BIO 111: **Biological Diversity and Evolution**

Varsha 2017

Ullasa Kodandaramaiah
&
Hema Somanathan

School of Biology

IISER
THIRUVANANTHAPURAM

MODULE: PRINCIPLES OF EVOLUTIONARY BIOLOGY

Part I - FUNDAMENTAL CONCEPTS

Evolution: change through time

Do species change over time?

Was long believed that all species on earth were created at the same time and that species never change over time

- e.g. Plato (ca. 400 BC) thought each organism was modelled after a 'perfect form', with some deviants

- George Cuvier (1769-1832)

  palaeontologist

  observed that many species with fossils don't exist any more – *extinctions*

- Erasmus Darwin (1731-1802)

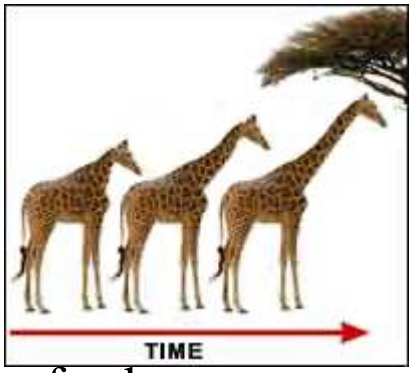
  grandfather of Charles Darwin

  one of the first to propose that species change over time

- Jean-Baptiste Lamarck (1744-1829)

  first to strongly argue that organisms change over time and come up with a theory of how change takes place

- Lamarckism: use & disuse of organs
  inheritance of acquired traits



e.g. Giraffes originally had shorter necks. They stretched their necks to feed on vegetation high up a tree and thus their necks got longer. Long necks were inherited by the offspring

- Thomas Malthus (1766-1834)

Malthusian principle

All species have the potential to create far more offspring than there are resources to support

'struggle for existence'

Reading Malthus's essay helped Darwin & Wallace come up with the idea of evolution

- Charles Darwin and Alfred Wallace

  Exceptionally good naturalists

  Travelled around the world collecting and observing plants and animals

Independently came up with the theory of evolution in the 1850s

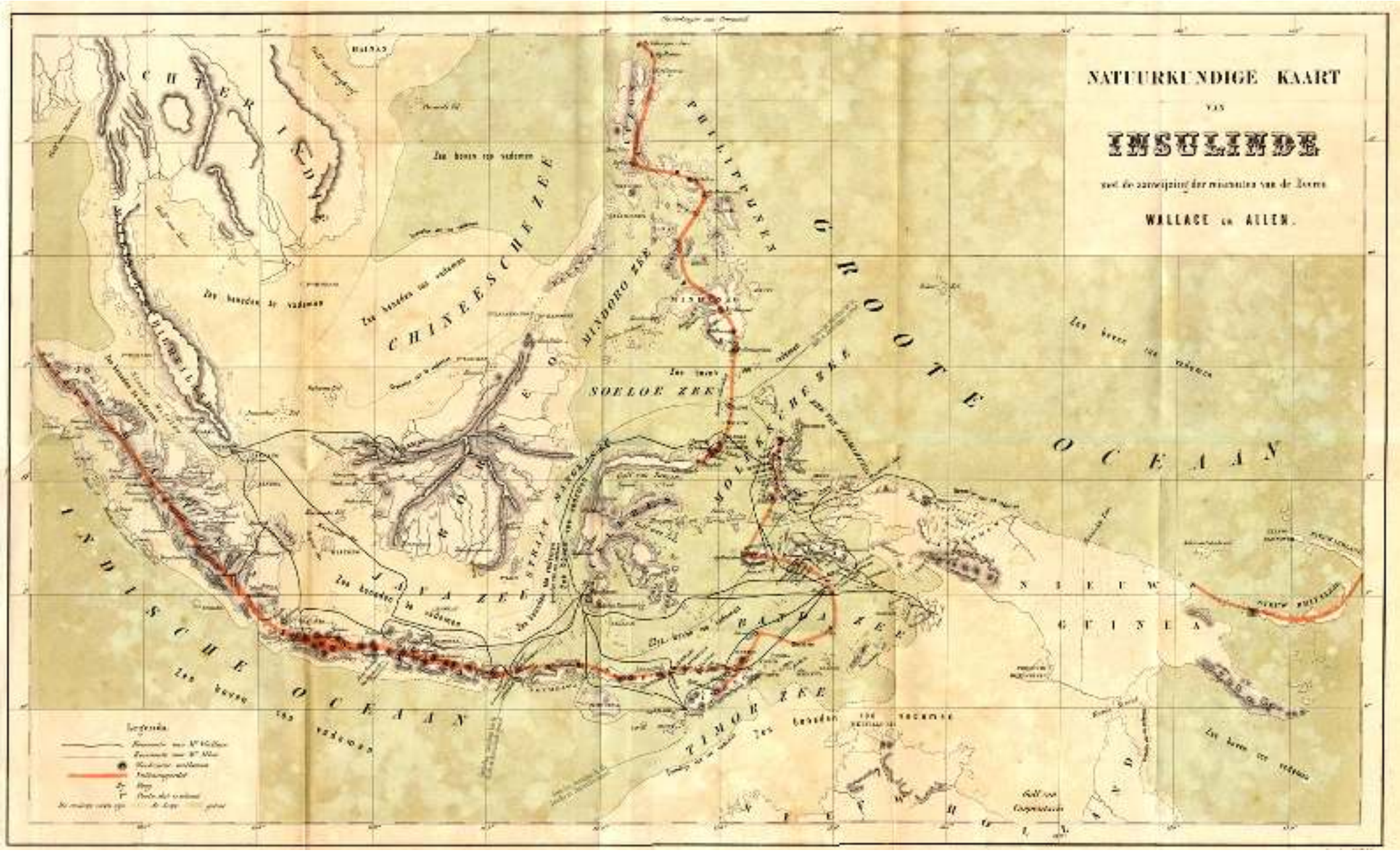
Voyage of the *Beagle*: 1831-1836

Copyright: Pearson Education Inc.

Photo: Wikimedia/ Matthew Field

- Galápagos Islands

Wallace's travels in SE Asia (thick black lines)

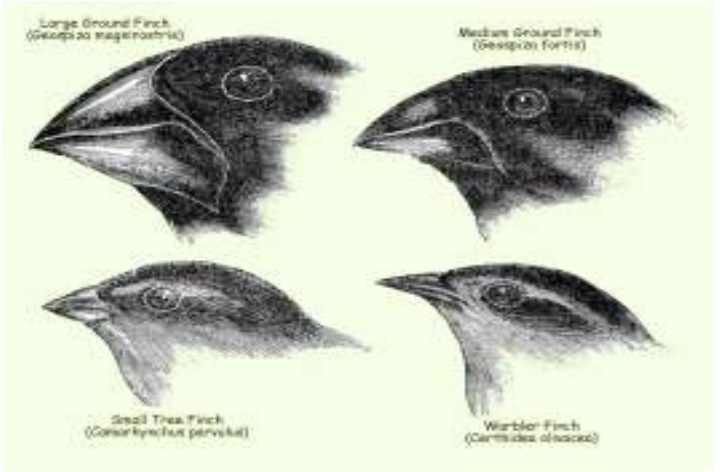


Source: Wikimedia Commons.Originally from Wallace's book ' The Malay Archipelago'

- Darwin and Wallace observed

  variation among individuals within a population of a single species

  variation among closely related species



Darwin's finches in the Galapagos archipelago. Source www.animalcorner.co.uk

Darwin & Wallace contd.

