NATURAL SELECTION AND ADAPTATION

An adaptation is a characteristic that enhances the survival or reproduction of organisms that have it. This characteristic has evolved by natural selection.

The members of the population become better suited to some feature of their environment through change in a characteristic that affects their survival or reproduction.

Natural selection is the only mechanism known to cause the evolution of adaptations.

ADAPTATIONS IN ACTION: SOME EXAMPLES

1. The skull bones of most terrestrial vertebrates are rigidly attached to one another, but in snakes, they are loosely joined. They swallow their prey by drawing it into a gullet with recurved teeth mounted on a number of freely moving bones that act as levers and fulcrums, operated by complex muscles.

2. Pseudocopulatory pollination in orchids. Several species of orchids have modified flower parts to look somewhat like a female insect, and the flower emits a scent that mimics the attractive sex pheromone of a female, bee, fly or thynnine wasp depending on the orchid species. The flower is pollinated in the process of copulation; the insect does not derive any benefit from this activity.

3. Australian arboreal weaver ants construct nests of living leaves by the intricately coordinated action of numerous workers, groups of which draw together the edges of leaves by grasping one leaf in their mandible while clinging to one another.

4. Not in your book. Philodendron and other aroids produce two kinds of leaves adapted to different environments: small leaves for the dark forest floor and growth toward the dark looking for a tree trunk to climb, and large leaves with long petioles to catch sunlight in the upper regions of the forest canopy.

THE NATURE OF NATURAL SELECTION

Design and mechanism.

Most adaptations are complex and appear to have a design, to be constructed to perform a certain function, e.g. growth, feeding, pollination, etc.

The process of natural selection is random and mindless.

- Those with variations that enhance survival and reproduction replace those less suited who reproduce to a lesser extent.

Adaptive biological processes appear to have goals but there is no conscious anticipation of the future in cells.

- Teleological statements express goals as the leading reason for an action in the physical world, e.g. “… in order to…”

The future cannot cause material events in the present.
This apparent purpose is caused by the interaction of environmental conditions and the operation of a program coded or prearranged information residing in DNA sequences, that controls a process.

**Definitions of natural selection.**

Natural selection is not evolution. These two words are not synonyms.

Evolution can occur by natural selection, artificial selection or by genetic drift.

Survival is a prerequisite for reproduction.

**Fitness** is often defined as reproductive success. It is the average per capita rate of increase in numbers.

The components of fitness are:

1. Probability of survival to reproductive age.
2. Average number of offspring produced via female function.
3. Average number of offspring produced via male function.

**Sexual selection** is based on the competition for mates. It can be considered a form of natural selection.

The **probability of survival** and the **average number of offspring** enter into the definition of fitness, and these concepts apply only to **groups** of events; all the individuals in a population with a particular genotype.

Natural selection exists if there is an average difference in reproductive success.

Differences in survival and reproduction exist among individual organisms, among genes and among populations and species.

Different kinds of biological entities may vary in fitness, resulting in **different levels of selection.**

- The difference among traits that affect fitness.

Natural selection may occur among genes, individual organisms, and groups such as populations or species.

Selection has an evolutionary effect only if there is inheritance.

Natural selection is a name for **consistent statistical differences** in reproductive success among genes, organisms, or populations.

**Natural selection and chance**

Neutral alleles are not affected by natural selection because they do not affect reproductive success.

Fitness differences are average differences, biases, differences in probability of reproductive success.
This does not mean that every superior genotype reproduces prolifically, and every inferior genotype does not reproduce and perishes.

Natural selection is a consistent difference in fitness among phenotypically different biological entities, and is the antithesis of chance.

It is not possible to tell if difference in reproductive success between two individuals is due to fitness or to chance.

**Selection **OF and selection FOR.

Natural selection may select for a certain body size, mating behavior or other feature. There may incidental selection of other features that are correlated with those features.

In speaking of a function of a feature, it is implied that there has been natural selection of organisms with that feature and of genes that program it, but for the feature itself.

A feature may have other effects or consequences that were not its function and for which there was not selection.

**EXAMPLES OF NATURAL SELECTION**

Look over these examples on pages 285 to 290.

- Bacterial populations;
- Inversion polymorphism in Drosophila;
- Male reproductive success;
- Population size in flour beetles;
- Kin discrimination in cannibalistic salamanders;
- Selfish genetic elements.

**LEVELS OF SELECTION**

We can consider higher-level units and included units: species/populations; populations/individuals, etc.

