CH 13: How populations evolve

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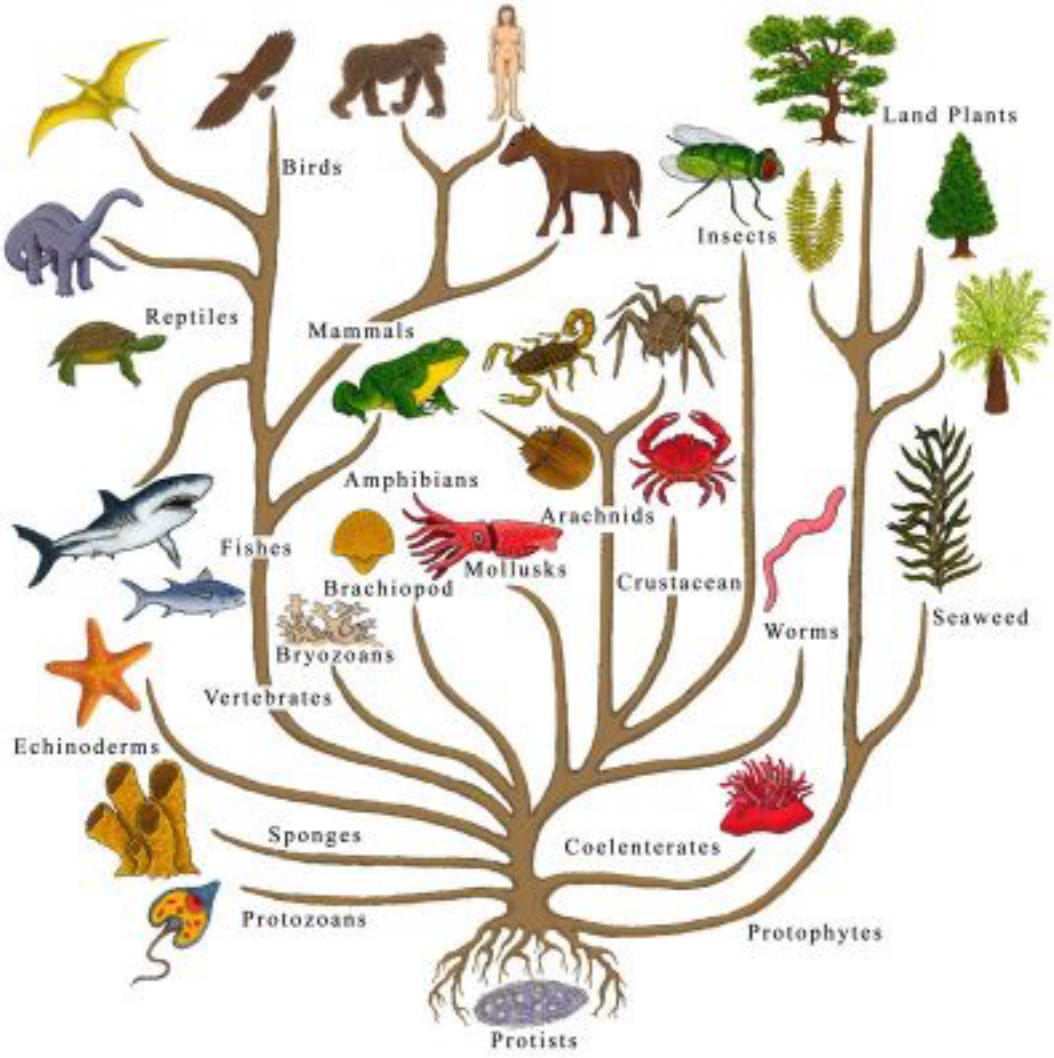
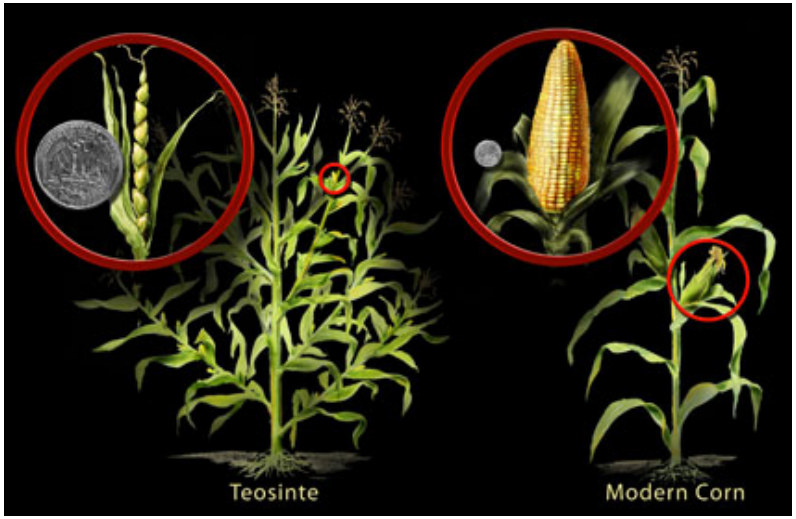
Macro-evolution



http://www.hyperkreeytiv.com/wp-content/uploads/2015/07/normal_tree_of_life.jpg

Micro-evolution

- Between sister species
- Within species or population
- Population genetics



http://blog.nationalgeographic.org/wp-content/uploads/2009/03/maize-and-wild-ancestor-comparison.jpg