- Observed that offspring resembled parents – i.e. certain traits are heritable (but they did not have knowledge of Mendelian genetics, which was formulated later)

- Knew what selective breeding in plants & animals could lead to

- Knew that many species clearly have certain traits that help them survive in certain environments (i.e. traits affected probability of survival)

- Reasoned that not all off-spring survive because of competition for resources (both were inspired by the Malthusian principle)

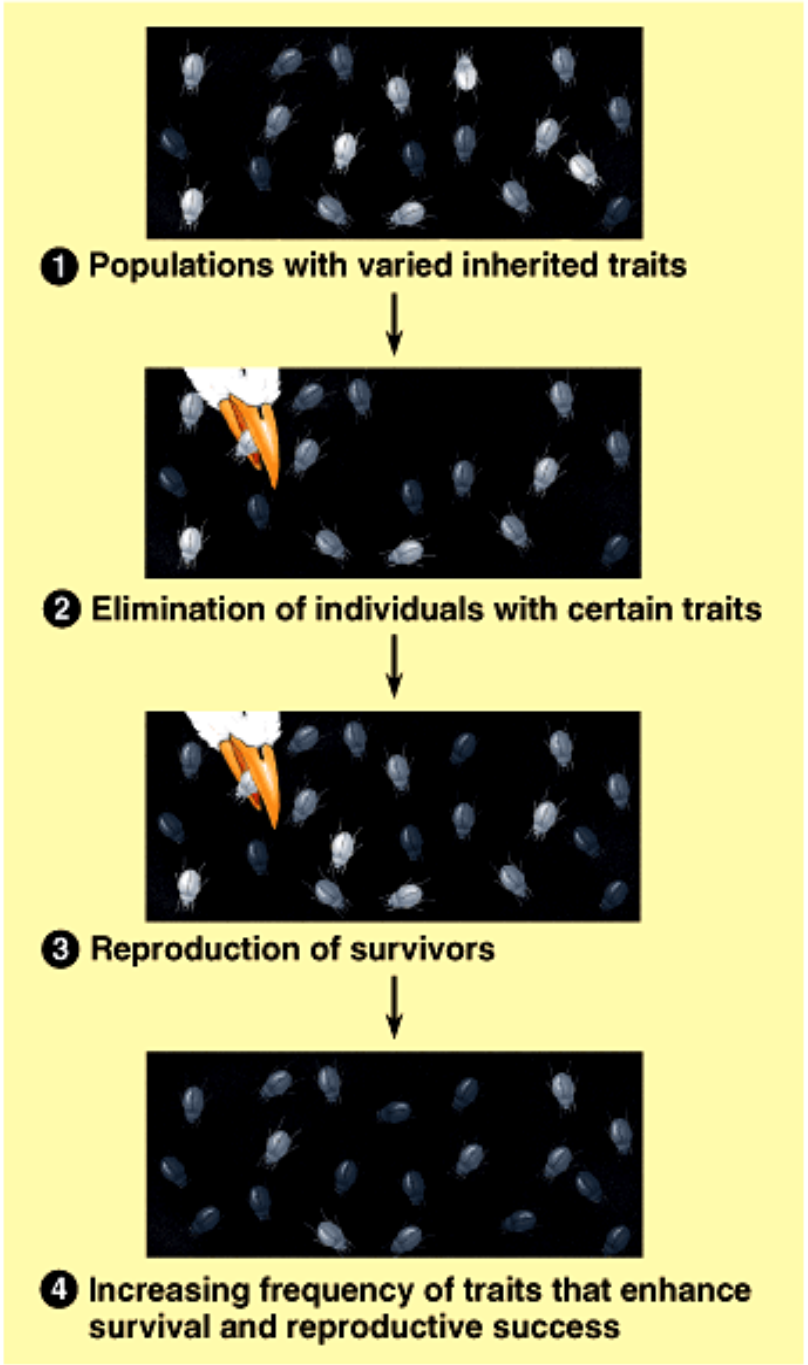
- Reasoned that not all off-spring survive because of competition for resources (both were inspired by the Malthusian principle)

- Individuals which have a trait that helps them survive and reproduce will pass on the traits to their offspring if the traits are heritable

- Reasoned that not all off-spring survive because of competition for resources (both were inspired by the Malthusian principle)

- Individuals which have a trait that helps them survive and reproduce will pass on the traits to their offspring if the traits are heritable

NATURAL SELECTION



Environment: includes the predator and the background

Selective agent or **Selection pressure**: Predation

- Over time, the proportion of individuals with the beneficial trait will increase in the population, as long as there is competition for resources

- Thus, favorable traits accumulate in a population over generations

EVOLUTION mediated by NATURAL SELECTION

Wallace and Darwin independently came up with this theory. Darwin's famous book 'On The Origin of Species by Means of Natural Selection' was published in 1858

Descent with Modification: new species are the modified descendants of older (ancestral) species

Argued that ALL species had descended from one or a few original types of life

- Evolutionary changes are heritable changes, ie those that are transmitted via genetic material from one generation to another

- Natural selection acts on individuals

- **Evolution acts on populations. Therefore populations evolve, not individuals**

Evolution results in changes in allele frequencies in populations

- An *Allele* is a variant of a gene. *Allele frequency* is the proportion of individuals in a population with an allele

Therefore evolution can be defined 'a change in the *frequency of alleles* within a *gene pool* from one generation to the next'

A gene pool is the total collection of genes in a population at any one time

Microevolution: changes within a species

Macroevolution: changes at the level of species or above

- e.g. changes in allele frequencies of two populations over many generations can lead to the two divergence of the two populations into two new species – 'speciation'

- e.g. dinosaurs went extinct

Evidence for evolution

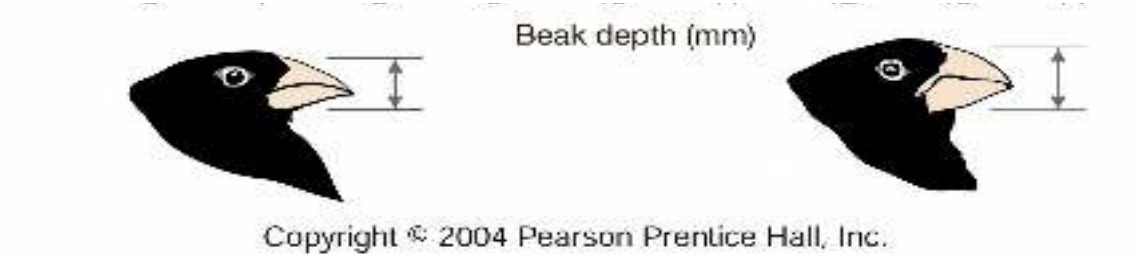
Rosemary and Peter Grant have studied Darwin's finches in the Galápagos island Daphne Major for more than 30 years

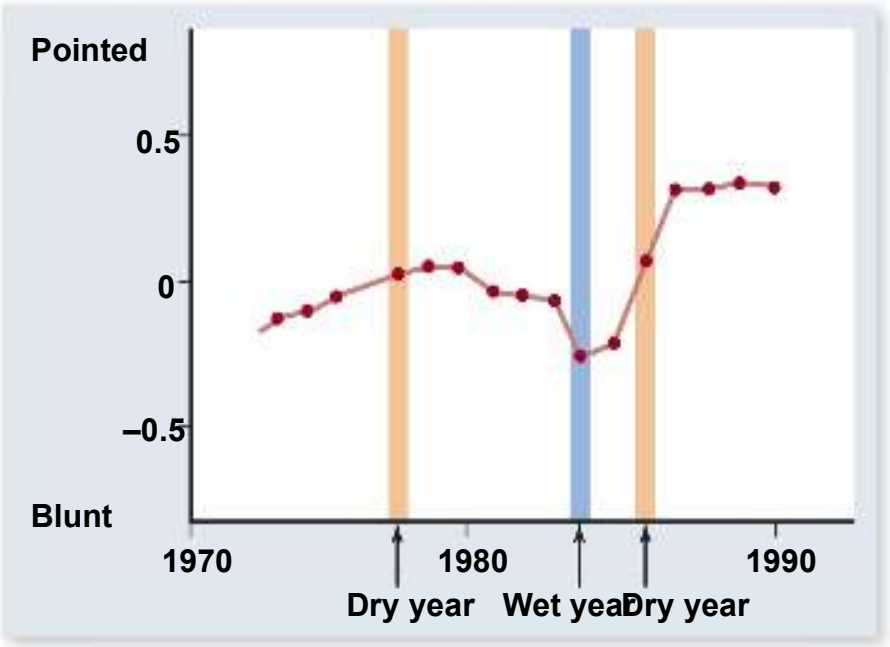
- **Droughts:** higher proportion of larger seeds

- **Normal rains:** higher proportion of smaller seeds

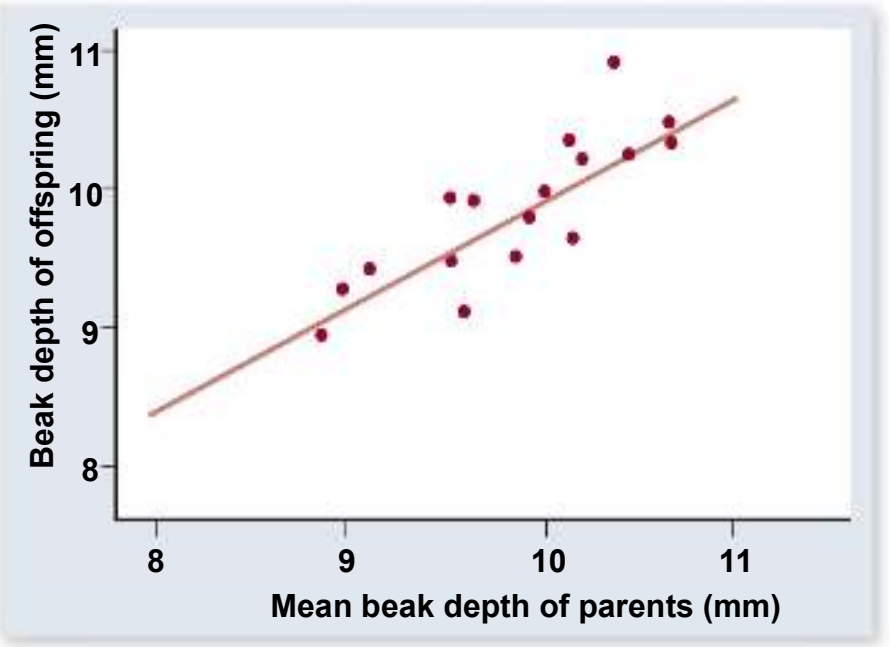
Geospiza fortis (Medium ground finch)

Adapted from slide by Joan Sharp, Pearson Education Inc





a.



b.