There are two measures of fitness:

1. Reproductive success of its constituent members, e.g. individuals that produce offspring.
2. Reproductive success of the higher level units, e.g. population that produces other populations.

**Selection of organisms and groups**

**Sociobiology** is the biological basis of social behavior in animals.

- E.g. flocking, parental care, territoriality, courtship, dominance, cooperation, etc.

**Altruism** is doing well for others.

- E.g. sharing food, warning of danger, adopting orphans, etc.

There is always cost to altruistic behavior.

It raises the genetic fitness of another individual while lowering its own.
How can altruistic traits be maintained in a population when the altruistic gene is selected against?

Altruistic trait cannot evolve by individual selection.

An altruistic genotype amid other genotypes that were not altruistic would necessarily decline in frequency, simply because it would leave fewer offspring per capita than the others.

If a population were to consist of altruistic genotypes, a selfish mutant – a cheater – would increase to fixation.

Statements about organisms acting against their own good for “the good of the species” are wrong.

Traits that benefit the population at the cost of the individual might have evolved by group selection.

Populations with higher rates of “selfish genotypes” may have a higher chance of extinction than populations with “altruistic genotypes.”

Group selection has been criticized by George Williams in his book *Adaptation and Natural Selection*, 1966.

Here is his reasoning:
- Individual organisms are more numerous than the populations into which they are aggregated.
- Individuals are born and die much faster than populations.
- Selection requires differences in rates of birth and death at both levels, individuals and populations.
- The rate of replacement of less fit by more fit individuals is potentially much greater than the rate of replacement of less fit by more fit populations.
- Therefore, individual selection will prevail over group selection.

Most biologists are of the opinion that very few characteristics have evolved because they benefit the population or the species.

**Kin selection** has been proposed as a mechanism for the evolution of altruistic behavior.


Kin selection is selection at the level of the gene.

Either the individual or its immediate relatives leave behind many offspring.

The altruist’s relatives are more likely to carry copies of the altruistic allele than are members of the population at random.

When the altruist’s enhances the fitness of its relative, even at some cost to its own fitness, it can increase the frequency of the allele.

- Genes reach the next generation via relatives.
As far as evolution is concerned, it makes no difference what animals passed the "good" genes to the next generation, the actor or its siblings.

Kin selection also explains eusociality.

- Division of labor. The sterile castes give up fitness entirely and devote their efforts to the good of the colony.
- Cooperative caring of the young.
- Overlap of at least two generations of life stages able to contribute to the colony's wellbeing. The colony is in fact a family made mostly of the queen and her offspring.
- It is found in bees, wasps and termites, and one mammal, the naked mole rat of Africa.

Most features are unlikely to have evolved by group selection, the one form of selection that could in theory promote the evolution of features that benefit the species even though they are disadvantageous to the individual organism.

**Species selection**

Species selection is the process responsible for the proliferation of species that have lower extinction and higher speciation rates.

It refers to a differential rate of extinction and speciation due to some characteristic of the species such as geographic isolation or allele frequency.

**Differential speciation**: Some lineages have higher speciation rate than other related lineages.

- For example: orchids, family Orchidaceae with about 19,500 species, have highly modified flowers to attract specialized pollinators and have produced more species over time than its close relative, the iris family, Iridaceae, which consists of about 1,750 species.

There has been differential speciation in this case caused by the flower type and the attraction of pollinators.

**Differential extinction** also occurs. Some lineages have long survival time, e.g. asexual forms have a higher rate of extinction than sexual forms.

*See Fig. 11.16.*

Many groups of plants and animals have given rise to asexually reproducing lineages, but also all such lineages are very young as indicated by their very close genetic similarity to sexual forms.

Asexual forms that arose long time ago have not persisted.

**THE NATURE OF ADAPTATIONS**

**Definitions of adaptation**

1. Adaptations can be defined from the point of view of its present effect in increasing the fitness of an individual.
“An adaptation is a phenotypic variant that results in the highest fitness among a specified set of variants in a given environment.” Kern Reeve and Paul Sherman (1993)

“A characteristic body part, shape or behavior that helps a plant or animal survive in its environment.”
www.reefed.edu.au/glossary/a.html

2. Adaptation can also be defined from the historical perspective of its phylogenetic origin:

“For a character to be regarded as an adaptation, it must be a derived character that evolved in response to a specific selective agent.” Paul Harvey and Mark Pagel (1991)

“A biological adaptation is an anatomical structure, physiological process or behavioral trait of an organism that has evolved over a period of time by the process of natural selection such that it increases the expected long-term reproductive success of the organism.”
en.wikipedia.org/wiki/Adaptation_(biology)

The presence of a particular feature versus another may be due to adaptation or phylogenetic history.

