<u>BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE PILANI</u>

BIO F214 REPORT

on

WANDERING ALBATROSS

And

TAKE HOME ASSIGNMENT

Instructor In-Charge

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PART A : Report on Wandering Albatross

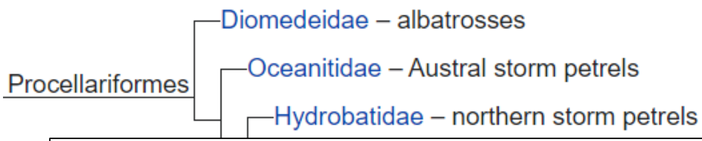
INTRODUCTION

The wandering albatross, snowy-albatross, white-winged albatross is a large seabird of the family Diomedeidae and was the last species of albatross family to be described. They are amongst the largest of flying birds and have the greatest known wingspan of any living bird. It is also one of the best known and most studied bird species.

- Scientific Name: *Diomedea exulan*
- Average life span in the wild: Upto 50 years
- Family: Diomedeidae
- Class: Aves
- Order: Procellariiformes
- Length: 107-135 cm
- Wingspan-2.5 to 3.5 m
- Weight: 5.9-12.7kg
- Habitat: Inhabit deep oceans. Come to land only in mating season
- Distribution: Atlantic, the Antarctic and Sub-Atlantic oceans. Breed on islands north to Antarctic circle, in particular UK's South Georgia Island, the Crozet and Kerguelen Islands etc.
- Population: 26,000 in wild
- Population Trend: Decreasing
- Population Threats: Longline fishing and pollution
- Conservation Status: Vulnerable.
- Diet**:** Cephalopods, small fish, crustaceans.
- Appearance**:** White with grey-black wings, hooked bill.
- Social Structure: Solitary when flying, feed in small groups
- Breeding: Monogamous and produce one chick every two years. Breeding takes place in colonies on sub-Antarctic island. Breeding season commences in early November and eggs are laid in December-January and hatched 11 weeks later.

EVOLUTION

Sibley and Ahlquist's molecular studies of evolution has hypothesized that order Procellariiformes evolved by adaptive radiation in Oligocene period about 30-35 million years ago. However, evidences suggest that this order evolved 70 mya from the seabird fossil Tytthostonyx, found in late cretaceous rocks. Earlier, fossil of Gigantornis from Eocene epoch(about 50 mya) from Nigeria was considered as the ancestor representative of albatross. In 1970, it was realized that although it had large wing span and dynamic soaring abilities like albatross, its DNA was more similar to pelicans(order: Ciconiiformes). Some theories suggest that penguins and albatross are distinct relatives and had a common ancestor. Due to evolutionary pressures, penguins occupied the ecological niche of diving and feeding under water surface and became flightless. On the other hand, the other group diverged to become present day tube-nosed sea birds(order: procellariiformes) specialized for flights. The oldest Procellariiform fossil is from the early Paleocene, some 60 million years ago. The tubular nasal passage of Procellariformes impart them olfactory capabilities. Along with smelling patchily distributed prey, it also helps them to locate their nests in nesting colonies. DNA-DNA hybridization and DNA sequencing have confirmed the common ancestry of all Procellariiformes, but the taxonomy within the order is complex and subject to constant revision.



Phylogeny of the extant procellariforms based on a study by Richard Prum and colleagues published in 2015

Study of mitochondrial DNA split albatross family into 4 genera further: *Phoebastria* for the North Pacific albatrosses and *Thalassarche* for the mollymawks, with the great albatrosses retaining *Diomedea* and the sooty albatrosses staying in *Phoebetria.* The split between North pacific albatross and Diomedea happened between 17 mya. The genus Diomedea consists of two species complex the wandering and Amsterdam albatrosses, and the royal albatrosses. For along time, Amsterdam albatross was considered as a subspecies of wandering albatross for a long time. mitochondrial control region sequence data shown that haplotype present in Amsterdam albatross was in three novel forms and highly divergent from haplotypes found in other species of Wandering albatross species complex. This divergence of Amsterdam albatross is believed to be caused due to geographic isolation in Wandering albatross species complex maintained by high natal philopatry. Unlike other species, Amsterdam albatross breed on Amsterdam islands of Indian Ocean leading to bottleneck effect and its divergence 2,65,000 years ago.