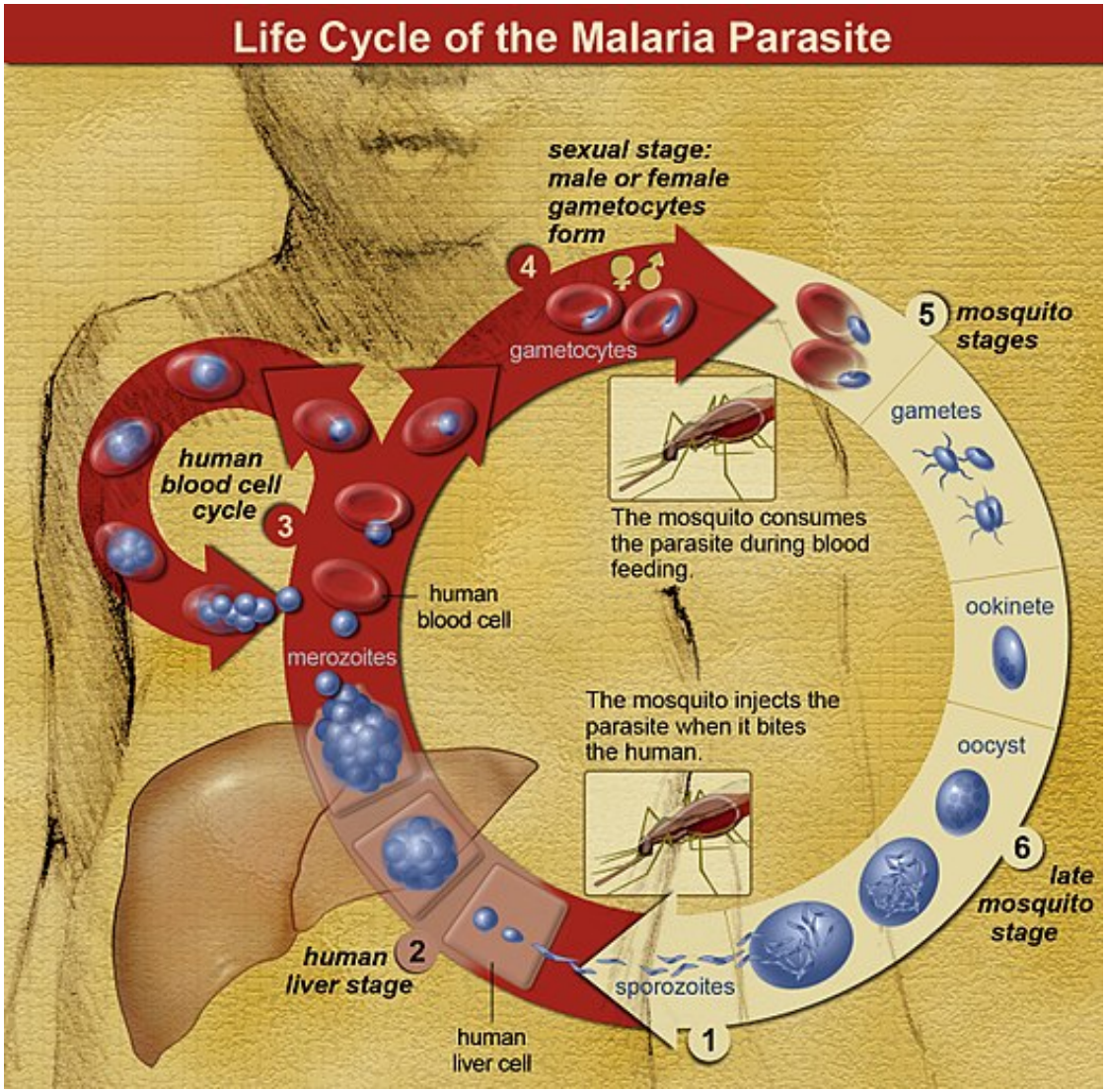
Evolution. 2013. Futuyma

Figure 13.0-1

Malaria: 瘧疾

Figure 13.0-1

Malaria: 瘧疾



Wikipedia

Introduction

- In the 1960s, the World Health Organization (WHO) launched a campaign to eradicate malaria.
- Killing the mosquitoes with pesticide DDT.
- Early success
- Mosquitoes evolved resistance to DDT.
- Today, malaria causes more than a million deaths and 250 million cases of illness each year.