**Preadaptation** is a feature that by chance serves another function: the swim bladder of rhipidistian fish became the lung of early amphibians.

An **exaptation** is an adaptation that performs a new function, different from the original function performed when the adaptation arose through natural selection. The concept involves the idea of modification for the new function.

- Wings of penguins and alcids are used for swimming rather than flying.
- Salivary glands of poisonous snakes have become poison glands.

The term “preadaptation” supposes forethought and it is being eliminated from biological vocabulary and replaced with exaptation or cooptation.

**Recognizing adaptations**

Not all traits of organisms are adaptations.

A trait…

1. May be the consequence of physics or chemistry, e.g. the red color of the blood.
2. May have arisen through genetic drift rather natural selection.
3. May have evolved not because of particular advantage but because it is correlated to another feature that was advantageous, e.g. pleiotropy, genetic hitchhiking.
4. A character state may be a consequence of its phylogenetic history, an ancestral character state that acquired a new function.

Several methods may be used to infer if a feature is an adaptation:

1. **Complexity** cannot evolve except by natural selection.
2. **Design** of a feature corresponds to its function.

   - **Functional morphology** and **ecological physiology** study how the design of features allows organism to survive and function in an ecological setting.
   - The relation of morphological variation and functional morphology to environmental change.

   “Ecological physiologists identify the physiological adaptations of organisms and organ systems, investigate the molecular, cellular and physiological mechanisms underlying these adaptations, and determine how these adaptations affect growth, reproduction, movement, survival and other basic biological characteristics of organisms and their ecological role in communities.” UC Santa Barbara, Santa Barbara CA 93106
   [http://www.lifesci.ucsb.edu/eemb/research/ecological_physiology/ecological_physiology.html](http://www.lifesci.ucsb.edu/eemb/research/ecological_physiology/ecological_physiology.html)

3. **Experiments** may show that a feature enhances survival or reproduction in a way that increases fitness relative to individuals in which the feature is modified or absent.

4. The **comparative method** consists of comparing sets of species to pose or test hypotheses on adaptation and other evolutionary phenomena.

   - **Convergent evolution**: A feature that evolves independently in many lineages because of a similar selection pressure.
     - E.g. the similar beak of birds that feed on nectar appeared in six different lineages.
     - E.g. Human digestion of milk and its occurrence in areas where milk and dairy products are an important part of the diet.
   - Phylogenetic information may be necessary in some cases for the proper use of the comparative method.
   - The number of independent convergent evolutionary events by which a character state evolved in the presence of one selective factor versus another should be considered.

**WHAT NOT TO EXPECT OF NATURAL SELECTION AND ADAPTATION**

Natural selection does not necessarily produce anything that can be called evolutionary progress.

**Necessity of adaptation**

Not all environmental changes reduce population size.

An environmental change that does not threaten extinction may set up selection for change in some characteristics.

New adaptations may evolve in an unchanging environment if new mutations arise that are superior to the previously existing one.

**Perfection**

Selection may fix only those genetic variants with a higher fitness than other genetic variants in that population at that time.

Selection cannot fix the best of all conceivable variants if they do not arise; the best possible variants may fall short of perfection because of various kinds of constraints.
Progress

Evolution does not have goals

Measurement of “improvement” or “efficiency” must be relevant to each species’ special niche or task.

Harmony and the balance of nature

Selection at the level of genes and individual organisms is inherently selfish: the gene or genotype with the highest rate of increase increases at the expense of other individuals.

Cooperative behavior can be explained by kin selection.

Kin selection does not work across species boundaries: natural selection cannot produce any modification in a species exclusively for the good of another species.

Mutualistic relationships between species consist of mutual exploitation.

The equilibrium observed in ecological communities does not reflect any striving for harmony.

Morality and ethics

Natural selection is the name for differences among organisms or genes in reproductive success.

Natural selection cannot be described as moral or immoral, just or unjust, kind or cruel.

Hence, it cannot be used as a justification or model for human morality or ethics.

Neither the evolutionary theory nor any other field of science can speak of or find evidence of morality or immorality.

Science describes what it is, not what ought to be.

The naturalistic fallacy, the supposition that what is natural is necessarily good, has not legitimate philosophical foundation.