour; however, as temperatures exceed 70 ^{o}C, their survival decreases until no specimens survive at 100 ^{o}C [1]6.

Cryobiosis

Cryobiosis is a form of cryptobiosis that occurs at low temperatures. Ice-nucleating proteins located outside the tardigrades' cells act like water magnets, drawing water out of the cell to prevent the formation of ice crystals which can disrupt and destroy cellular structures and membranes. Glycerol presented inside the cell also acts as an antifreeze and prevents cell damage. In this stage, tardigrades can survive for decades.

Osmobiosis

Most organisms have sodium-potassium pumps in their cells that maintain a constant gradient of sodium and potassium inside and outside the organism's cells. High salinity results in dehydration of the cell by osmosis. Tardigrades found in aqueous surfaces and oceans form osmobiotic tuns to survive high salinity.

Anoxybiosis

Tardigrades are very sensitive to changes in oxygen concentrations, and prolonged oxygen deficiency results in failure of osmoregulation. Anoxybiosis is the only cryptobiotic stage in which a tun is not formed. During this stage, tardigrades take in water until they are fully turgid and immobile with a fully extended body. This allows the tardigrades to reduce movement and metabolic activity, which helps them survive low oxygen levels. Most tradigrades cannot survive for very long (at the most, for 3–4 days) under low oxygen conditions [17].

Radiation

An investigation has shown that the tuns of *R. coronifer* can survive gamma radiation up to a dose of 1 kGy without any adverse effects. In comparison, the hydrated stage of this tardigrade can survive up to 5 kGy of gamma radiation [18]. Another experiment on *Milnesium tardigradum* showed that these tardigrades can tolerate up to 8 kGy of gamma radiation [19]. These results suggest that tardigrades rely on an unidentified DNA repair mechanism to repair radiation- damaged DNA. Another set of experiments carried out by the European Space Agency on the survival of tardigrades exposed to outerspace conditions suggests that these organisms can survive the extremes of outer space, including vacuum, ionizing and solar UV radiation, and extreme cold.

Conclusion

Tardigrades can survive almost all extreme conditions. However, they are not immortal, and do die due to natural causes, predation, or under long periods of abiotic stress. Tardigrades cannot be classified as extremophiles as they do not prefer to stay in extreme environments. However, they are capable of surviving in extreme environments. Even though one can argue that exposure to extreme conditions can drastically increase the lifespan of a tardigrade, these conditions are still not favorable for the tardigrades' growth and reproduction, and most tardigrades do not survive extreme conditions indefinitely. Another important observation is that limnoterrestrial tardigrades have much more effective survival strategies to unfavorable environmental conditions than their aquatic counterparts.

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Creativity in the face of danger – a glimpse into the survival strategies of Spiders

Spiders have many strategies to ensure their survival. These encompass anatomical variations, foraging strategies, and adaptations to suit the habitats that they find themselves in; from using bright colors on their abdomens to warn away predators, to spinning webs to capture prey, spiders' survival strategies are myriad. This paper analyzes different survival strategies of spiders in light of their habitats.

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Introduction

Spiders are air-breathing arachnids that fall under the phylum Arthropoda. Unlike other arthropods, spiders have a two-segmented body, the cephalothorax (prosoma) and the abdomen (opisthosoma). The cephalothorax contains the legs, brain, and stomach, while the abdomen contains the heart, reproductive-organs, gut, and silk glands of the spider. A narrow stalk known as a pedicel connects the cephalothorax to the abdomen. The pedicel contains nerve cords, blood vessels, and respiratory tubules.

Abundant and ecologically important in many ecosystems as predators, spiders have recently gained attention as a result of significant studies in the field. Due to their small sizes, short lifespans, and strong genetic influences on their behaviors, spiders are now being recognized as good model organisms for behavioral ecology [1].

Aestivation

In temperatures that are too warm, some spiders 'aestivate' to ensure survival. Aestivation is a form of dormancy seen in some animals in the tropical summers. These creatures retire into dens or nests and remain torpid or semi-torpid during the hot dry season. It is a state similar to hibernation which is seen in animals in colder countries [2]. During perfect aestivation, normal functions, such as respiration, digestion, and voluntary muscle action, are entirely, or almost entirely, suspended. Spiders usually find a burrow or crevice to aestivate in during the hot summer months. The Californian Mason spider goes into aestivation by May or June and emerges only in November when the weather conditions suit them better [2].

Cold Adaptation

It is important to note that spiders have adapted to survive in colder temperatures. Certain spiders even build warm, protective web nests that they can hunker down in during winter months. These nests are much like spider egg sacs and provide insulation during winter months. The fishing spider and tarantula are perfect examples of this behavior. An alternative solution native to species in cold climates is the accumulation of glycol compounds in their bloodstream over time. These compounds function like an antifreeze that allow the spider's tissues to "supercool" and remain unfrozen even when exposed to below-freezing temperatures. Many antifreeze-producing spiders work their way through the top layer of snow and soil to reach the "subnivean zone" where temperatures are warmer. Spiders stop producing their biological antifreeze when the air temperature begins to rise again in spring [3].

Predators

Apart from unfavorable environmental conditions, another challenge to survival that spiders face are predators. First, let us take the example of a spider living near a water body, namely the Eurasian diving bell spider *(Argyroneta aquatica)*. The open water is a dangerous place filled with predatory fish and insects, which are generally better swimmers than the spider. However, these spiders have adapted to survive in water by constructing a net of silk in vegetation beneath the surface of the water and filling it with air carried down on their abdomens [4]. They use this air for breathing, which allows them to stay underwater. The spiders spend their entire lives submerged and even lay their eggs in their diving bells. The diving bell's gill-like properties help spiders stay safely in their bubbles for long periods of time. Another survival strategy in spiders is called 'autotomy'—the ability to self-amputate a leg when grabbed by a predator. This allows the spider to escape by leaving a limb behind. Some spiders can even regenerate this limb later on [5].

Mimicry

Spiders use mimicry, warning signs, and camouflage to escape their predators. The dung spider *(Phrynarachne decipiens)* and the bird dropping spider *(Celaenia kinbergi)* use mimicry to blend into their surroundings to escape predators. Figure 1 highlights the bird dropping spider's use of mimicry, as both, its body and its eggs resemble bird droppings, which predators usually ignore. The black widow spider, on the other hand, uses a highly visible warning sign—the red, hourglass-shaped mark on its abdomen—to warn off potential predators. The wrap-around spider *(Dolophones sp.)*, spins its orb web at night, but by day, it wraps itself around a twig and 'disappears.' This is an excellent use of camouflage and ensures protection from predators like birds and wasps, which are mostly active by day.

Figure 1: The bird dropping spider and its egg sacs.[6]

Figure 2 shows the camouflage technique adopted by the wrap-around spider. The color and texture of the spider's body resembles it surroundings in order to make this possible. Sand spiders that live in deserts and arid conditions are often lightly colored to blend into their surroundings so that they can not only avoid predators, but also remain invisible to their prey.

Figure 2: The wraparound spider with coloration and texturing resembling the stem of a plant and protuberances that mimic the thorns.[7]

Hunting for food

Spiders are extremely adept hunters, using many methods to capture prey, such as active pursuit, cautious stalking, and sit-and-wait ambushes. However, their ability to spin silk is one of their most versatile survival tools [1]. Using a web to hunt for prey is less tiring and hazardous than active hunting. Webs allow spiders can catch prey even while sleeping, which makes it an extremely efficient hunting mechanism. Spiders perceive vibrations in their webs through slit sensillae located on their legs; these sensillae can detect even faint movements. Several spiders, however, do not use webs to hunt prey; instead, spiders like the wolf spider, have evolved fast and strong limbs to pursue and capture prey on foot quickly. Funnel web spiders are another example of this aggressive strategy, using their strong legs to catch and kill their prey, although these spiders usually use a camouflage and sit-and-wait technique to lure prey close. Furthermore, some spiders even engage in 'group foraging', a phenomenon where many spiders either build colonial webs (like the cobweb spiders) or cooperate with each other to catch prey [1].

Conclusion

Spiders have evolved various strategies to overcome a multitude of threats to their survival. This paper highlights the numerous strategies that these eight-footed creatures have employed in their quest for survival—from different hunting techniques to suit their habitats and mimicking objects to avoid predation, to surviving under extreme temperatures.