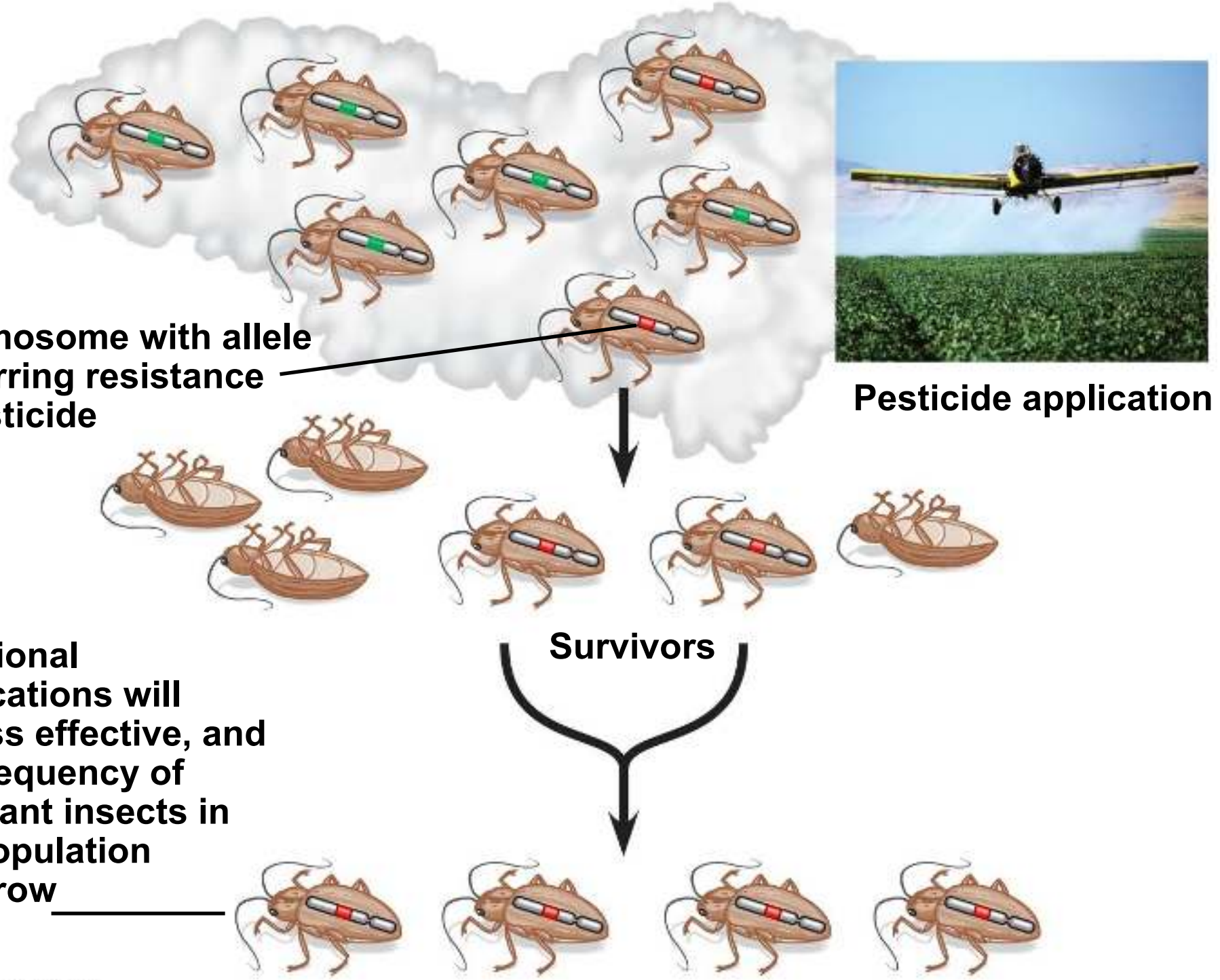
Development of pesticide resistance in insects

Initial use of pesticides favors those few insects that have genes for pesticide resistance

With continued use of pesticides, resistant insects flourish and vulnerable insects die

Proportion of resistant insects increases over time

Adapted from slide by Joan Sharp, Pearson Education Inc



Slide by Joan Sharp, Pearson Education Inc

More examples

- Antibiotic resistance

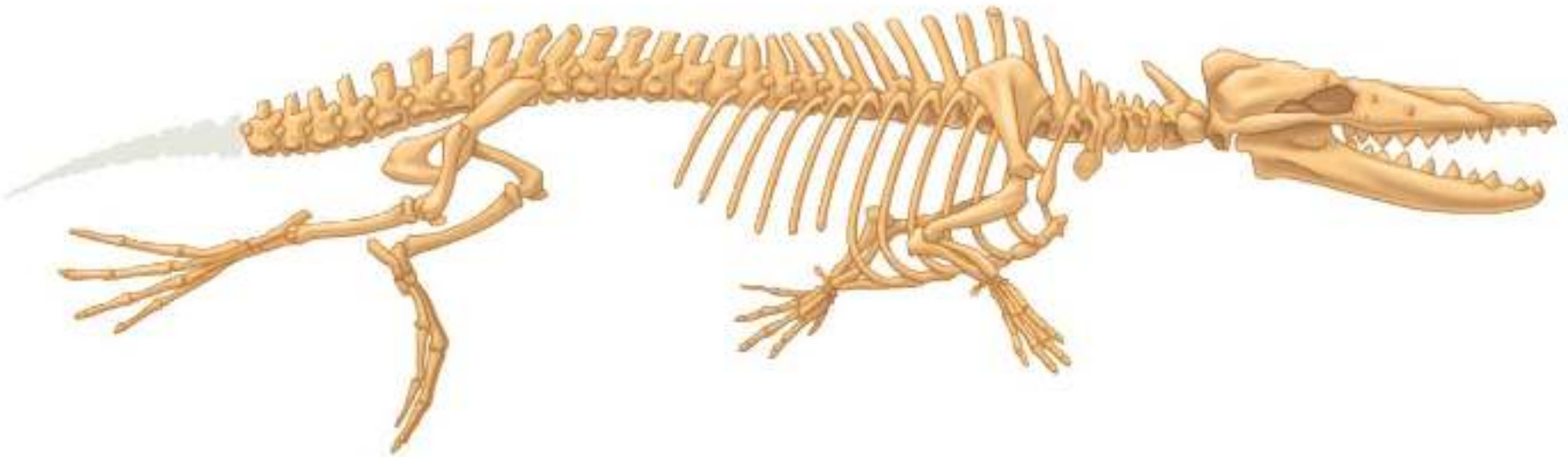
- Industrial melanism in *Biston betularia* (Peppered moth) – (Tutorial)