UNIQUE ASPECTS

- Albatross doesn't flap their wings while flying. This unflapped flight is called dynamic soaring. It is a flight technique used to gain energy by repeatedly crossing the boundary between air masses of different velocity.
- These birds can travel upto 1000 kms daily at an average speed of 46kms/hour using same energy as it would have burned while nesting.
- They exploit kinetic energy of wind by soaring-gliding effect. This minimizes the need, time and energy spent on flapping as flapping is metabolically more energy demanding than gliding.
- Mechanism within base of wings ensure that albatrosses lock their wings in gliding positions without straining them.
- Also, albatrosses have more slow-twitch fibres which continuously make small adjustments in wings during long flight for gliding. They have smaller composition of fast twitch fibres required for flapping compared to other birds.
- The two theories try to explain the mechanics behind the albatross flight:
    1. **Surface-level gusty wind propelling**
    2. **Wind Speed Gradient Theory**
- According to surface-level gusty wind propelling theory, birds extracts energy from surface-level gusts in a continuous manner when it is at high altitude.
- However, on plotting wing-gradient vs. altitude plot, it is found that where energy gain is obtained by the albatross, in those region wind speed gradient is very low and thus can't be the cause of bird's energy. This means low altitude wind gusts and flying at high-altitude has negligible effect on bird's energy and flight efficiency.
- The physical mechanism of energy gain is the propulsive effect exerted by wind. The local shear wind facilitates the bird to change its direction generating a propulsive force when the bird is at higher altitude (upper curve) of the cycle. Here, the winds act as an outboard engine. Afterward, ad bird dives close to the water and then returns back up at higher altitudes causing a breaking effect. However, propulsion profit is just sufficient to overcome this drag effect. This pattern of dips, swoops and turns produce energy efficient flight of a wandering albatross.

RESEARCH IDEAS

- **Low genetic diversity in albatross:**
    - Albatrosses generally produce one chick every other year. They have small colony size (between 10 to 2000 pairs), generations overlap (due to its average lifespan of 50 years) and it practices natal philopatry. These factors have led to inbreeding depression, and genetic drift due to bottleneck effect. This has been shown by studying their microsatellite loci, mitochondrial DNA phylogeny and AFLP (Amplified fragment length polymorphism). Some theories, on analysis of cytochrome *b* data also hypothesize that wandering albatrosses inherited poor genetic diversity from their ancestors.
    - It is generally believed that inbreeding depression and bottleneck effect leads to poor genetic variation and hence, reduced fitness of the species. However, wandering albatross have evolved as one of the most efficient fliers and have maintained a stable population until man-made factors became the reason of their decline. This indicates wandering albatross have not suffered a lot due to their impoverished genetic diversity.
    - Wandering albatrosses' uniqueness in this regard, is a challenge to classical view of negative impact of genetic diversity on species survival. More research should be done to explore the genetic, anatomical, physiological and population factors which lead to sustained wandering albatross' population despite having poor genetic variation.

- **Wandering albatross strong sense of smell**
    - Birds are generally believed to have poor sense of smell and a strong sense of sight. However, some researchers believe that wandering albatross can smell their prey from distance of 20 kms making it olfactory capabilities highly exceptional among birds. Research has proved that these birds have large olfactory bulbs and have responded to prey-scented odors in trials. While following its prey, wandering albatrosses use crosswind flight, followed by upwind or zigzag flight to locate its prey. It is because odors dispersing from the prey disperse laterally and downward of the odor source and acquire irregular and patchy concentration due to turbulence. In contrast, birds following their sight fly directly in direction of their prey irrespective of wind

direction. This proves wandering albatross rely on their strong olfactory senses while foraging.

- More research can be done to trace evolutionary as well as morphological traits which led to development of strong olfactory senses in these birds.