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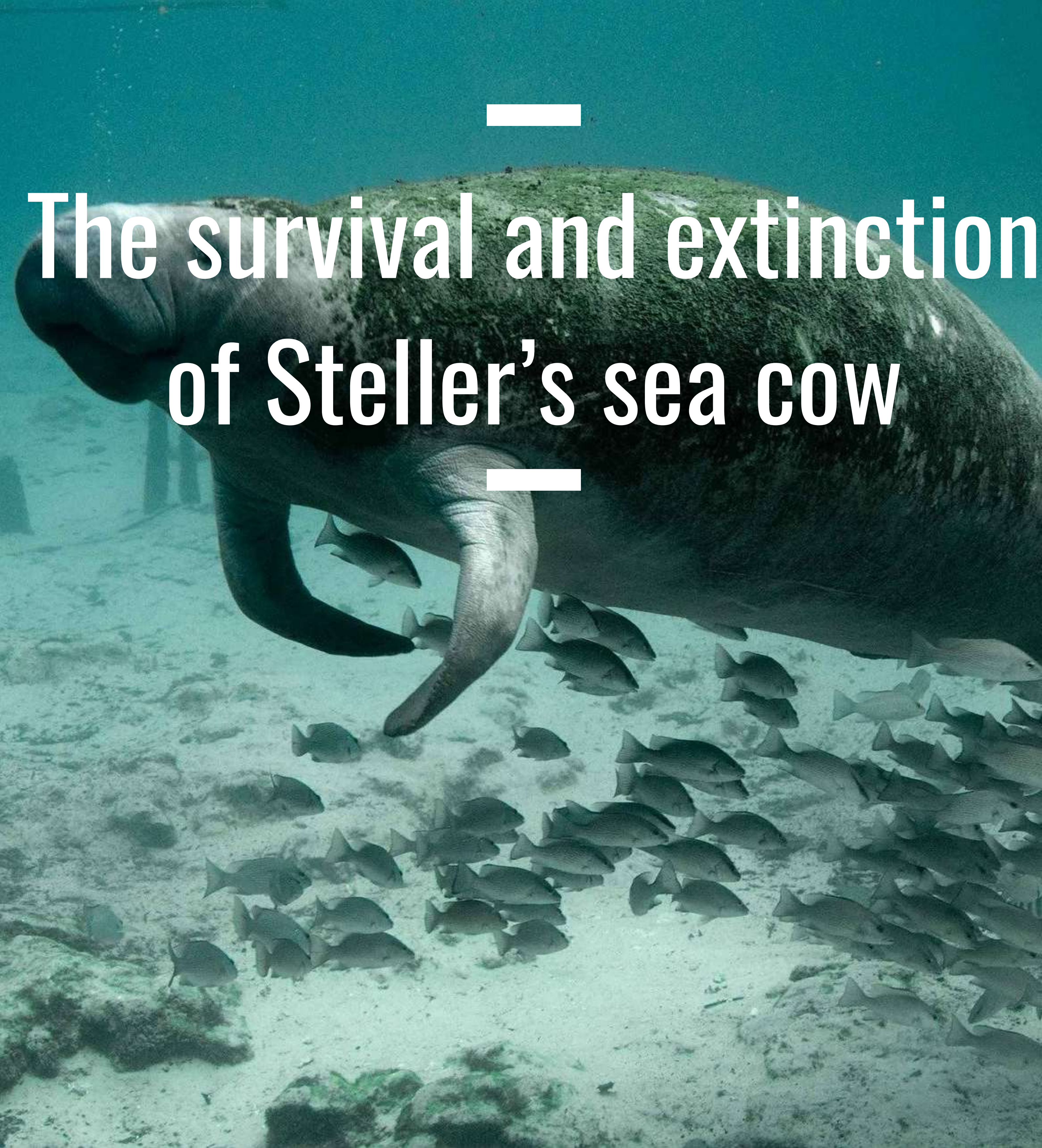

The survival and extinction of Steller’s sea cow

Unknown to humans until 1741, the now-extinct Steller’s sea cows (*Hydrodamalis gigas*), were the largest sirenians ever discovered. These magnificent beasts were discovered by the German naturalist, Georg Wilhelm Steller, on his voyage in the northern Pacific Ocean. This paper describes the various survival strategies that had been used by this member of the Dugongidae family and explains some of the reasons for its extinction.

ABHED MANOCHA
UG 21

Introduction

The end of the Pleistocene epoch saw the extinction of various megafaunal species across the globe. The cause(s) of these mass extinctions, whether attributed to climate change, human involvement, or a combination of both, are still intensely debated among scientists. However, it is a fascinating fact that a few Pleistocene giants survived the Quaternary extinction event. Most of these survivors found refuge on islands or other remote areas. One of these giants was the Steller's sea cow *(Hydrodamalis gigas)*, which found refuge in the near-shore areas of the Commander Islands in the Bering sea. As the austral algae in the central Pacific region evolved stronger chemical defenses against aquatic herbivore feeders such as the Steller's sea cow, these animals moved towards the northern part of the Pacific region, where relatively non-toxic kelps proliferated.

Most of our knowledge about the Steller's sea cow is based on Steller's observations in the Commander Islands, which were published posthumously in the book *'On the Beasts of the Sea'*. Further studies on the Steller's sea cows were not possible, as, within just 27 years of their discovery, humans hunted these mammals into extinction. Before going into the strategies that the Steller's sea cows used to survive, we will take a brief look at their origins, characteristics, and the reasons that led to their extinction.

Characteristics and behavior

Hydrodamalis gigas, or the Steller's sea cows were megafauna. They were quite possibly the largest recently alive non-cetacean mammals, measuring up to 9 meters and weighing about 11 tons. These sea cows were much larger than their present-day relatives, the manatees and dugongs [1].

Despite the differences in size, Steller's sea cows and dugongs are very similar, with relatively small heads and broad, horizontally forked tail flukes. Like all sirenians, Steller's sea cows had downward pointed snouts to allow them to grasp kelp better during feeding. Their upper lips were large and broad, extending so far beyond the lower jaw, that their mouths, which were toothless, appeared to be underneath their skulls. Instead of teeth, these animals had a dense array of interlacing white bristles on their upper lips, which they used to tear seaweed stalks and hold food. Additionally, they also had two keratinous plates located on their palates and mandibles for chewing. It has been hypothesized that since other sirenians do not have such features, Steller's sea cows developed these adaptations in order to consume kelp, which was likely the only readily available food source in their habitat.

Ecology and Survival Strategies

It is likely that the Steller's sea cows grew to such large sizes (as compared to the extant sirenians) in order to conserve heat by reducing surface-area-to-volume ratios, a commonly found adaptation in many mammals in cold areas. The Steller's sea cows also had thick, one-inch deep dermises with blubber layers that could be 3–4 inches thick.

These features were probably crucial in allowing the sea cow to survive in the colder areas of the Northern Pacific. There is fossil evidence which indicates that Steller's sea cows once roamed widely across the north Pacific region; bones of these sea cows found in places as far apart as the Boso Peninsula and Japan bear testimony to this [3,8].

Fossil evidence also indicates that Steller's sea cows were confined to the shallow waters around the uninhabited Commander Islands (Bering and Copper Islands) only by the late Holocene. Their tendency to stay near shores was likely due to the availability of kelp, their main food, and to avoid predators such as sharks, which do not prefer to hunt in shallow water. Another reason for these sea cows' preference for shallow water, was their high buoyancy; for sea cows, it may have been impossible to submerge completely in order to feed on the sea/ocean beds in deeper water. It is believed that Steller's sea cows would not dive deeper than 1 meter below the tide, further compelling it to remain near shores. However, this buoyancy also helped them avoid predators, which would have had to expend great efforts to kill these sea cows by drowning.

According to Steller, these sea cows were extremely gregarious. They lived in small family groups and were extremely loyal towards their families. In addition to being monogamous, they also displayed exemplary parental care by going to great lengths to keep their young safe from predators. Steller recalls a situation where a harpooned sea cow was circled by its family. Taking advantage of these sea cow's protective behaviors, hunters would often specifically target females to draw all the nearby male members of her family; as the males tried to ram the boat to protect the wounded female, hunters would capture or kill them easily. Steller, in his accounts, noted that when a mated female was killed, her mate would visit the beach where the female's carcass lay day after day.

The only protections that the Steller's sea cows had against human hunters were incredibly thick hides and strength due to their large size. However, the sea cows' non-violent natures, allegiance towards one another, and buoyancy (they were easy to spot and hunt as they floated) worked against them and ultimately led to the extinction of the species.

Extinction

The reasons behind the extinction of the Steller's sea cow have been subject to debate for almost a century. Stejneger (1887) [4], along with Turvey and Risley (2005) [5] concluded that extinction correlated positively with human persecution and habitat loss. Human greed also contributed to the pressures against the sea cows by indirectly causing a boom in the sea urchin population (due to overhunting of sea otters that fed on the sea urchins) in that area; since sea urchins competed with the sea cows for kelp, this was another factor that contributed to the extinction of the Steller's sea cows. In addition, some studies highlighted relationships between the decline of the sea cows and other non-human factors such as the sea cows' shift towards a kelp diet (along with the demands of a colder environment) and large body size, higher birth weight, prolonged maternal care, and a lower reproductive rate.

Steller noted that sea cows were obligate herbivores and spent most of their day feeding and lifting their heads out of the water for air every 5 minutes. Their diet primarily consisted of kelps belonging to the genera Laminaria, Hedophyllum, and Alaria. These shallow water kelps were also a staple diet for sea urchins. Several authors concluded that hunting alone was insufficient to exterminate sea cows, and that their decline was instead driven largely by the loss of their primary food source [10]. This argument posits that imbalances in the kelp–sea urchin–otter relationship was the main cause of the sea cows' extinction. Humans not only hunted the sea cows, they also hunted sea otters in vast numbers. Since sea otters are major predators of sea urchins, steep declines in otter populations due to indiscriminate hunting set the stage for a boom in the sea urchin population, which, in turn, affected kelp populations.

As Jacob Mikanowski puts it, *"the decline in the number of sea otters around the Commander Islands happened so swiftly that it would have rippled through the ecosystem in just three decades, leaving the sea cows with nothing to eat and nowhere to go. In other words, the sea cows weren't murdered; they were collateral victims in a separate crime."* [8]

Comparison with its Surviving cousin: Dugong

In this section, we will draw parallels between the Steller's sea cow and its closest living cousin, the dugong, which is currently the only living member of the Dugongidae family; both species share a common ancestor which lived during the Miocene epoch. In a nutshell, the dugong is a much smaller and more adaptable version of the Steller's sea cow. Although dugongs, like the Steller's sea cows, are also very social, they are usually found alone or in pairs. Larger gatherings of dugongs only occur for short periods of time. This is an essential part of the dugong's biology, as the seagrass beds on which the dugongs feed, usually cannot support large populations of these mammals [9].

Additionally, dugongs are known to dive down to depths of 39 m below the tide, where they can eat invertebrates such as polychaetes [10] or marine algae if and when the supply of their choice of grass is inadequate. Dugongs are also 'semi-nomadic' and can travel long distances in search of food or better habitats. This ability has probably helped them establish a broader range than those of the Steller's sea cows and has made dugongs much more adaptable.

Dugongs are also known to use different habitats for different activities. For example, shallow tidal sandbanks and estuaries are usually used as calving sites, whereas shallow and sparsely vegetated waters are used as lekking areas during the mating seasons [11].