Evidence for evolution from fossils

Many fossils link early extinct species with species living today

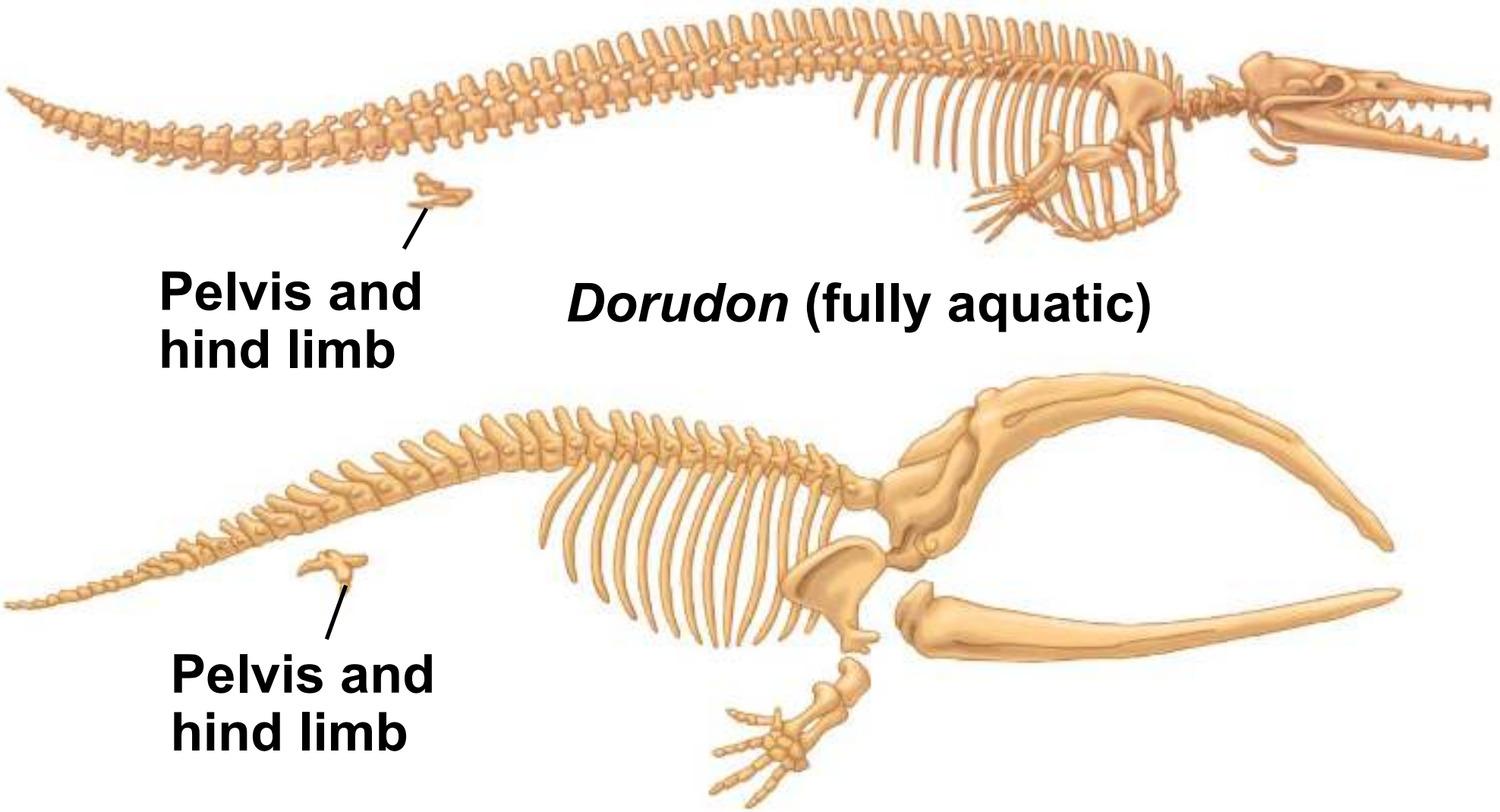
e.g. A series of fossils documents the evolution of whales from a group of land mammals

***Pakicetus* (terrestrial)**



***Rhodocetus* (predominantly aquatic)**

slide by Joan Sharp, Pearson Education



slide by Joan Sharp, Pearson Education

“Survival of the fittest”

- This saying is misleading and does not quite capture the essence of what is natural selection
- You can be as “fit” an individual as can be but it is the ability to reproduce that is the key feature for an increase in representation in the next generation

Fitness

Related to **the number of offspring of an individual, i.e. Fecundity**

- ***Evolution favours traits that increase fitness***
- Consider individual 'A' – small, frail and diseased. It produces an offspring before death and the offspring goes on to reproduce. Consider another individual 'B' - strong, large and free from disease, but does not reproduce.

'A' has higher *fitness* from the point of evolution.

Adaptation

Adaptation is a **trait that helps an organism to maintain or increase fitness of an organism in a given environment**.

Adaptations are the result of past selection pressures

Adaptations are not perfect

Prerequisites for evolution by natural selection

1) Variation in traits

- acts on *existing* variation.

eg. Elephants cannot be directly selected to have larger wings, but can be selected to have smaller tusks

Prerequisites for evolution by natural selection

2) Heritability

unless a trait is heritable, natural selection cannot act on it.

Prerequisites for evolution by natural selection

3) Differences in fitness

there can be no selection if there is no difference in fitness.

Natural selection has no goal, no predefined end point, no race for perfection.

Organisms DO NOT purposefully acquire traits that they need

The environment ‘selects’ the traits that will increase

- Are traits in human beings evolving?

Artificial selection

Artificial selection is induced by man. It has predefined goals & end point and strives for perfection

Examples of artificial selection

Rice plants with more and heavier seeds
More lipid content in oilseeds
Larger fruits
A dog with long legs or floppy ears
A cow that yields more milk
A domestic cat with the spots of a jungle cat

Some practical applications of evolutionary principles

- Food
  - artificial selection for better crops & livestock
  - pesticide resistance
- Health
  - drug resistance
  - emerging diseases
- Environment
  - invasive species
  - endangered species
- Evolutionary Psychology

Adapted from Slide by Allison Welch

Summary of key principles of evolution

- Variation is very common in natural biological systems
- Variation results in differences between individuals in their survival and reproduction, ie differences in *fitness*
- If the variation in traits is heritable then it provides the raw material for natural selection
- The process by which advantageous traits are maintained and disadvantageous traits are weeded out of a population is known as natural selection.
- The outcome of natural selection is what we call evolution
- Populations evolve. Not individuals
- Populations become better adapted to their environments as a result of natural selection.

Selection pressures may conflict (*Trade-offs*)

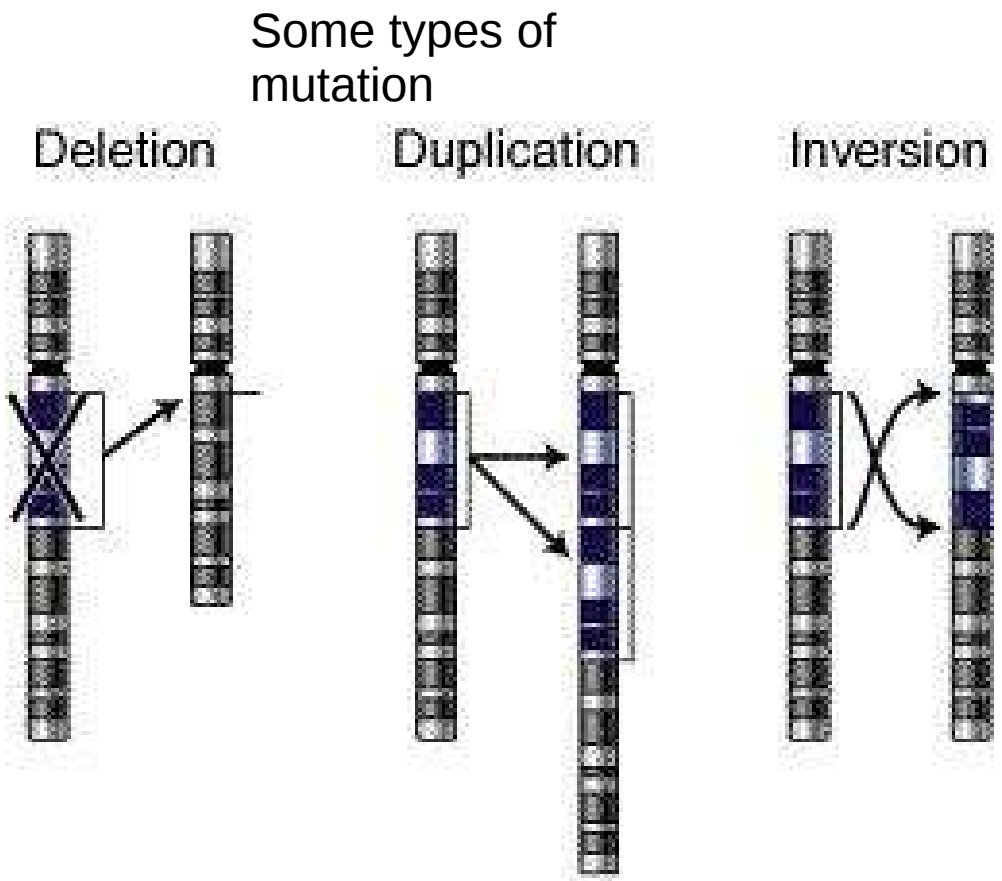
Adapted from slides by Jana Vamosi

Sources of heritable Variation

- Mutation is the ultimate source of variation

Occasionally, mutant alleles improve the adaptation of an individual to its environment and increase its survival and reproductive success (for example, e.g. DDT resistance in insects)