OTHER RELEVANT POINTS

- **Presence of Salt Gland:** To survive long days in ocean, wandering albatross needs to drink sea water. To maintain body salts level, they have a salt gland above the nasal passage which excretes out a high saline solution as mist. These salt glands contain thousands of capillaries called tubules. Salt follow concentration gradient through blood and tubules to move to the glands. Salt gland is then excreted out through a duct of beak as mist.
- **Highly Acidic Stomach:** The pH of the acid in their stomach is about 1.5, comparatively higher than other sea water species. Since, the birds need to fly long distances for extended periods, they need to ingest large amount of food whenever available. Hence, they evolved to have a large stomach with volume 3-4 litres. They can ingest prey up to 30% of their total body mass. High pH in stomach leads to rapid digestion and this allows them to feed on patches of prey whenever they are available.
- **Longline Fishing as Threat**: Longline fishing uses a main line to which baited hooks are attached at intervals to catch fishes which have large seafood market like tuna. Albatrosses are attracted by baits, become hooked and get drown. Almost 8000 birds are killed every year in this way, pushing them into IUCN list of vulnerable species.
- **Effect of Global Warming:** Due to climate change resulting in faster air currents, hungry albatrosses can travel greater distances in short time and hence, can catch more prey. This has led to an average weight increase of 20% since the 1970s. Since, they now need to spend few hours on food gathering, they can breed more. However, this model is not sustainable. If wing speeds keep increasing, the excessive fast air streams can be dangerous for soaring birds.
- **In Literature and Folklore:** The early explorers of the Southern Sea believed these birds to be harbinger of companionship in dreary solitudes and killing them is considered a bad omen. This was depicted in Samuel Taylor Coleridge's famous poem "The Rime of An Ancient Mariner". The idiom "Albatross around his neck" indicated unwanted burden or anxiety.

My Views On Evolution

In a supreme act of divine
Life emerged in the Garden of Eden
Wheels of time paced
And the garden bloomed
And one day
A mere creation
Rose up to its creator
The grim reality shattered faith
The great magician, the perfect creator
Was none but an old Socratic philosopher.
But the origin is always and always one
From the biome which walked and perished
We should learn
Divinity is in life
And in its celebration
And none but us together
Can adorn it
With benevolence and pride.

In this poem, I wanted to depict the philosophical and theoretical clash of religion and evolution. Here, by Garden of Eden, I wanted to indicate the holy books and the theory of Creationism that world and it's inmates were created by God in a miracle however, Darwin, a mere human challenged this long established theory. And by Socratic philosopher I am referring to that evolution is not an intelligent design but something which improves over time. But as every religion and science says that life arose from a single entity, we must celebrate life and as Duelism says, religion should be human adaptation to life and not a way to escape from reality and hardships of life. Also, here I want to convey that we should respect every organism and treat them with patience and kindness. Only then, we can make this world a better place.

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PART-B

1. **Psychiatric disorders can hamper a person's day-to-day functioning and can be life threatening in some cases. They often have genetic links. But, then why has natural selection not weeded them yet? Do psychiatric disorders defy theory of natural selection or did they provide some survival advantage and hence were selected in course of human evolution?**