It is possible that all of these characteristics make dugongs more adaptable to change than the Steller's sea cows. However, this does not mean that the dugong is thriving. The IUCN has currently classified dugongs as 'vulnerable' in the IUCN red list. Coupled with the dangers of human activity, the dugongs' low reproduction rates and specific food sources are causing dugong populations to shrink every year.

Learning from extinction

Once, most naturalists, including Steller, shared the belief that marine animals could never become extinct. Steller envisioned a future in which a huge amount of trade would exploit tons of meat, oil, and fur from what he considered an inexhaustible supply of sea cows from the seas and oceans. However, the sea cow became extinct within just 27 years, not even 3 full decades after its discovery (the last sighting of a Steller's sea cow was in 1768). This disaster helped persuade European biologists that marine animals can also go extinct if they are indiscriminately hunted.

According to the environmental historian Ryan Tucker Jones, the disappearance of the sea cow urged scientists to study extinction. This event was also a key example highlighting the need for understanding how the overhunting of one species can lead to the extinction of another, and the concept of complex ecological systems [8]. The sea cows found on the Commander Islands were a small remnant of what had once been a significant population. Although the Steller's sea cows did face severe population growth limitations in their subarctic environment, it was human activities that drove them to extinction.

Richard Sabin, the principal curator of mammals at the Natural History Museum, London, says, *"what fascinates me most about the development of our awareness of extinctions caused directly by human actions, is at what point in our recent history did we realize—from a compassionate perspective and not an economic one—that numbers were decreasing and there were problems on the horizon?"* [12]

Unfortunately for Steller's Sea Cow, this realization came too late.

"They hold up as an example of the first sea mammal in modern times made extinct by human ignorance and greed," adds Sabin [12].

Conclusion

The Steller's sea cows' failure to adapt to the new threats (indiscriminate hunting and loss of food resources) caused by humans was one of the key causes of their extinction. According to Leonhard Stejneger (1887) [8], the Steller's sea cow population in the Commander Islands was no more than about 1500, with similar sized populations in a few other areas. Such a low population size coupled with intense hunting, and the loss of the sea cows' main food source due to the indirect effects of hunting sea otters, led to the extinction of these magnificent sea mammals.

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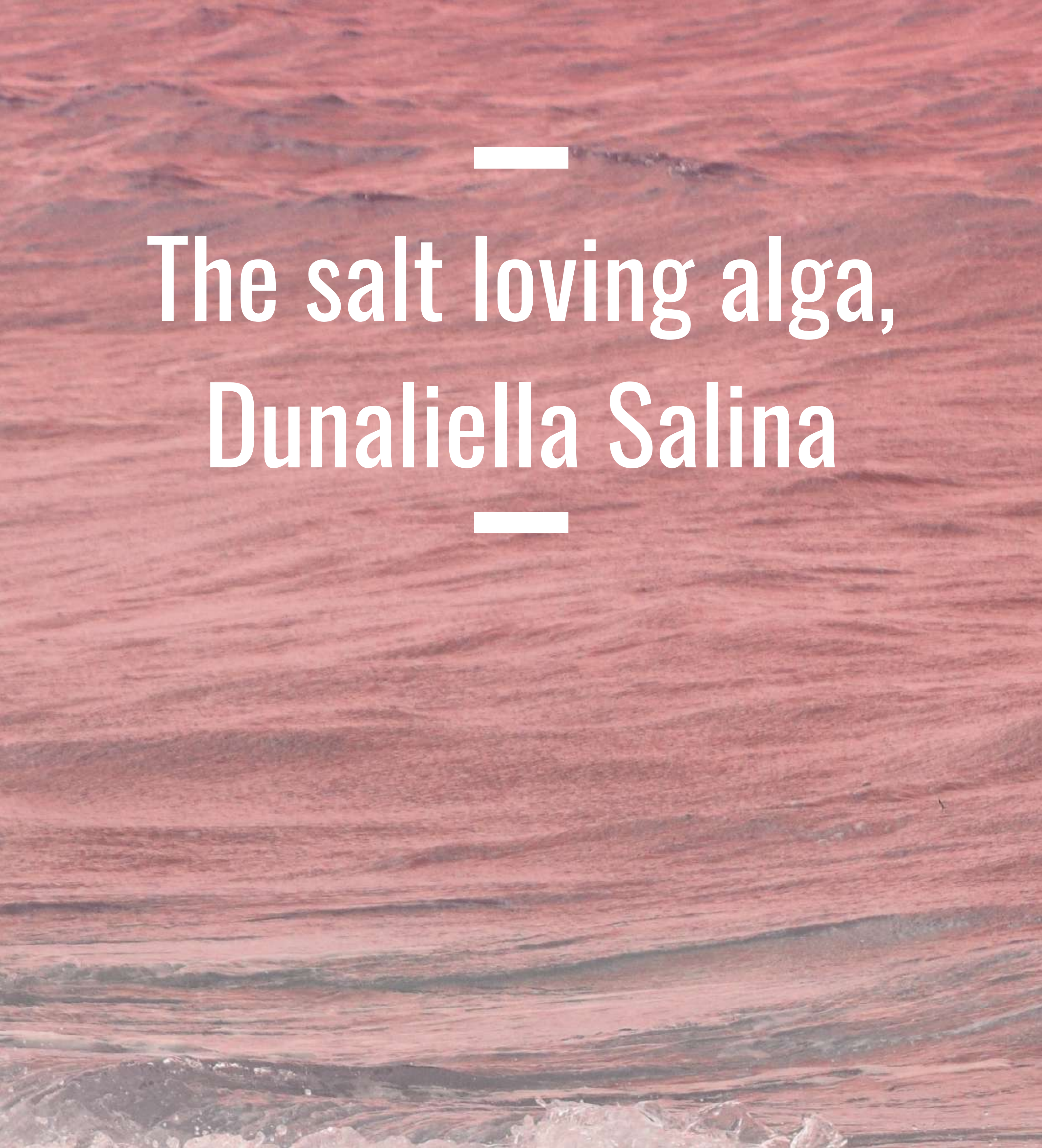

The salt loving alga, Dunaliella Salina

Dunaliella salina are halophilic or salt-loving algae. They are generally found in highly saline water bodies. Living in an environment with high salt concentration has many challenges as it alters the osmoregulation of organisms. This paper analyzes the different survival strategies adopted by *D. salina* to overcome the pressures of living in a saline environment.

NIHARIKA WAGH
UG 21

Introduction

The word 'halophile' literally translates to 'salt-loving'. Halophiles are extremophiles (organisms that can live and grow in challenging conditions that most living being could not survive) that thrive in highly saline conditions. Most halophiles belong to the domain Archaea; however, some bacteria and eukaryotes also display halophilic properties. One such example is the unicellular microalga, *Dunaliella salina* [1].

D. salina was discovered in 1838 by Michael Felix Dunal and was named after its discoverer by Teodoresco in 1905[2]. After its discovery, researchers used it widely as a model organism for studying salt adaptation. The alga belongs to the order Dunaliellales, which falls under the algal class of Chlorophyceae. These algae are usually green in color because of the presence of different pigments like chlorophyll a, chlorophyll b, and beta-carotene [2]. The cells of *D. salina* are pear-shaped with two flagellae of equal length. This organism reproduces both sexually and asexually. In general, it reproduces sexually through the fusion of two gametes into a single zygote and asexually through the division of motile vegetative cells. The zygote is extremely resistant and can survive exposure to both freshwater and desiccation [4].

The *D. salina* in Australia's lake Hillier, turn the water into a bubblegum pink, orange, or sometimes a lighter shade of red. This color does not change when the lake's water is stored in any container. The dead sea and the Great Salt Lake in Utah are other places where *D. salina* are found [2].

Survival Strategies

In general, halophiles sustain themselves in highly saline environments by the process of osmoregulation. They possess enzymes that are capable of operating in extreme conditions in which most other proteins would denature, aggregate, and precipitate. Many halophiles have negatively charged enzymes due to an excess of acidic residues and a difference in hydrophobicity. The presence of the negative charges on the proteins enhances their solubility and promotes their enzymatic functions in low water activity (high saturation) conditions. However, even though *D. salina* lives in highly saline conditions, and its enzymes are adapted to functioning at high salt concentrations, the cells usually maintain a lower concentration of sodium within themselves as compared to the external surroundings [3].

Researchers have studied osmoregulation in the genus Dunaliella extensively. Organisms in in this genus usually lack a rigid cell wall but have a distinctive mucilaginous cell coat. The genus can tolerate a wide range of salt concentrations, ranging from 0.3% to 35%. Dunaliella survive high salinity by synthesizing and maintaining high levels of glycerol inside their cells. Glycerol is produced either by photosynthesis or by degradation of starch reserves. Although many different mechanisms initiate the synthesis of glycerol, the most common trigger is a change in cell volume. Following an osmotic shock, changes in the plasma membrane, concentrations of inorganic phosphate, and pH are also involved in triggering glycerol synthesis [4].

Intracellular glycerol concentrations in *D. salina* can be very high, and the cell membrane of *D. salina* has many unique properties to maintain this high concentration of glycerol within the cell. Most biological membranes are generally permeable to glycerol; however, the cell membranes of *D. salina* exhibit an unusually low permeability for this moleculeNW [4].

Conclusion

The organism, *D. salina*, is well adapted to survive the pressures of highly saline environments. Their suitably adapted physiological and morphological characteristics aid in their survival in such extreme conditions. Further research on this organism and similar halophiles is required to understand the ecology of saline environments.

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A puppeteer of zombie ants: the brain-manipulating fungus, Ophiocordyceps

Ophiocordyceps fungi are responsible for wiping out entire ant colonies in as little time as a few weeks, thanks to their spore dispersion tactics. These fungi, which infect a particular group of ants, manipulate their hosts' brains to make the ant climb up to the top of a plant; here, the host ant is killed and the fungal spores are dispensed from a higher altitude to cover a large surface area so that more ants can be infected. This paper will explore this fascinating survival strategy used by this fungus and its effects on the host ants.