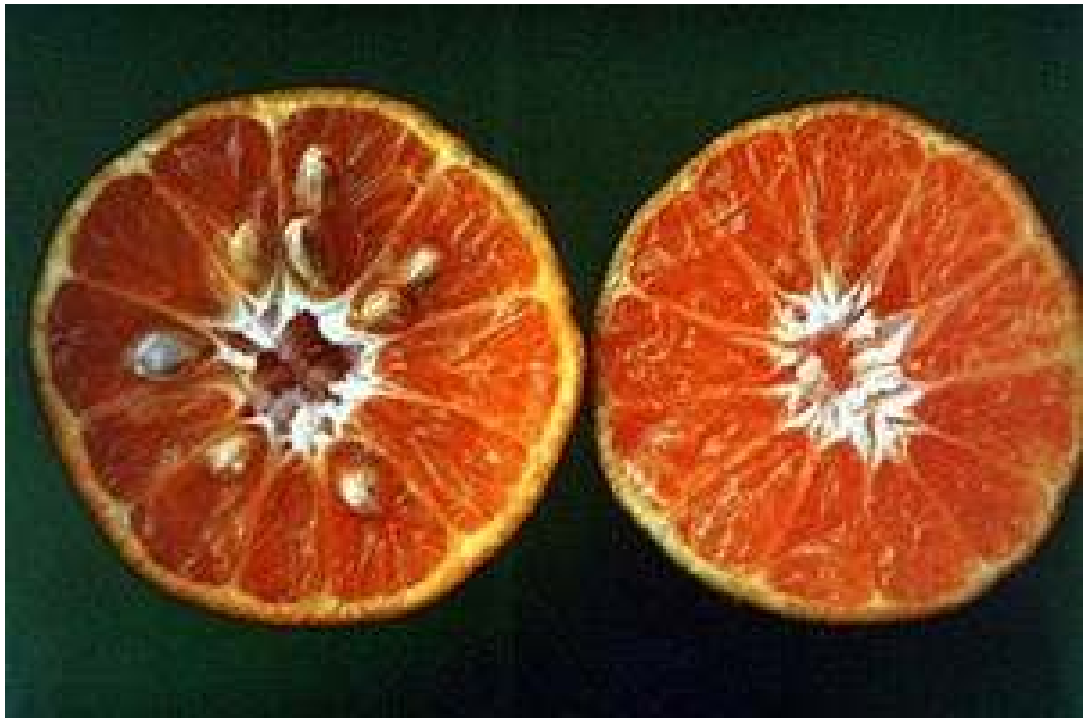
Mutation at the DNA Level



- A mutation is caused when the chromosomal machinery makes a mistake

Adapted from slides by Jana Vamosi

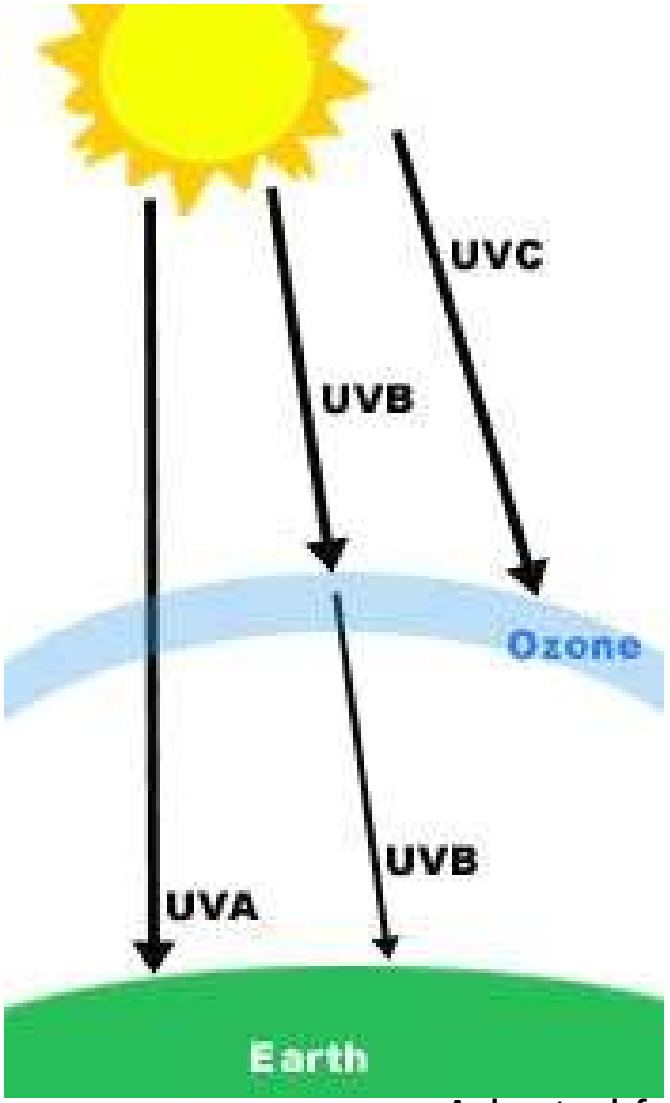
Mutation at the Phenotype Level



- Mutations can be:
  - beneficial
  - detrimental
  - neutral

Adapted from slides by Jana Vamosi

Mutagens



- Many things may increase the mutation rate:
  - radiation
  - certain chemicals (e.g. carcinogens)

Adapted from slides by Jana Vamosi

Other sources of variation

- *Gene flow*: immigration can bring in new genetic material into a population

- *Recombination*

- *Gene duplication* or *Chromosomal duplication*: If a gene is duplicated, a copy can undergo mutation without affecting the other copy

Adapted from slides by Jana Vamosi

Variation is random

- When a new recombinant or mutant genotype arises, there is no tendency for it to arise in the direction of improved adaptation