   In his book, "Good Reasons for Bad Feelings", evolutionary psychologist Randolph Nesse suggests that anxiety and depression evolved from the evolutionary functions which are called as building blocks of adaptive and behavioural cognitive functions. To see from lens of evolutionary psychology, he classifies these disorders as, one, genetic disorders like bipolar and schizophrenia. Other are emotional disorders in which extreme type are maladaptive yet intermediate phenotypes are beneficial. He argues that although bipolar disorders and other severe disorders don't contribute to reproductive fitness, they are present due to cliff-edge effect. In this phenomenon, where some traits are pushed to a level where fitness collapses for few organisms. Further research into this topic can provide a new way for looking at genes which expression remains undetermined. His views were supported by theory from evolutionary theorist George C. William who suggested that some genes which cause ageing evolved because they enhance fitness early in life. This type of antagonistic pleiotropy involves genes coding for at-least one beneficial and one detrimental trait, representing complex biological trade-off. Similarly, emotion and other mental processes are also embedded in similar complex biological pathways. Genetic evidences suggest that genes which increases risk for schizophrenia also code for higher iq, improved mathematical reasoning. The other reason could be alternating selection. A special case is sexual antagonism in which alleles impart fitness in one sex and harmful for other. Some possible evidence indicates that genes for autism and schizophrenia might have led to improved fitness in females whereas proving harmful in males. Nesse and George C. William collaborated in 1994 and worked on newer perspectives of 'proximate' causes (driven by anatomy, biochemistry and physiology) and higher-level 'ultimate' (evolutionary) causes. They noted that evolution will select for reproductive fitness rather than health and happiness. Nesse also provided instances where anxiety may be useful, such as by signalling distress, depression can prompt for assistance in foraging by other organisms of community. In one research conducted on Vervet monkeys, it was hypothesized that depression evolved as signal loss of its status in social hierarchy, deflecting attacks from dominant males. Looking from a Darwinian perspective, an oversimplified version in favour of selection of psychiatry disorder is: Recent research suggested that depressed people tend to have elevated levels of proinflammatory cytokines, acute phase proteins, chemokines, and cellular adhesion molecules circulating in the bloodstream. The moody states can also be induced by injecting pro-inflammatory cytokines. This inflammatory response might have served adaptive value as when hunter-gatherer might come into the contact with a pathogen, moody feelings must have promoted a tendency to isolate and rest. It would have conserved energy, aided in recovery as well as have reduced risk of spreading the infection in its kin.

   The rapid increase and prevalence of psychiatry disorders in modern human populations are indicative of the environmental mismatch, i.e., the genomes are designed for a different environment than modern industrialized settings. The immune insults faced by primal ancestors were acute in nature. Modern humans face chronic immune insults such as physical inactivity, species inappropriate diet and lack of sufficient sleeping hours. This has led to chronic inflammation and hence, as a result, psychiatry disorders are on the rise. Also, I believe that the advent of modern technology has led to decrease in social interactions, which formed the backbone of human evolution. Due to lack of empathetic communication and chronic stress, epigenetic factors would have caused over-simulation of otherwise, beneficial stress hormones resulting n increased psychiatry disorders.

2. **Did culturally defined human races are a result of bottleneck effect and have a biological basis?**

The meaning of the word "race" is inconsistent across various cultures and demographic regions. Also, humans are a product of the same evolutionary process as other species. Therefore, definition of race must not be restricted to human context and to be applicable to all organisms. Hence, there arise the need to address "race" in the context of genetic and biological basis which can be further extended to all organisms. Conservation biologists have given two operational definitions for race and subspecies, applicable to all vertebrates.

a) According to the first definition, races are geographically circumscribed populations within a species and have sharp boundaries which separate them from the rest of the members of their species. The commonly used threshold to define two populations as "races" separated by a sharp boundary is 25% or more of the genetic variability that they collectively share is found between these two population groups.
b) According to the second definition, races are distinct evolutionary lineages within a species. The evolution lineages used in context of subspecies are the smallest population units functioning as evolutionary lineages within a species. These lineages are a result of hybridization, or geographical barrier limiting gene exchange.

Building on these two definitions, genetic ancestry of most humans are traced back to one group which came from Africa. This group was further categorized into 5 major groups: 1) sub-Saharan Africans; 2) Europeans, Near & Middle Easterners, and Central Asians; 3) East Asians; 4) Pacific populations; and 5) Amerindians. Upon increasing the number of groups from five, they obtained a classification into smaller, more regional groups. Hence, it was concluded that with the use of enough genetic markers, regional populations of humans can be discriminated. However, when threshold value needed for classification into races or subspecies was done, it was found that 5 major human races account for only 4.3% of human genetic variation. So, using threshold definition, there is no existence of race in humans. This was also confirmed by other laboratory analytical methods. Like increased geographic sampling and ML_NCPA. In increased geographic sampling, by using computer program STRUCTURE, it was revealed that human genetic distances fit an isolation-by-distance model. This was further confirmed by Multi-locus nested clade phylogeographic analysis (ML-NCPA) based on 25 human populations.