RITIKA NARA

UG 21

Introduction

*Ophiocordyceps*is a genus of fungi within the family Ophiocordycipitaceae. First described by British scientist Tom Petch in 1931, there are nearly 140 known species in this genus, all of which parasitize insects. Here, we will discuss *Ophiocordyceps unilateralis* (division *Ascomycota*: order *Hypocreales*) [1], which is a species complex that specializes in infecting, manipulating, and killing formicine ants. This paper will discuss the life cycle, biology, and infection strategies of *O. unilateralis s.l*, based on research that first began with a preliminary study in the remnant Atlantic forest in Minas Gerais (Brazil) [2].

The Host-Parasite Interactions

The invasion of a host ant by the fungus is initiated through the formation of a limpet-like specialized fungal cell structure called an appressorium. The infective hypha of the fungus then drills through the host ant's exoskeleton by using a mix of mechanical pressure and enzymes such as chitinase, lipase, and protease. Once the infective hypha pierces the exoskeleton of the ant, it needs to dodge its host's cellular and humoral host defenses; thereafter, the fungus flourishes in the hemocoel of the ant as free-living yeast cells [3].

Once the fungal parasite within the infected ant is ready to reproduce, it manipulates the ant to climb a plant/grass stem roughly 25 cm from the ground, bite an adaxial leaf midrib with a "death grip," and sprouts a nunchuk-like fruiting body from the ant's head. The fruiting body of the fungal parasite consists of a stromal plate (in the teleomorph or sexual stage) that is produced laterally on a stalk that emerges behind the head of the infected ant host, piercing the exoskeleton in a classic zombie fashion. The stromal plate contains thick flask-shaped ascomata, that produce sac-like asci. A specialized firing cap on each ascus launches multiseptate sexual spores (ascospores) under pressure [3].

Aside from the sexual reproductive stage, *O. unilateralis* also has asexual reproductive strategies that ensure successful reproduction when the primary mode of firing ascospores fail to infect new hosts. These built-in insurance mechanisms are still under scrutiny; in other fungal–ant parasite systems, these mechanisms vary significantly in structure

By studying other entomopathogenic fungi (fungi that parasitize insects), researchers have identified different types of critical host-recognition factors. Circumstantial evidence from newly released ascospores from different *Camponotus* ants suggests that there are many sophisticated chemical signals between the ant host and fungal parasite. The parasite-host interaction involves a lot of protein expression, before which RNA silencing (or suppression of silencing) is also likely to have occurred.

Conclusion

In this paper, one example of a fungus controlling insect behavior for its reproduction and survival has been illustrated.

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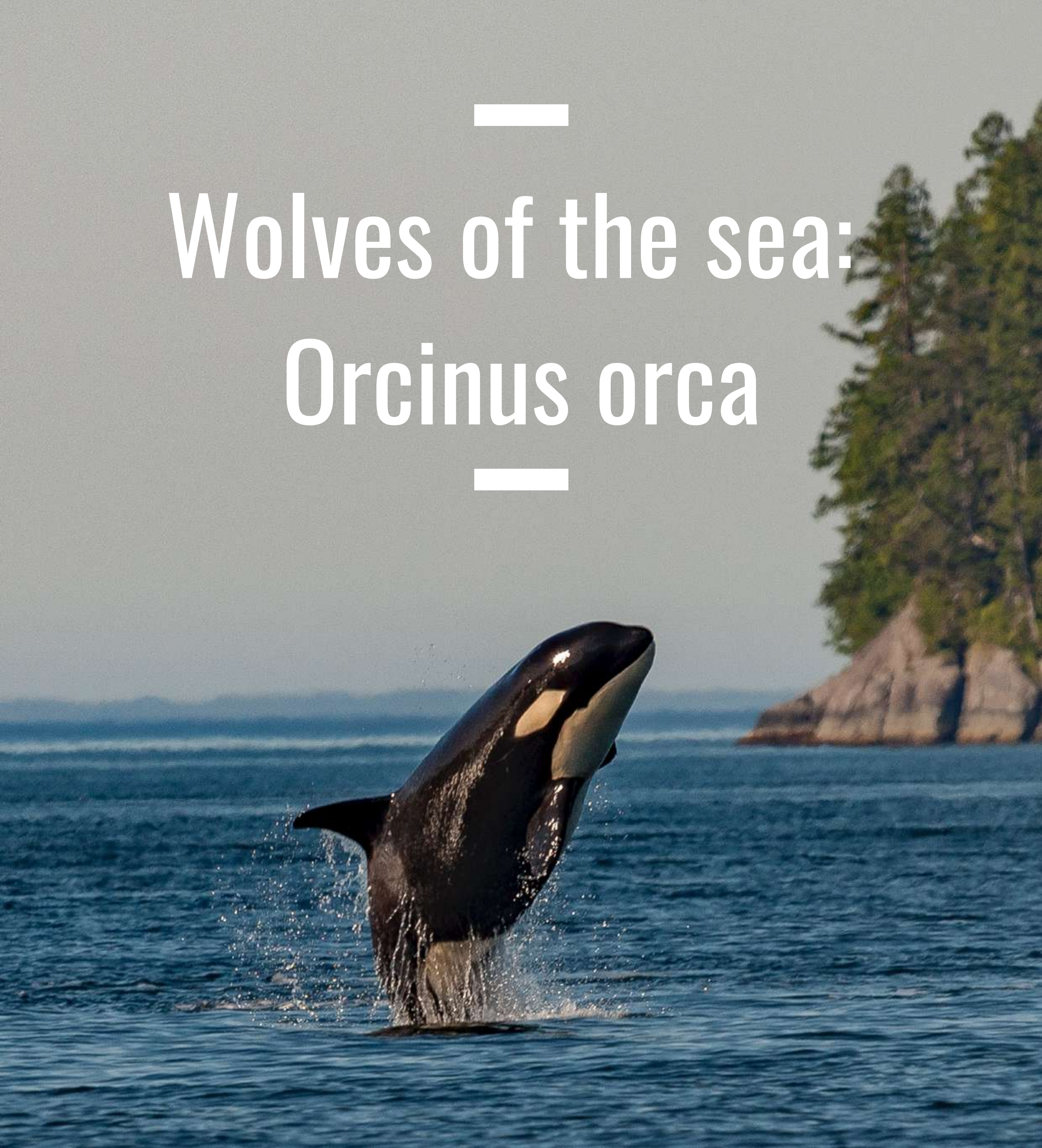
Wolves of the sea: Orcinus orca



Killer whales (*Orcinus orca*) are not whales, but a species of dolphin. They are the largest species of dolphin and highly specialized carnivorous mammals that have adapted to live in water. This paper describes the various physiological, predatorial, and behavioral adaptations that these organisms have undergone in order to survive in the marine ecosystem. It examines why killer whales are so successful as a species and how they acquired a cosmopolitan distribution. Furthermore, it also explores the evolution of culture in these animals, which have developed unique hunting strategies.

ADITYA SATISH
UG 22

Introduction

Orcas are large dolphins with a contrasting black and white coloration and a distinctive white patch above each eye. Adult male orcas can grow to 9 m in length and weigh 6 tons, while females are typically 5–7 m long and weigh up to 4 tons. Orcas show sexual dimorphism, with males being larger and sporting bigger dorsal and pectoral fins than females [1].

Orcas belong to the infra-order Cetacea, which comprises all whales, dolphins, and porpoises. The oldest ancestors of cetaceans lived 53 million years ago when they separated from the even-toed ungulates. They evolved from hippopotamuses—their closest living land relatives—who lead a semi-aquatic lifestyle [2].

Physiological and morphological adaptations

The forelimbs of orcas evolved into flippers for swimming while the hindlimbs became vestigial as an adaptation to the marine environment. Unlike fish, they move using vertical strokes of their tail fins since they evolved from terrestrial mammals which moved in a vertical plane. They have long, rounded, and streamlined bodies for efficient locomotion underwater aided by fins and a tail. Orcas have a layer of fat called blubber instead of hair to keep them warm. This blubber negates the need for hair, although most whales have hair follicles on their snouts that may have a sensory function. Most marine mammals lack hair as it is a poor insulator compared to blubber, and having a hairless body also helps reduce drag while swimming.

Fused vertebrae stabilize these animals in the water at the cost of mobility. Parts of the bony skeleton are replaced by cartilage and fat, improving hydrostatic qualities and stabilization. Respiration in orcas occurs through an outlet called a blowhole located on top of the head. Orcas use up to 80% of their total lung volume to breathe, allowing them to stay underwater for extended periods of time. Compared to terrestrial animals, they absorb almost twice as much oxygen from the air in their lungs. The oxygen is stored in the blood, lungs, as well as in certain muscular tissues in a protein called myoglobin. This stored oxygen is helpful when orcas dive to depths at which the lungs experience tremendous pressure. Breathing, which is usually an autonomous reflex in other organisms, is not so in orcas and is regulated by the individual itself; this means that drowning is an extremely likely possibility in an unconscious orca. Therefore, orcas have evolved to keep one hemisphere of their brains active while sleeping in a phenomenon called unihemispheric sleep to control breathing [1].

Hearing is an extremely important sense in orcas. Sound is received through the throat, from which it passes through a low-impedance fat-filled cavity to the inner ear. The ear is acoustically isolated from the skull by air-filled sinus pockets, which allow for greater directional hearing underwater. Orca ears also contain a highly dense bone shaped specifically to allow better sound conduction. Orcas send out high-frequency clicks from an organ known as a melon. The melon is largely composed of fat and is located in a large depression in the skull; this organ allows these animals to produce biosonar vocalizations. Using these vocalizations, in a phenomenon called echolocation, orcas sense their environments by calculating the size, shape, distance, and characteristics of objects in their surroundings. Echolocation is an evolutionary adaptation developed by orcas in response to an aquatic lifestyle because oceanic waters are often murky and using vision to navigate under these conditions is not practical. This, however, does not imply that orcas have poor eyesight; orcas, with their eyes positioned on the sides of their heads, have excellent binocular vision and depth perception. Tear glands protect the orcas' eyes from saltwater and the eyes have spherical lenses which permit light to be focused even at great depths in the ocean.