- Natural selection imposes direction on evolution, using undirected variation

Concepts: Frequency Distribution & Histograms

Frequency distributions of heights of students in the class

Mean, Variance, Range

- Fitness function, fitness proxy

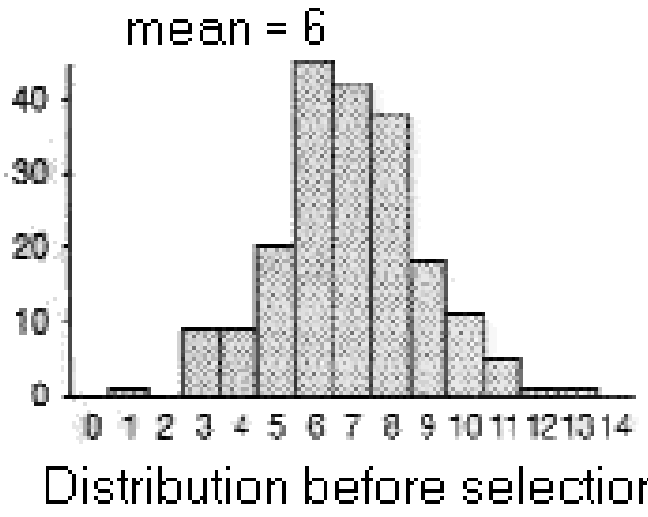
Types of Natural Selection

Directional selection

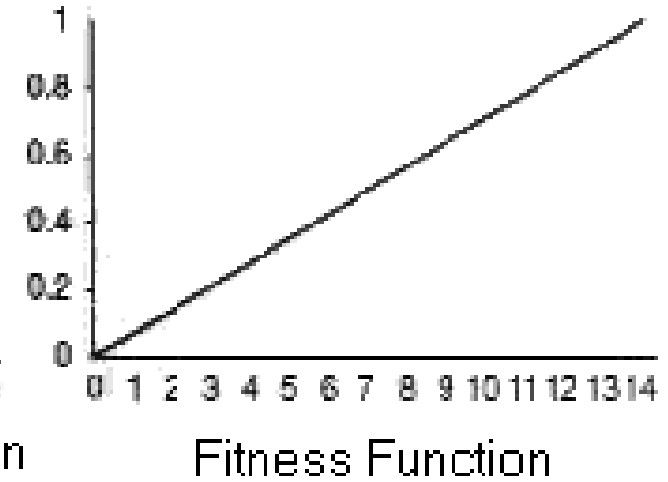
Stabilizing selection

Disruptive selection

Directional Selection

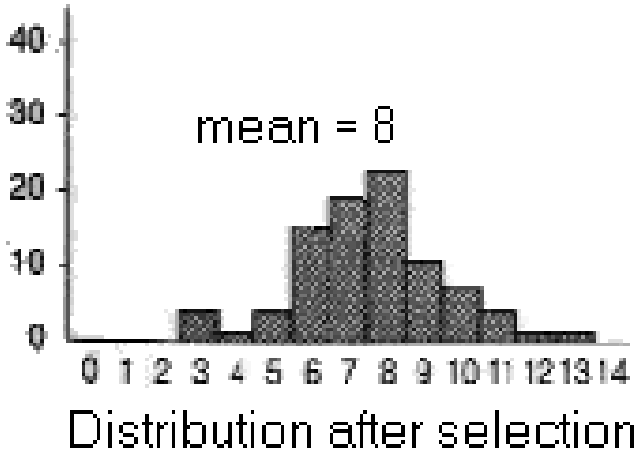


Distribution before selection



Fitness Function

(modified from Freeman & Herron 1998)

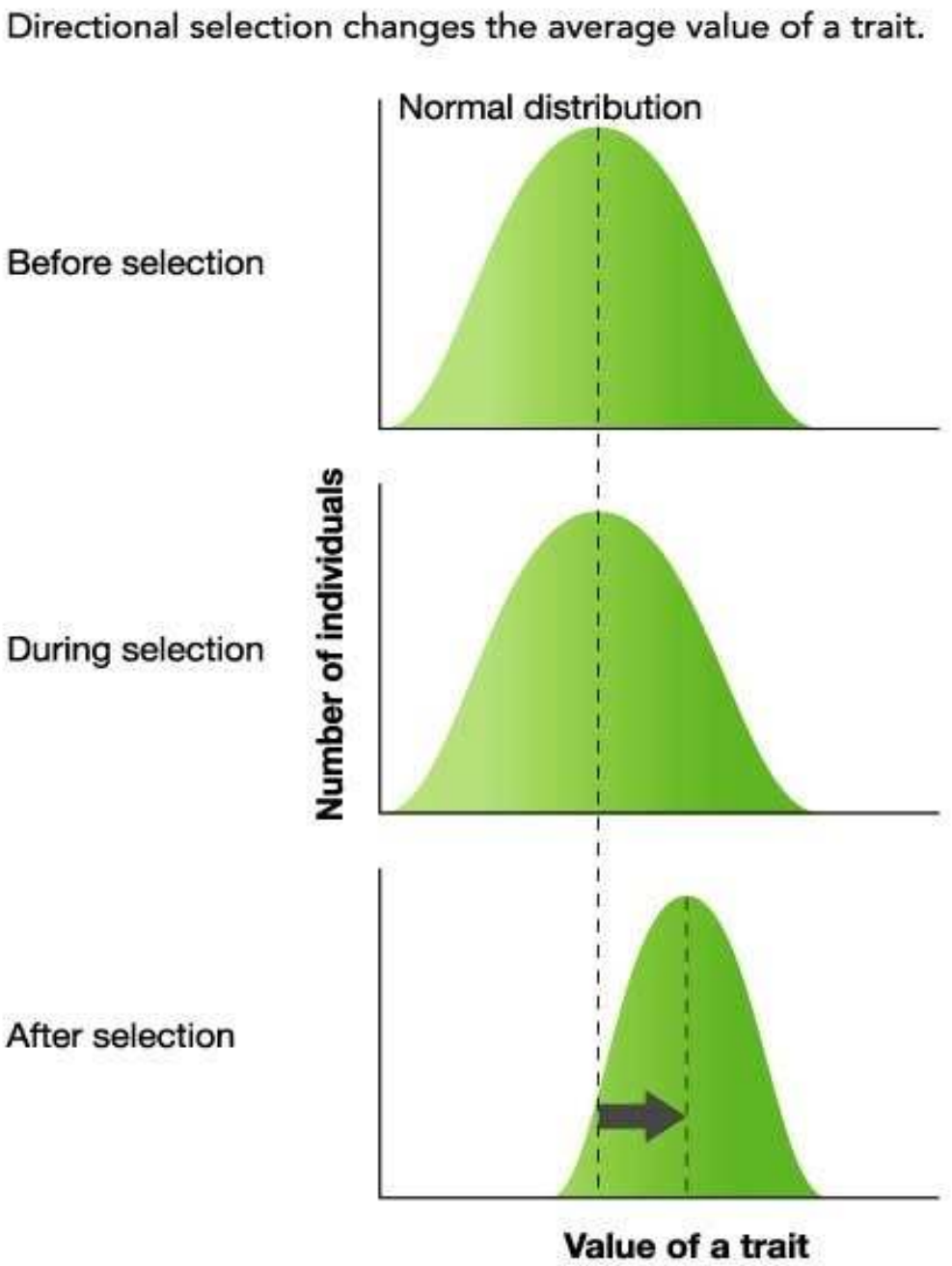


Distribution after selection

Larger individuals may have higher fitness (i.e., produce more offspring) than smaller individuals.

Adapted from slides by Jana Vamosi

changes the population mean



Adapted from slides by Allison Welch

Directional Selection

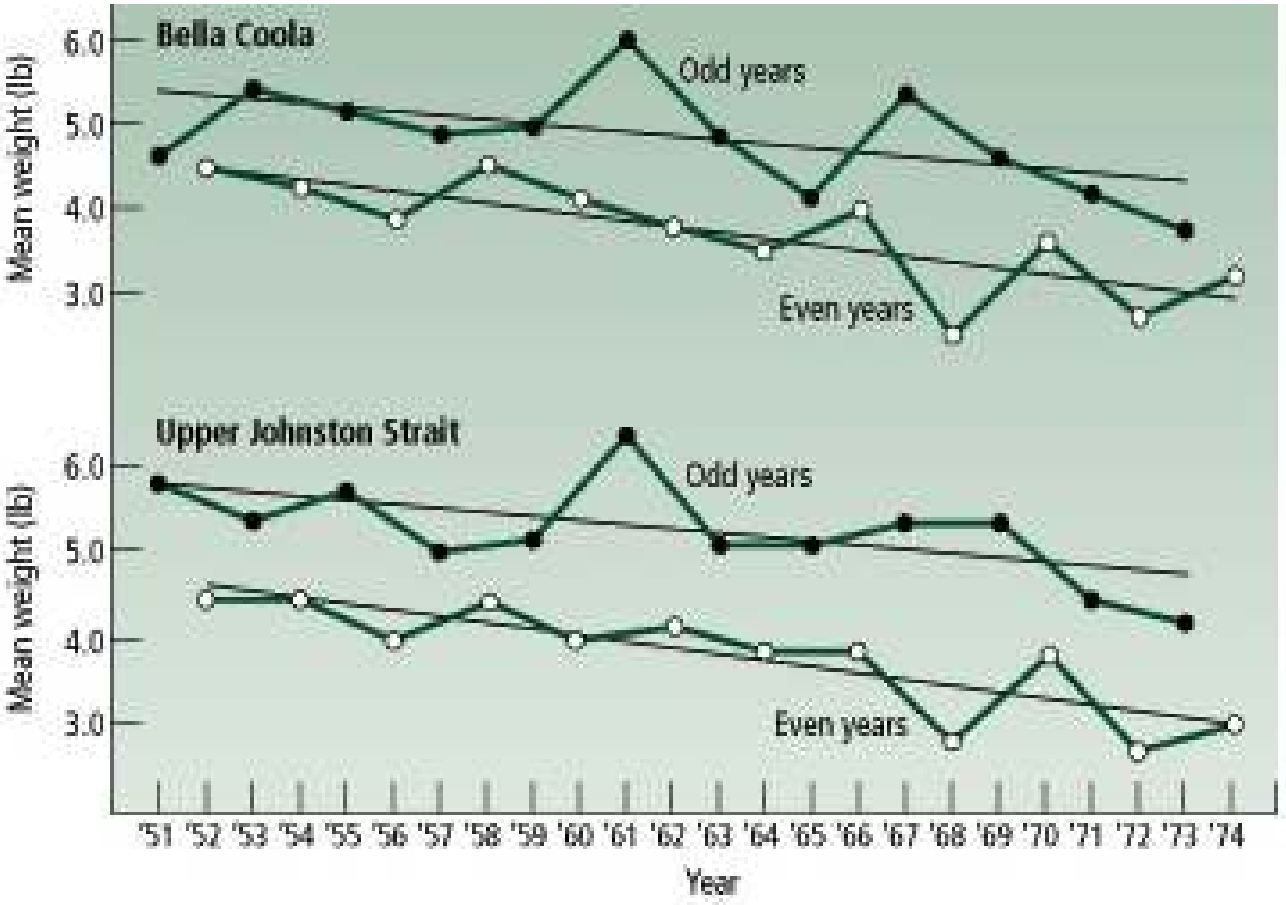
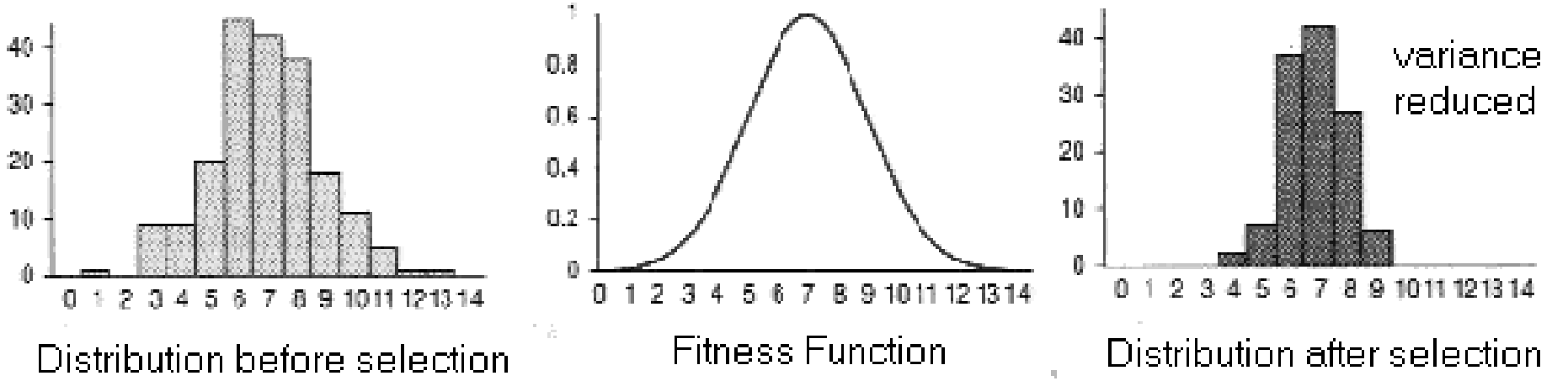