Skin colour, long considered as a racial trait is due to adaptations to UV radiations in the local environment. However, skin colour does not reflect overall genetic divergence. Another adaptive trait is human resistance to malaria, widespread in African populations. However, malarial resistance is found in European and Asian populations as well with highest frequency in certain populations of Arabian and Indian peninsula and provides little genetic variability. By these evidences, it can be concluded that the concept of race can't be verified objectively through biological and genetic standards. It also indicates that there was some degree of gene exchange prevalent between two geographically separated areas. Technological and cultural advancements would have eased the migration of humans continuously in wake of negative environment stresses subsequently weakening the bottleneck effect and reducing the genetic variability.

3. **Language, complex emotions and deep social sensibility are unique to humans. Did these traits co-evolved and helped in development of complex social structure in humans?**

Language is considered as an integrated part of the evolved and sophisticated social and cognitive suite, which co-evolved with culture and genes. The social emotions which regulate cooperative alliances, consolidate social hierarchy and structure include linguistic information sharing. Waddington first suggested that the evolution of language was brought by genetic assimilation. It is a process where selection for the developmental capacity to respond to new and persistent environment stimulus leads to the construction of a genetic constitution facilitating ontogenetic adjustments. The behaviour trait, initially learned after many trials, start appearing with fewer trials and learning, and in extreme cases, by exposure to a single stimulus. Then, the trait is said to be genetically assimilated. According to Waddington, the extent of the genetic assimilation can vary, and in case of language, learning is still required though the number of learning trials is reduced. This partial genetic assimilation creates learning-dependent biases. It is interpreted that persistent developmental, semantic and structural features of the language is shaped by genetic accommodation of both domain-general cognition aspects such as general memory, associated learning, symbolic representation etc. and language-specific modifications. The coevolving factors in the evolution of language are tool construction, alloparenting and social emotions. Corballis argued that voluntary motor control required for tool construction caused the evolution of gestural communication, generalized to oral movements which ultimately led to the speech. Humans are the only one of higher apes, which practice alloparenting - i.e care of young by individuals other than parents. It is suggested that as alloparenting needs more coordination and greater control over emotions, social selection for intra-group cooperation and information sharing became necessary. The patience and tolerance needed for tool-making and alloparenting require higher hormonal and cognitive conditions, which were manifested by subsequent genetic variations. It is believed these hormonal and cognitive conditions gave rise to complex social emotions like gratification, empathy, docility as they further strengthened mutual cooperation and social organization.

The evolution of linguistics signs greatly enhanced the need to exercise and extend human control. For instance, control over fear and instinct to run away, when signalled of the predator. Volitional imagining, a crucial part of linguistics imposes an inhibitionary control over emotions and triggered actions, making a distinction between human thoughts and feelings. The inhibition by language also indicates positive cultural selection. Using abstract words like ‘lion’ would have allowed instructive signals to move between different contexts and have enabled to be used in combination and operation with other symbols that would otherwise not be possible with iconic symbols like imitating roaring of a lion. The inhibitory control by language must have led to sharing the experiences promoting empathy and community cooperation. Crucially, language must have reinforced social norms and collective perspective, increasing social bonding and affecting complex social behaviours and responses.

4. **How the advent of technology can affect human evolution?**

Popular writings in media, by academicians commonly claim that as a species, modern humans rely on culture and technology, then the selection of traits for evolution. It is speculated that technological evolution has replaced the biological evolution in humans. Humans are adapting faster to most extreme environmental stressors due to the advent of technology. Since the advent of agriculture 12000 years ago, surplus food has allowed people to specialize in various tasks and pursue cultural and technological advancement. Our society rests on agricultural production and effective distribution of food resources. Gene frequencies might still change over time by factors like genetic drift, but if due to culture, environmental stressors are removed repeatedly, natural selection will no longer take place. Humans also have physiological characteristics as well which allow them to adapt efficiently. For example, ability to digest cooked food gives humans greater dietary flexibility than other higher apes. Humans can store larger amount of body fats and have flexible growth patterns to sustain short-term environment fluctuations. Human beings also have more flexibility in terms of birth spacing and fertility rates which allow the population to bounce back after high mortality periods.