Orcas obtain the majority of the water they need from the breakdown of carbohydrates and fats in their food. In addition, since they feed on prey with levels of salt similar to those in the orcas' own blood, their bodies usually have a low demand for freshwater. Furthermore, orcas can drink seawater because of specialized kidneys that can filter out excess salt. Orcas also require much less freshwater as compared to terrestrial animals as less water is lost to the surroundings due to their aquatic environment [3].

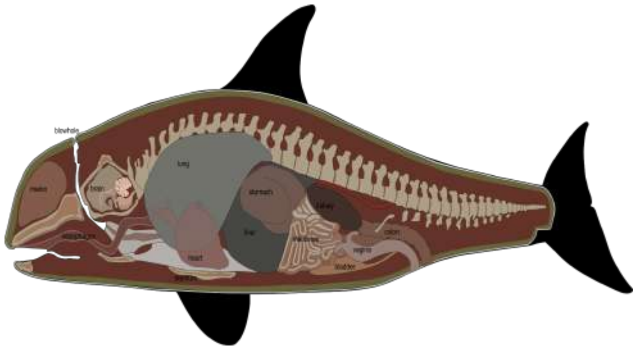


Figure 1: Anatomy of a female orca.[10]

Adaptations to a predatory lifestyle

Adult orcas are at the top of the marine food chain and prey on more than 140 species of marine mammals, fish, seabirds, etc. Their high intelligence and well-formed social structures have allowed orcas to evolve specific hunting strategies for different types of prey. For example, when orcas hunt seals resting on ice floats, they stick their heads above the water surface, in a behavior known as 'spy-hopping', to locate their prey. Subsequently, orcas use a technique called 'wave hunting', in which they generate a tremendous wave to tip over seals resting on ice floats. Some individuals are responsible for creating the wave, while others wait for the prey to be overthrown. If more than one attempt is required to tip over ice floats, or if some individual orcas begin tiring, other orcas in the group either switch roles or use multiple relays in a single attack. Orcas have also been documented to beach themselves in order to snatch seal pups from the shore; this is a fairly dangerous tactic as the orca engaging in this activity puts its own life at stake [4].

When hunting larger marine mammals like whales, orcas often target sick or weak individuals, mothers with calves, and sometimes, though rarely, even adults. Orcas usually intercept whales on their migration routes, or chase whales in the open ocean until the prey tires. Subsequently, the hunted whales are overpowered by multiple orcas and drowned. Orcas also hunt other species of dolphins in this manner [4].

Orcas use another strategy known as 'carousel feeding' to hunt fish which are usually present in large shoals. They blow air bubbles from their blowholes and flash their striking undersides to direct the shoal out of deep water to the ocean surface. The orcas then use their tail flukes, like battering rams to stun or kill the fish, which they subsequently consume. To feed on cartilaginous fish like sharks and rays, orcas induce tonic immobility in these animals. Cartilaginous fish such as sharks and rays, when overturned (belly facing up towards the surface), are rendered immobile, a condition known as tonic immobility. Orcas hunt sharks by inducing tonic immobility, but often feed only on the shark's liver, which is rich in fat, by making a clean tear through the corresponding position of the body [5]. How orcas discovered tonic immobility and the exact position of a shark's liver is a mystery, and a fascinating example of these top predators' intelligence.

Behavioral and cultural adaptations

Orcas are highly social creatures, usually living in pods for the entirety of their lives. On average, a pod usually consists of 6–12 individuals, although pods of up to 30 individuals have been observed in the wild. Killer whale societies are matriarchal, with an aged dominant female leading the pod. The pod comprises the matriarch, her progeny, and their descendants. Both males and females stay within their residential pods, unlike other social animals like lions or elephants. To avoid inbreeding, sexually mature orcas avoid mating within their own pods and always mate with individuals from other pods [6].

Living in groups gives orcas multiple survival benefits; juveniles and most calves have a good chance of survival if they get through their first year traveling in a pod due to lower chances of them being preyed upon. Orcas also share food that the pod has hunted, ensuring survival for all individuals, irrespective of age or health condition. They also spend a significant portion of their time socializing through vocalizations. This constant communication is crucial in honing hunting techniques, perceiving their surroundings, and strengthening family bonds. This complex social structure enables orcas to be ruthlessly efficient predators; it also allows them to pass on the pod's techniques to younger generations [7]. When hunting, adults sometimes deliberately do not kill prey and injure them instead. The adults then allow juveniles to practice ramming the prey with their snouts and tails to develop their hunting skills. In other instances, female orcas encourage their young ones to beach themselves to practice hunting young seals; if the endeavors fail, the mothers pull the calves back into the water [8].

In the Northern Hemisphere, 'resident' orcas often occupy a fixed territory around coastlines and feed only on fish by carousel hunting. These orcas have complex, highly evolved, and distinct dialects as a result of close bonding and are present year-round in the same areas. 'Transient' orcas have relatively smaller pods and specialize in hunting marine mammals. Transients vocalize in less variable and complex dialects. They too hug the coastline like residents, but these two groups typically avoid each other. Offshore orcas live in the open ocean and feed on sharks. They are smaller in size and genetically distinct from the aforementioned groups.

In addition to populations being separated by food habits, there are other types of killer whales in the Southern Hemisphere that are split by physical features. These include Type A, B, C, and D orcas. These populations also target different groups of prey [9].

These groups are separated from each other by characteristic morphological features such as differently shaped dorsal fins, differently colored 'saddle patches', skin colors, and the lengths as well as shapes of their eye patches [9].

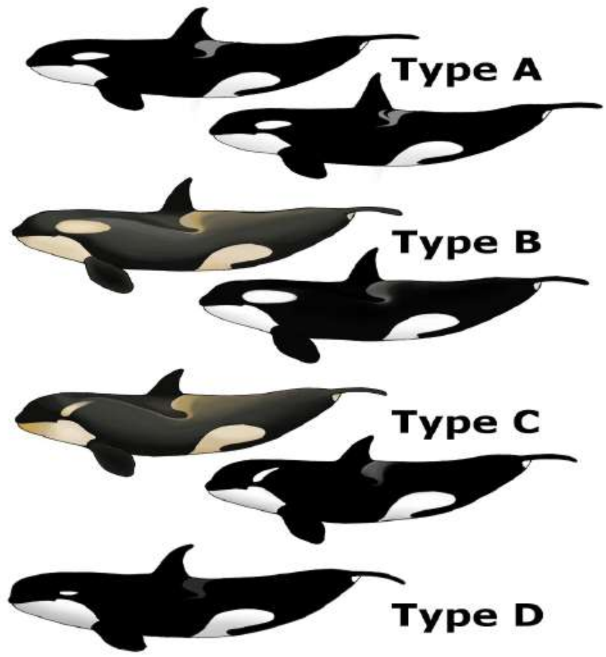


Figure 2: Variations in orcas [11]

Conclusion

Each population of orcas has carved out a niche for itself, with genetic and phenotypic changes in response to diet, hunting techniques, and social interactions. Each 'culture' in the orca population was founded by a small population that rapidly became specialized with respect to its local environment in a phenomenon known as 'cultural divergence'. When juveniles learn social behaviors from adults, it helps solidify group identity and gradually reinforce its distinct characteristics. This behavioral flexibility and the ability to pass on information through generations can help each group carve out separate evolutionary journeys. Individual culture groups have become genetically distinct, leading to the conclusion that killer whale genomes and cultures may have co-evolved. Their intelligence, adaptation, longevity, and sociability has enabled them to become apex predators of the marine ecosystem.

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Adaptations in vertebrates in the bathypelagic and deeper regions of the sea

The marine environment of the deep-sea holds a peculiar self-sustaining ecosystem. It hosts a large domain of organisms ranging from single-celled protists to highly evolved vertebrates. In these life forms, we can observe many adaptations that allow organisms to survive the unique selection pressures of the deep-sea, including high pressure, salinity, low temperature, and low food availability. This paper focuses on the survival strategies, both, at the molecular and cellular levels, of vertebrates in the deep-sea.

SHWETA PRASAD
UG 21

Introduction

Deep-sea vertebrates have adapted to survive and thrive in high hydrostatic-pressure and low-temperature conditions via their unique physiological and morphological adaptations. The direction of adaptation leads to analogous present-day morphs across species and genera. Since it is difficult to study barophilic organisms in vitro, there is a lack of detailed literature on these highly specialized organisms; despite this, there have been some detailed studies on smaller deep-sea organisms such as bacteria and several invertebrates. However, vertebrate adaptations to deep-sea conditions are hardly understood. It is evident from the available literature that maintaining a high-pressure aquarium to study these organisms is a mammoth task.

The ocean is divided into several zones, as shown in the following image, based on the depth at a given point.

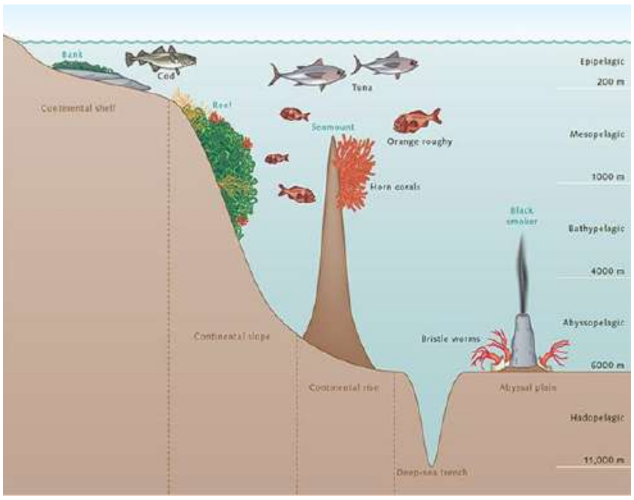

Figure 1: Depth Zones of the Ocean

Deep-sea fauna are the animals that live in and below the bathypelagic zone. These are mostly carnivores and detritivores, feeding on marine snow (a continuous shower of mostly organic detritus falling from the upper layers of the sea), and generally have slow metabolisms to help adjust to the dearth of food resources in this region. Morphologically, some animals in this region of the sea have light pigments, while some are entirely transparent.