Figure: Directional selection by fishing on pink salmon *Onchorhynchus gorbuscha*. The graph shows the decrease in size of pink salmon caught in two rivers in British Columbia since 1950, driven by selective fishing for the large individuals. Two lines are drawn for each river: one for the salmon caught in odd-numbered years, the other for even years. Salmon caught in odd years are consistently heavier, presuambly because of the two year life cycle of the salmon. From Ricker (1981)

Figure source: Blackwell scientific

Stabilizing selection

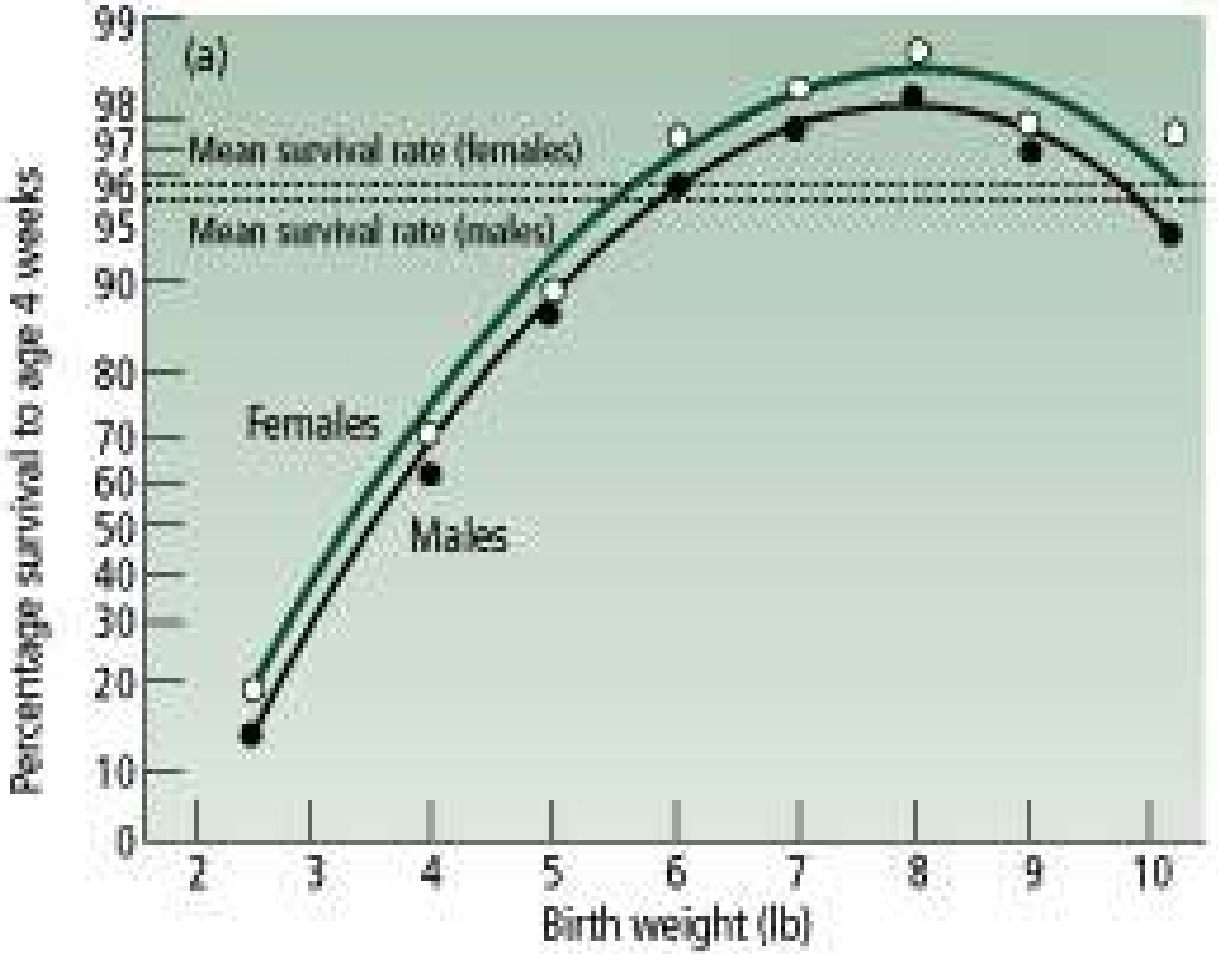
(modified from Freeman & Herron 1998)



The average members of the population may have higher fitness than the extremes.

Adapted from slides by Jana Vamosi

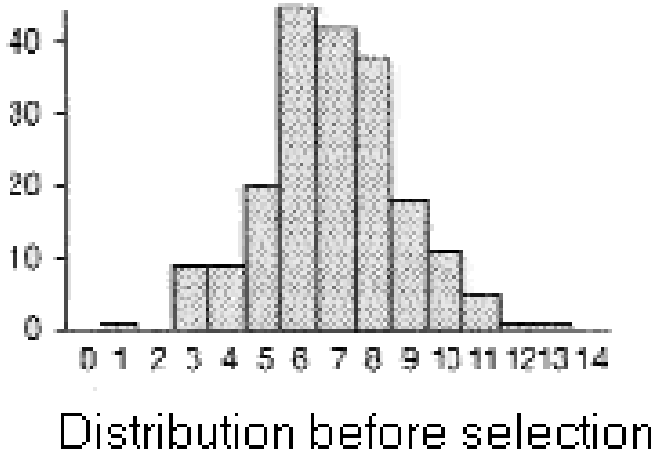
Stabilizing Selection



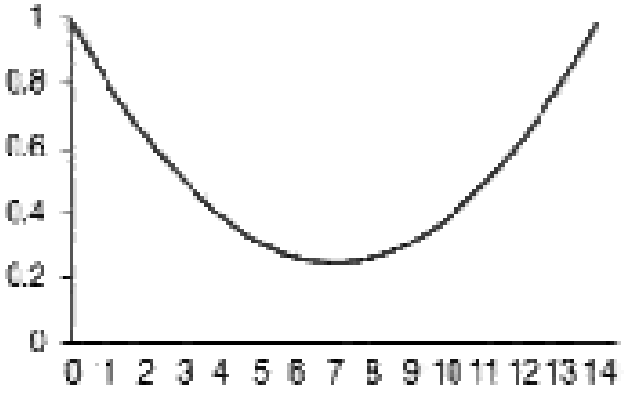
In humans, babies of intermediate birth weight have higher chance of survival