Considering greater range of physiological, cultural or technological mechanisms humans possess, is it easy to conclude that humans have stopped evolving. But, the few points against this theory are:

- Classical studies on evolution are done on species with short life span and fast-reproducing species. Human, by contrast, have long generation time of 20 years. Also, homo sapiens are relatively new species evolved only about 200,000 to 300,000 years ago. Therefore, it is not easy to observe intergenerational gene change.
- Much of genetic variation in humans have developed after moving out of Africa. This little variation could be due to result of genetic drift.
- Examples of human evolution subsequent to rise of agriculture. Some of these are – natural selection of heterozygous carriers of sickle-cell gene to maintain population of sickle-cell anaemia in population exposed to malaria, lactose-tolerance etc.
- Growing evidence that epidemics are exerting selective pressure on humans. For example, signature of genes like glucose-6-phosphate dehydrogenase (*G6PD*), which resists malaria. Chemokine receptor 5 (*CCR5*) among Europeans which provide resistance to HIV, with CCR5 being evolved only 2,000 years ago.

These observations are markers to study human evolution and contemporary genetic diversity and represent history, not future. So, it is possible that technology can act as buffer for humans against natural selection. It is also quite worthy to note that our technological and cultural abilities to react to environmental pressures depends on economics of agriculture. Agriculture originated and spread in past 12,000 years ago which were highly stable climatically. But in wake of rapid climate change, future stability of global agriculture can’t be guaranteed. This can lead us to conclusion that our future course of evolution will depend on if we can adapt to environmental stresses through technological and cultural means. Natural selection might not seem to be the strongest force in our course of evolution right now, but it has potential to become stronger in future.

5. **Can a completely extinct species be re-introduced with the help of genomics?**

   The idea to undo historic extinctions and reintroduce new species is termed as de-extinction. IUCN has defined de-extinction as " de-extinction is the ecological replacement of an extinct species by means of purposefully adapting a living organism to serve the ecological function of the extinct species by altering phenotypes through means of various breeding techniques, including artificial selection, back-breeding and precise hybridization facilitated by genome editing.'' IUCN has defined the goal of de-extinction as to restore vital and dynamic-process sustaining ecological systems and increasing biodiversity and bio-abundance. The three main approaches to carry out de-extinction are discussed as follows:

   a) Back-breeding: It is the selective breeding to restore ancestral traits in the species. Similar to traditional breeding programs, organisms are selected based on their phenotype for mating. It aims to restore ost or diluted morphological and behavioural traits of a species One limiting factor in this approach is that target ancestral genes should essentially persist within divergent species, which is not always the case for every trait. This is only possible if the extinct species has a very closely related existing species. Back-breeding can also induce inbreeding leading to the selection of harmful alleles reducing population fitness over time.
   b) Cloning: Since, the cloning of the sheep Dolly, technological advancements have made this technique quite efficient. De-extinction can become possible by interspecies cloning. Unlike back-breeding, in cloning the resultant organism will be similar to nuclear genome levels. However, cloning requires live cells. Therefore, it can only be used to restore recently extinct species whose cells, tissues are stored and frozen. This technique may prove useful to restore species which live under the threat of extinction or are extinct from the wild.
   c) Genetic Engineering: By using ancient DNA extraction and sequencing techniques can help in constructing complete genome sequences from extinct species. Once, key differences are known in the genome between extinct and closely related extant species, genome editing can be done in vitro on living cells so that they have the same genome as extinct species. However, ancient DNA dating back to late Pleistocene will most likely be present in fragments, and hence, DNA sequencing and assembly will need some reference genome. The greater the evolutionary distance between the genome of ancient and reference organism, the less reliable will be the assembly.

      Once, the genome is sequenced, recognition of the regions of genes for target phenotype will be needed. After genome editing is complete, the next task will be to transform the engineered cell into a functional living organism. For mammals, this is possible by Somatic cell nuclear transfer (SCNT). However, for egg-laying species where reproductive physiology limits access and manipulation to early stages of egg, this is not possible. One possible solution can be to edit the germ cell rather than somatic cells. However, none of the above techniques guarantees the resurrection of exactly the same species, they can be used to construct organisms occupying the same ecological niche and can be useful in conservation and restoration of ecosystem and biodiversity. In my view, if we can develop techniques such as the development of a full genome from highly fragmented DNA and can manipulate all levels of the cell (somatic, germ cells), then we can witness reconstruction of functional species.

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