Deep-sea fauna face uniquely extreme conditions. The average depth of the oceans, which cover about 70% of the earth's surface, is 3800m. Such places have an average pressure of 381 atm (38.5 Mpa) [1]. As we move further below sea-level, hydrostatic pressures increase immensely. In addition, temperatures also get substantially lower towards the bottom of the sea, except in deep-sea vents where extreme thermophilic and barophilic fauna flourish.

The stresses faced at a cellular level under these conditions are immense. Since a cell can only function if: 1) all its enzymes are in its functional conformations; 2) there is sufficient mobility for substrates, across and through membranes; and 3) the lipid bilayer is in its natural semifluid state, and therefore, incompressible, it is logical to assume that deep-sea organisms will have adaptations against protein denaturing, freezing, thermodynamic death, and ordering of the lipid bilayer. Since functions like diffusion, muscle contraction, and nerve impulse conduction are all either protein filament or enzyme-mediated functions, deep-sea organisms must have specialized proteins to function at these depths. Deep-sea vertebrates further face issues related to the low oxygen levels at such depths along with the threat of lung collapse under high pressure. All these problems may also be aggravated by the constant seasonal changes and hence the need for quick acclimatization to survive at these depths.

Adaptation to the Lack of Primary Production

The lack of widespread primary production (production of chemical energy in the form of organic compounds by organisms such as plants, algae, etc.) in the deep-sea requires organisms in this are to acquire adaptations to save energy. Deep-sea creatures typically have less dense tissues to save energy by requiring less protein and maintaining near ambient density (that of seawater). To accomplish this, most deep-sea marine species are osmo-conformers so that they have to spend less energy on osmoregulation.

Most marine organisms use organic osmolytes, such as neutral amino acids, to attain osmoconformity. In contrast to inorganic ions, organic osmolytes (such as trimethylamine N-oxide (TMAO)) do not perturb macromolecular functions and may even help stabilize protein function and counteract macromolecular perturbations caused by urea, temperature, or sodium salts. One study even suggests that deep-sea teleosts have osmotic contents as high as double that of shallow-water species [2]. Another study indicates that TMAO might have effects that are able to oppose the effects of high pressure and hyperosmotic conditions. Although hyperosmotic conditions and high pressure apply empirically different stresses, their effects are comparable; for example, the stress exerted by 4 molal NaCl is equivalent to 1400 atm of pressure. Therefore, adaptations to counteract perturbations by hyperosmotic conditions may also be of use in counteracting the effects of high pressure [3]. Studies are underway to test if TMAO contributes to energy conservation by increasing buoyancy as it does in elasmobranchs. Recent studies have revealed a striking, fairly linear increase in TMAO contents with depth of habitat in several families of teleosts [3]. Therefore, TMAO in deep-sea organisms is likely a very effective replacement for the major osmolytes found in shallow water organisms.

The musculature in deep sea-fish has higher water content and lower proportions of red muscle than that of shallow-water fish; deep-sea fish also have lower erythrocyte counts than their shallow-water counterparts. These physiological adaptations help deep-sea fish to limit energy expenditure that arises due to high oxygen consumption in red muscles. As mentioned before, deep-sea fish are mostly detritivores or carnivores, which sometimes also prey upon smaller deep-sea species. The mouths of deep-sea anglerfish are interesting examples of morphological adaptations suited to luring/trapping food that sinks downwards.

Adaptations at the Molecular and Cellular Levels

Membrane-based processes and enzyme-mediated functions are two broad categories of systems that are highly sensitive to temperature, pressure, and any changes in ambient conditions. Neural conduction and muscle contractions, for example, are mediated by enzymes and secondary messengers. The membrane systems also play a crucial role in intercellular interactions [1]. Extensive studies on *Coryphaenoides rupestris* and *C. armatus* reveal that primary adaptations at the cellular level in these fish involve the use of systems that are insensitive to perturbations in pressure relative to shallow-water species like plaice.

These adaptations involve changes in the lipid bilayers and proteins, and shall be discussed below:

1. Lipid bilayers – Lipid bilayers exist in a high entropy, anisotropic, and disordered state. This randomness is necessary for the membrane proteins to have sufficient mobility for membrane functionality. Otherwise, the transportation and diffusion of substrates across membranes cannot take place. For every 1000 atm increase in pressure, the temperature drops by 13–21. High pressure and subzero temperatures have a doubly effective ordering effect on lipid bilayer systems, which means that the entropy of the bilayer decreases, and the state of the membrane will no longer be fluid or even liquid crystalline. In fact, without their adaptations in place, the cells of deep-sea organisms would simply be crushed under the massive pressure forces acting on it. If the membrane solidifies

due to the extreme ordering effects of pressure and low temperatures, then essentially, the cell cannot interact with its environment in any manner. The most common adaptations that one would expect in membranes having to survive such low temperatures would be the incorporation of unsaturated fatty acids in the lipid bilayer. The presence of unsaturation in the hydrocarbon chains make them harder to freeze and largely incompressible. Moreover, the insertion of a cis-double bond into membrane fatty acids has a steric consequence, which creates an open volume and increases intermolecular spaces to permit greater conformational freedom of the hydrocarbon chains. This consequence of the adaptation is much like how saturated fat solidifies quickly below room temperature, while oils with unsaturated fats stay liquid over a larger range of low temperatures [4]. Myelin membranes from different species of fish trawled from around depths of 4000 m have more disorder than those from shallow-water species. Yet, measurements of anisotropies were similar for each species when subjected to tests under their respective ambient pressure ranges. This analogy implies that there is a straightforward translational difference between the membranes of deep-sea fish (such as *C. rupestris* and *C.armatus*) and those of shallow-water fish like plaice [4]. The above-stated adaptations fall under the ambit of homeoviscous adaptations, which are essentially adaptations made to conserve the fluid nature of a membrane. These adaptations also allow membranes to maintain their fluid natures despite seasonal changes in temperatures.

2. Proteins – Another important way in which deep-sea organisms evade the effects of pressure is by using proteins with structures (conformations) that are largely insensitive to pressure, which in some cases, work efficiently only under high-pressure conditions. Deep-sea fish with different shallow-living ancestors have certain enzyme pathways—such as that of lactate dehydrogenase—with reduced sensitivity to pressure [5,6]; however, the structural modifications that likely confer resistance to pressure and enhance structural stability appear to cause a reduced rate of enzymatic function.

The adaptations found in the actin filaments (muscle filaments) of deep-sea fish such as *C. acrolepsis* and *C. armatus* include lower entropies and enthalpies of polymerization, as well as lower volumes of self-assembly. These adaptations are consistent with the need for reduced dependence on hydrophobic interactions for stabilizing the filamentous form of actin and ensure that the system is not only less perturbed by high pressure conditions, it is also more energy efficient, as the heats for polymerization are minimized. Studies suggest that mitochondrial adaptations also play a significant role in helping such organisms survive.

In addition to the strategies elaborated upon above, deep-sea fish stay afloat at a certain depth using a lipid-filled swimbladder, instead of a gas-filled one. This adaptation provides a more incompressible alternative than gases for the fish to attain sufficient buoyancy to stay afloat.

Conclusion

For organisms to survive in conditions where the ambient pressure exceeds 1100 atm at temperatures that would freeze the human body in minutes, we see that adaptations must begin at the cellular level. Research indicates that adaptations in two critical cellular components determine the ability of an organism to survive in these conditions, namely, adaptations in lipid bilayers, and those in proteins Apart from these, several other adaptations such as those of liquid-filled swimbladders in deep-sea fish have accumulated over millions of years of evolution to allow these organisms to survive the stresses of the deep sea. These survival strategies serve to demonstrate the convergent evolution of analogous functions and organs. A proper understanding of these adaptations could play a crucial role in developing technologies resistant to extreme conditions; studying deep-sea fish may also open doors to newer areas of science that have thus far remained unexplored.

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Survival strategies of the bharal or blue sheep

In this paper, I will focus on the survival of the bharal and analyze the morphological aspects of their anatomy that allow these animals to traverse rocky terrains. I will further discuss the known threats and hazards to these animals, and how they respond to these threats. Further, I will discuss the roles played by predators and competitors on survival pressures that the bharal faces. Finally, I will conclude with an analysis of the functional implications of these strategies in the real world.

VARSHINI KRISHNAKUMAR
UG 21

Introduction

It is often presumed that complex adaptations are ones that stem from unique habitats and the rare organisms that occupy them. This conjecture, however, may not be true as several so called 'ordinary and common' animals exhibit nuanced adaptations to their environment. The bharal *(Pseudois nayaur)* or 'blue sheep' is one such organism; these animals, which are considered fairly commonplace in the high Himalayan areas of India, are amazingly well adapted to their environmental niches.

Bharal usually live in hilly and rocky areas covered in shrubland [1]. They belong to the family Bovidae, and are closely related to goats according to morphological, behavioral, and molecular analyses [2]. Male bharal are generally larger than females and can weigh up to 165 pounds, whereas females only grow to around 100 pounds [2]. The bharal have a dull grey-brown coat, which often turn slate-blue or develop a bluish sheen (hence the name 'blue sheep') with white patches on their hooves and underbelly, and a pair of horizontally inclined ridged horns.