Figure source: Blackwell scientific

Disruptive selection

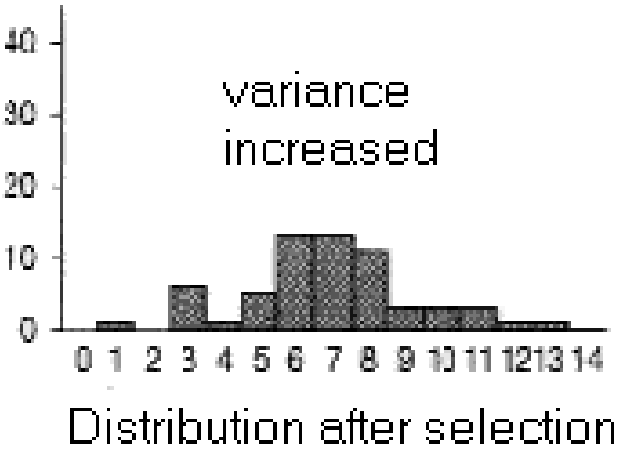


Distribution before selection



Fitness Function

(modified from Freeman & Herron 1998)

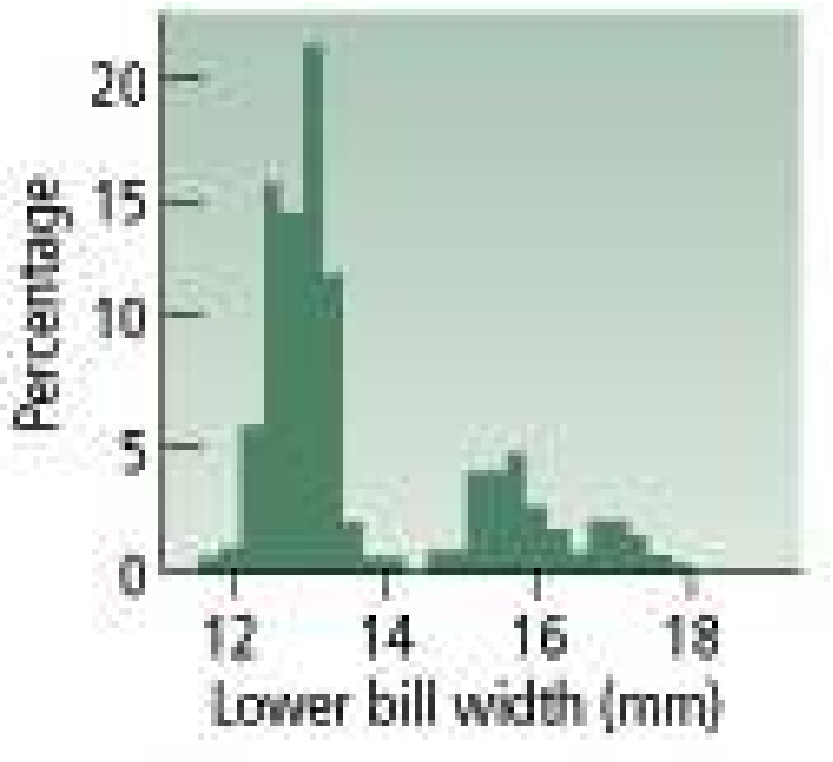


Distribution after selection

Natural selection could favour both extremes over the intermediate types

Adapted from slides by Jana Vamosi

Disruptive Selection



In the seedcracking finch, *Pyrenestes ostrinus*, beak size is bimodally distributed. Very large and very small bills are beneficial for eating large and small
seeds, respectively. But overall body size is normally distributed

Figure source: Blackwell scientific

Directional selection – change in population mean

Stabilizing selection – reduced variation, no change in mean

Disruptive selection – increased variance, no change in mean

In nature, selection can be a combination of two or more types of selection

Viability/Survival selection

Fecundity/Fertility selection

Traits can evolve even without natural selection through chance events. This is called *Genetic Drift* (or Random Genetic Drift)

Genetic drift - "**a change in the gene pool of a population due to chance**"

- In practice, not easy to know whether a trait has evolved due to natural selection or drift

Example of genetic drift in a small population – '*founder effect*'

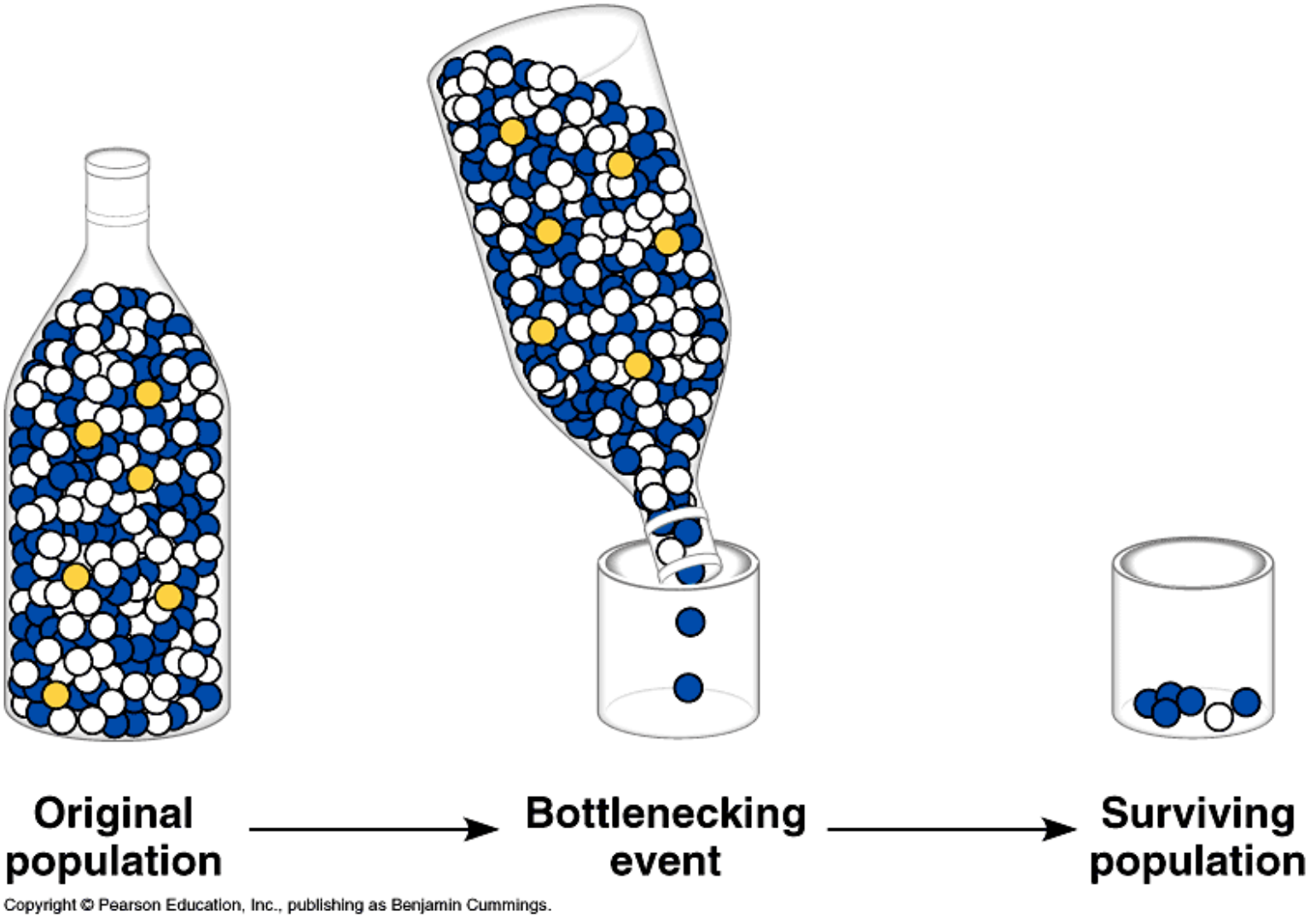


Fig source: Pearson Education Inc

Allele frequencies change following forest fire. Drift or selection?