The bharal are found in the high mountains of the Himalayas, across China, Pakistan, Nepal, Tibet, and India [3]. The bharal pimarily feed on dry grass, mosses, leaves, and lichens [3]. Male bharal display several types of fascinating rutting (mating) behavior, which includes rubbing horns, fighting, tending (following fertile females and protecting them), blocking, and coursing (disturbing a tending pair to gain access to a female); rutting usually begins in late November and end in mid-January, and the young are born in late June and July [2].

Survival Pressures

The rocky terrains that the bharal live on pose one of the biggest threats to their survival, along with deforestation and poaching. Since they prefer living in the mountains, their terrain can occur at elevations of up to 5,500 meters above sea level [1]; in these areas, extreme differences in temperatures across seasons make finding a constant source of food and general survival difficult. In addition, the bharal face predatory pressure from snow leopards, wolves, and sometimes, even eagles. Snow leopards, in particular, account for a significant number of bharal deaths, as the blue sheep are this predator's main food source [4].

Apart from these, interspecific competition for food with livestock such as sheep and goats in the same habitat, invasive plant species, and emerging pathogens are also major threats to the bharal's survival. Competition for food with livestock often dilutes the quality of a bharal's forage; this can affect bharal populations significantly, as lactating female bharal require high quality food resources. However, the intensity of competition with livestock is somewhat mitigated by rotational grazing, and seasonal movement of the livestock between different altitudes. During winters, the bharal are often more likely to share the same land area, resources, and food plants with yak, whereas, during spring, there is a dietary overlap with local people's domestic stock that is brought to graze in the bharal's native landscape [4].

Survival Strategies

Given that the bharal faces a wide range of hazards and threats, it is safe to assume that they have certain strategies to help them survive. The bharal have thick wooly coats to protect them from extreme cold during the freezing winter times. They also have large dewclaws that help them navigate hilly terrains with stability and firmness [5]. The grey-brown color of the coat, with its often slate-blue sheen provides very efficient camouflage against the bluish-grey rocks that are generally found in their habitat [6].

Additionally, bharal have stocky bodies with stout legs, which are built to climb [4]. Bharal usually prefer to graze on gentler hillsides covered with grasses and shrubbery; however, these areas must be within 650 feet of cliffs, which the bharal bolt towards to escape predators [7]. The bharal's horns may also help in their defenses against predators as these animals use their horns to jerk and lunge at predators. Furthermore, the bharal use loud alarm calls to warn others of their herd about nearby predators [8]. Due to the high variability in food availability in its environment, the bharal has evolved to feed on dry grasses during wintertime and alpine pastures during summertime.

Perhaps the most surprising strategy that the bharal exhibit, is their ability to move easily across nearly vertical surfaces across cliffs and mountainsides. It is astonishing that they are able to balance the weight of their entire bodies almost entirely on a few inches of hooves, which is largely due to the hooves' specialized structures. The hooves of the bharal are composed of two cloven claws that move independently of each other. The surface morphology of cloven hooves is truly unique in that it allows for a more efficient landing orientation and agility. Further, investigations into the complexities of the hoof structure reveal that the hoof can actively grasp rocky surfaces in order to avoid skidding. This anti-skidding ability could also be attributed to the stripe morphology (longitudinal stripes across the front and rear cloven hooves) of the bharal's hooves. There is evidence to indicate that the frictional coefficient (the ratio of the frictional force resisting the motion of two surfaces in contact to the normal force pressing the two surfaces together) is higher in areas of the hooves that have these longitudinal stripe structures. Essentially, the stripes on the bharal's hooves act as brakes to prevent skidding, and allow the hooves to better grip rocky surfaces. Additionally, the lamellar morphologies on certain parts of the hooves are also found to coincide with higher frictional coefficients, contributing to high friction between the surface of the hoof and rock.

It appears that the survival strategies of the bharal are efficient enough to maintain healthy population numbers; as classified by the IUCN Red List, the bharal are currently listed in the 'least concern' category. [1].

Conclusion

It is evident that 'commonplace' animals that appear to have little or no outward signs of adaptation can have astonishing strategies to counter survival pressures, as are evident in the behavioral and morphological adaptations seen in the bharal.

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A Frog That Survives by Freezing Itself

Wood Frogs have an astounding ability to freeze themselves during the winter months and come back to life in spring. This phenomenon—that is, the preservation of living cells and tissues at very low temperatures—is called cryopreservation. This paper will explore the ways in which wood frogs adapt to living in areas where temperatures can go as low as -16 ºC and conclude with the importance of studying cryopreservation for humans.

VIHAAN BHATNAGAR
UG 20

Introduction

The Wood Frog has two scientific names: *Lithobates sylvaticus* and *Rana sylvatica*[1]. Around 1.4 to 3.25 inches in length, this small amphibian is found in three colors: brown,orangish-red, or tan. It is found mainly in Canada, Alaska, and down to the Northeastern United States [2]. However, this is not the only amphibian in North America that can freeze during the winter season. Other amphibians that can freeze during the winter include the gray treefrog, Cope's gray treefrog, spring peeper, and the western chorus frog. However, the wood frog is the most remarkable of all of these for the following reasons. First, it has the northernmost distribution. Second, wood frogs found in Alaska can survive frozen for up to seven months in temperatures as low as -16 °C.

How does it survive?

As the winter approaches, the wood frog prepares for the big freeze by producing and storing large amounts of urea and glucose in its bloodstream. The mixture of sugar and urea acts as a cryoprotectant and not only safeguards cells from lethal dehydration (by limiting the amount of ice formed), but also inhibits the formation of ice crystals which can disrupt membranes and kill cells.

A State of Suspended Animation

The wood frog enters a state of suspended animation as temperatures fall. Its metabolic activity almost halts as its lungs stop working, and the heart eventually also stops beating. In this form, with almost two-thirds of its body frozen, the wood frog can survive for up to seven months.

Once spring begins and temperatures rise, the wood frog also begins to thaw. Water slowly flows back into its cells until they are fully rehydrated and regain their original shapes. Within thirty minutes of thawing, the heart restarts and the wood frog's blood begins to flow. After the first breath, wood frogs coming out of their frozen hibernation breathe rapidly for a few minutes. After nearly 48 hours of thawing, the frog then heads out to look for food, a mate, and a much-awaited pee to rid itself of the accumulated urea in its body.

Conclusion: Why Study Cryopreservation?

The wood frog is a remarkable amphibian with an incredible survival strategy. An organism that can survive having up to two-thirds of its body frozen for seven months in a year in order to survive, is truly special.

Scientists have been studying these amphibians in the hope that one day we can utilize their abilities in the medical industry, and perhaps, be able to store organs for extended periods of time. As Linda Crampton succinctly puts it, "the adaptations that enable the wood frog to survive freezing may be helpful in understanding and perhaps even in dealing with human medical problems. These problems include the safe freezing and thawing of organs for cryopreservation and transplants, a high glucose level in the body, and the safe resumption of blood flow after a heart attack or stroke"[1].

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RED WOOD ANTS

Formica rufa or red wood ants live in colonies that typically have several queens and thousands of workers and brood. These ants locate food sources with the help of 'landmarking' techniques and are known to manipulate their surroundings to maintain nest/colony temperatures. These ants fend off competitors and predators by spraying formic acid and other toxic substances.

PRIYANSHU RAJ
UG 21

Introduction

Red wood ants *(Formica rufa)* of the *Formica* group of ants are native to Europe and Anatolia but may also be found in North America. They are mainly found in boreal habitats (ecosystems also known as the taiga, having sub-arctic climates found in the Northern Hemisphere), including forests, woods, and parks with coniferous and broad-leaved trees.

Red wood ant workers are red and brownish-black in color, and display color polymorphism, meaning that the ants have variable coloration. These ants' defenses lie in their large mandibles and the formic acid stored in their abdomens. Large colonies of these ants can have 1,00,000–4,00,000 workers and up to 100 queens. Workers tend to the brood and exhibit parental care and brood nursing. In many cases, a new queen can oust an existing queen and begin laying eggs; in such cases, the existing workers take care of the new queen's offspring. Each colony of red wood ants are very possessive about their territory, and do not allow other ant colonies to thrive in the same area. Nuptial flights for the alates (winged reproductive male and female ants) take place during the springtime, which often lead to battles between neighboring colonies to reestablish territorial boundaries.

Although the redwood ants' primary diet is honeydew from aphids, they are also scavengers and feed on small insects and arachnids. Thus, they are used in forestry management as a pest management tool. These ants' foraging efficiency extends to a distance of 100 m from the nest. Nests of these ants are large dome-shaped mounds of grass, twigs, and other materials, often built against a rotten stump where the nest is exposed to sunlight. New nests often arise by budding from existing nests in the spring. These ants also have multiple nests; in the event of drastic environmental changes, attacks by neighboring colonies, or scarcity of food, these ants can relocate to alternate nests. Turnover of wood ant nests is rapid, and the sizes of their nests increase as the colonies age.

Foraging Behavior

The red wood ants use an interesting technique to relocate food sources that they discover during foraging sessions; these ants periodically turn back and memorize a nearby landmark in a behavior termed as 'landmark fixation'. When a foraging ant locates a food source near a prominent landmark, it walks a little way towards the landmark to 'fixate' it. The ants also often inspect the territory near the landmark, especially at short distances. As the image of the landmark on the ant's retina changes rapidly with distance, ants require more views of a landmark when they are nearer to it than when they are further away [1] in order to locate the landmark again. Since image matching is easier without rotation and the ants cannot walk sideways, the red wood ants have a strategy to optimize the imaging process. By aiming successively at different landmarks close to the goal, the ants store images when fixating landmarks frontally; in this way, they know that the images of the landmarks must be matched in the same manner in order to relocate the food source [1]. The ants' frontal retina, therefore, plays a vital role in image storage and path control. On a coarse scale, the paths followed by red wood ants are not straight, but rather sinusoidal [2]. The ants also account for the heights of the landmarks that they fixate by maintaining a reasonable distance from the structure and by focusing on the top of the structure at a particular retinal elevation.

Thermoregulation Strategies

Temperature is an important environmental variable that affects the survival of ectothermic organisms like ants. As ambient temperatures rise, the ants' rates of development, movement, and the consumption of food and energy also increase. Higher temperatures may lead to an increase in overall colony fitness; however, increases in temperatures will also lead to higher energy expenditure.

How do red wood ants use various thermoregulatory strategies to maintain their nests' temperatures? These ants use two main strategies, namely, modifying nest structures and sun basking behavior to maintain optimal temperatures in their nests.

Modifying Nest Structures

Red wood ants use materials like twigs, soil, coniferous needles, and pebbles, which are good insulators, to build their nests. A well-insulated nest and the metabolism of the ants in the nest keep the temperatures of the nests reasonably constant. The composition of organic matter, however, is not uniform throughout the nest structure; in addition, the structures of the mound are not rigid. Ants regularly renovate nest structures by pushing organic matter into the outer layers of the nest. The tunnels and passages built by these ants are mainly for ventilation and humidity control, which, in turn, affect the temperature. Therefore, the ants actively regulate the temperatures of their nests by varying its structure. The ants also use pieces of resin with antimicrobial properties in their nests to deter the growth of potentially pathogenic bacteria and fungi within the nest.

Sun-Basking Behavior

Red wood ants often sunbathe and 'carry heat' back into the nest [3]. Ants which undertake this sunbathing task are usually darker-colored to absorb heat quickly.

In spring, the ants sunbathe by clustering on the surfaces of their mound. Their bodies contain a substantial amount of water, which has a high thermal capacity, thereby making their bodies an ideal medium for heat transfer. This principle works throughout the year but is most apparent in spring as it can be observed by the clustering behavior of the ants on the nests' outer surfaces.

Defence System

In order to ensure their survival, most organisms develop defense mechanisms to protect themselves from predators. Red wood ants, in addition to their sharp and strong mandibles, also have a fairly well-developed chemical defense mechanism, namely, the mixture of formic acid and other substances stored in their Dufour's glands [4]. The ants seize any hostile organism—for example, another ant—with their jaws and spray this chemical defense on the enemy [4] whenever threatened. In case the hostile organism is another ant, this chemical mixture is most effective if it penetrates their cuticles or reaches their vital organs through the tracheal system. The initial penetration of the epicuticle of the enemy with the red wood ant's jaws further facilitates penetration of the chemical mixture into the enemy.

Although this chemical defense is a very effective deterrent of enemies, competitors, and predators, it comes with a fairly heavy cost—the lives of the defending ants. The secretions from the red wood ants' Dufour's glands also contain hendecane and tridecane, which are hydrocarbons useful as wetting agents for the formic acid. This secretion makes the ants' chemical defense toxic to themselves. Exposure to the chemicals from their own Dufour's glands can kill red wood ants in under 15 minutes [4].

The relationship between red wood ants and tree-canopy herbivores (aphids)

Red wood ants are used to study the effect of a predator on a canopy herbivore population [5]. These ants largely farm aphids and feed on aphid honeydew; however, these ants also help to control forest pests, as they 'patrol' plants and trees on which they farm their aphid herds. Studies have shown that trees patrolled by red wood ants have significantly lower populations of other sap-sucking insects at lower heights.

Social Interactions

Social insects like the red wood ants protect their nests from con- and hetero-specific competitors. Thus, workers of most ant colonies keep a continuous and close watch at the entrances of nests to guard against intruders. In response to perceived threats, red wood ants use alarm pheromones to recruit their nestmates to battle. Once a red wood ant receives such a signal, the ants attack unfamiliar objects and intruders with their mandibles and chemical sprays. The nestmate recognition system plays an important role in establishing social contexts between the individuals and helps the ants recognize conspecific intruders (ants of the same species, but from another, possibly competitor nest) [6]. These ants can distinguish between nestmates and non-nestmates from the surface chemicals on their bodies, which vary with nest material and food; the ants in a colony have almost completely uniform colony-specific odors by exchanging cuticular hydrocarbons between nestmates through trophallaxis (mutual exchange of regurgitated fluid between two ants) and allogrooming (reciprocal grooming between nestmates). The ants recognize their nestmates by matching individual cuticular hydrocarbons with their colony odor; a process often termed label-template matching.

Conclusion

Red wood ants have several survival strategies to ensure their survival. They are very efficient in relocating newly discovered food sources, which is a key survival trait. They also have an impressive defense mechanism that allows them to protect their nests from con- and hetero-specific competitors, predators, and other intruders.

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The Snapping Turtles

Turtles are usually considered slow, friendly, and calm organisms. However, snapping turtles are bulky, strong, and aggressive. This paper analyzes the biology of two types of snapping turtles, namely, the common snapping turtle, and the alligator snapping turtle. It also examines the problems of survival faced by snapping turtles and the different methods they use to hunt for food and fight off potential predators.

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Introduction

The common snapping turtle or *Chelydra serpentina* is a large and bulky turtle with a carapace length of 19 inches and a maximum weight of 40 Kgs. Similar to other turtles, this turtle has a characteristic shell that shields its soft-scaly body from rough terrain and potential predators. The reduction in the plastron and accumulation of muddy sediments do not allow its body to enter the shell. The skin consists of a dense mixture of organized scales and multiple skin folds due to which these turtles often have variable coloration. The common snapping turtle has a large head that ends in a wide beaked mouth, along with a flexible neck which can be as long as its own carapace when fully extended. The turtle's eyes are dorsally directed with black and yellow patterning. Their bulky, stout, and scaled legs have five claws. The tail is divided into three rows of dermal ridges, in which the middle ridge can be raised, resulting in a distinctly saurian (dinosaur-like) appearance. Males usually have a longer and thicker tail than females. Baby turtles resemble the adults, but their carapaces have a rough texture, which becomes smoothened in the later stages of life [1].

The alligator snapping turtle *Macrochelys temminicki* is very similar to the common snapping turtle, with many common characteristics such as the big carapace on a soft and a scaly body, multiple folds of skin covered with scales, a flexible and extendable neck, and heavy legs with five claws. The most striking difference between the two turtles is the carapace morphology. The alligator snapping turtle has a shell composed of rows of strikingly jagged scutes, while the common snapping turtle has a comparatively smooth shell. The second differentiating feature between the two lies in their heads; the alligator snapping turtle has sharper and more rugged features, including a more pronounced beak than the common snapping turtle, which has a more rounded head than its cousin.

In addition to these features, the alligator snapping turtle has a bright pink lure, similar to a worm, to attract prey towards it, which the common snapping turtle lacks. The two species also differ in their habitats; the common snapping turtle occupies shallow trenches of water while the alligator snapping turtle occupies deep water trenches. Another striking difference between the two species lies in their ability to handle low temperatures. The common snapping turtle can tolerate temperatures below 0 °C, which the bigger alligator turtles cannot. Both these species are commonly found in North America and some parts of South America, usually in trenches or muddy waters.

Differences between common turtles and snapping turtles

There are many differences between common turtles and snapping turtles. Firstly, due to the smaller sizes of their bottom shells, snapping turtles cannot retract into their shells like common turtles. The small bottom shell, however, allows the snapping turtles' legs to extend much farther than a common turtle's, which helps them swim faster. The most prominent difference between common turtles and snapping turtles, is the latter's sharp beaks which make them dangerous predators underwater. Snapping turtles also have long nails on their legs, which many common turtles do not. The alligator snapping turtles differ from most other turtles including the common snapping turtle in having a rugged outer covering to its shell along with a worm-like tongue, which helps it to lure its prey while hunting [2].

Survival Strategies of snapping turtles

Progeny Survival

The eggs and new hatchlings of both species of snapping turtles are vulnerable to many predators like raccoons, red ants, and wild hogs. In order to protect their progeny, snapping turtles bury their eggs in shallow sand pits. Once the eggs hatch, the turtle hatchlings immediately seek out water, where their swift swimming skills and natural camouflage usually help them avoid predators.

Surviving Winter

Since snapping turtles are reptiles and cannot regulate their temperatures, they survive the low temperatures of winter through hibernation. These turtles hibernate underwater as water temperatures remain relatively stable as compared to temperatures on land, and also protect them from potential predators.

Symbiotic Relationship

Snapping turtle shells can accumulate many algae, microorganisms, and parasites, which may be detrimental to the turtles' health. Therefore, snapping turtles have a symbiotic relationship with the smaller painted turtles which feed on the algae growing on the snapping turtles' shells.

Surviving Underwater

Since snapping turtles hibernate underwater, they have unique adaptations in breathing and respiration to tide over the winter; for example, these turtles are able to undergo extrapulmonary respiration, where the membranes in their mouths and cloaca allow them to acquire oxygen from water. These turtles also have multi-chambered lungs to accumulate more oxygen. However, as oxygen levels drop over the winter, these turtles begin to respire anaerobically (without using oxygen) and can survive for up to 6 months without oxygen.

Food Intake

Common snapping turtles are quite active and are termed 'chasers' as they move around in the water to catch prey. When these turtles swallow their prey, they may also swallow a lot of unwanted water, which can choke them. Therefore, they have sharp and keratinized projections on the walls of the oesophagus which helps in trapping food and expelling excess swallowed water.

Reproductive Strategies

Usually, snapping turtles do not face much predation pressure as adults; however, they are often preyed upon as hatchlings. Since these turtles face fluctuating predation pressures as hatchlings, they rely on bet-hedging strategies for successful reproduction. They delay sexual maturity until their bodies become large enough to support reproduction without reducing their chances of survival. This adaptation enables them to lay eggs over 60 or 100 years.[3].

Conclusion

Despite all the survival strategies catalogued above, snapping turtles are endangered. This is because these turtles face major habitat losses and have been extensively hunted for meat and other purposes. Current conservation measures, especially those in the Louisiana Wildlife Conservation Park will hopefully bring these turtles back from the edge of extinction.

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