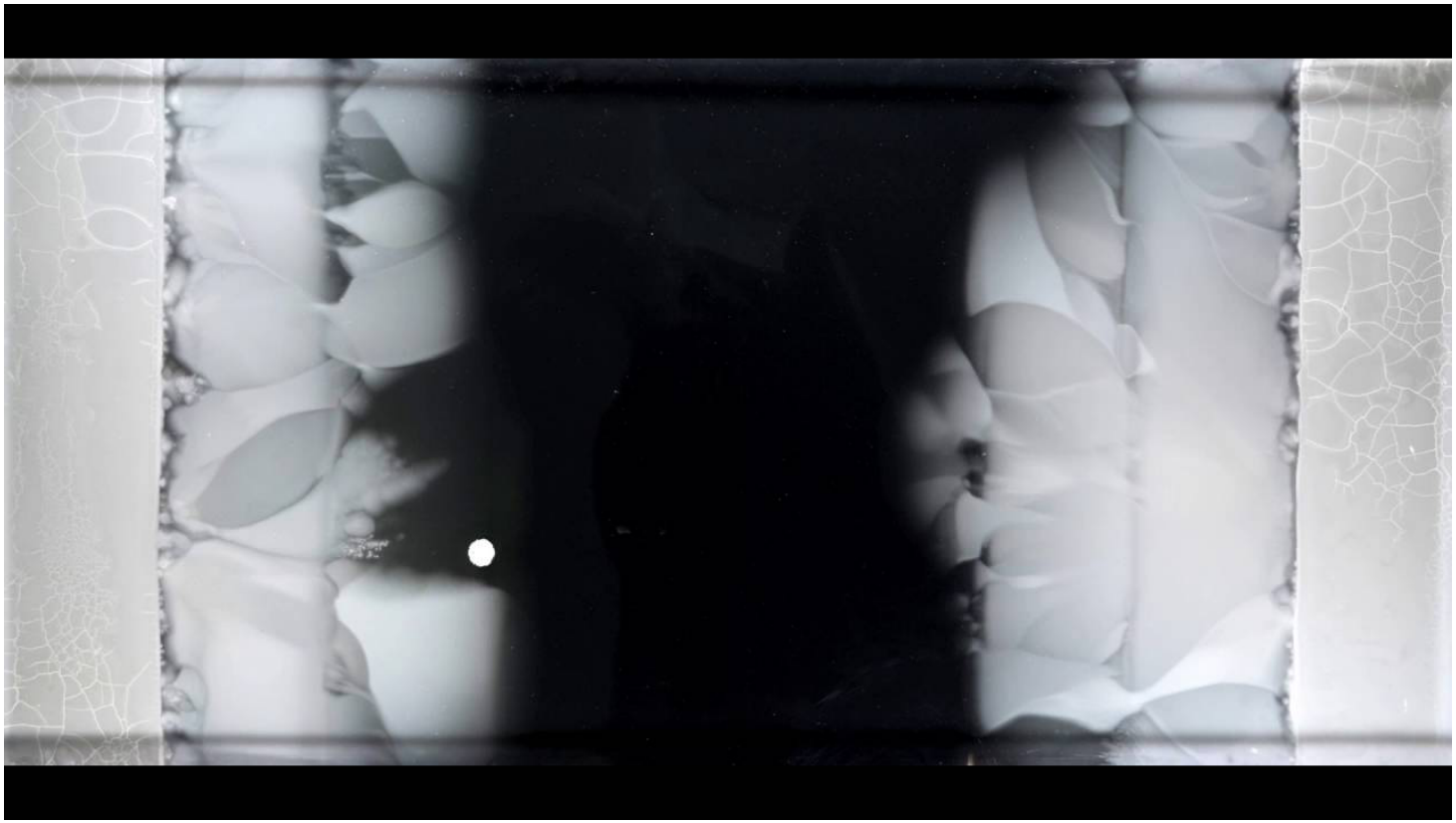
Introduction

- Chloroquine: drug killing parasite
- But drug resistance evolved in the parasite

- Currently, most effective drug: artemisinin
- 青蒿素
- But the parasite will evolve resistance soon

E. coli experiment

https://www.youtube.com/watch?v=plVk4NVIUh8



Behavior

- Can genetic differences determine behavior?
- Can behavior evolve?
- Can behavior respond to selection?

The silver fox experiment

https://www.dailymotion.com/video/xwq3rs

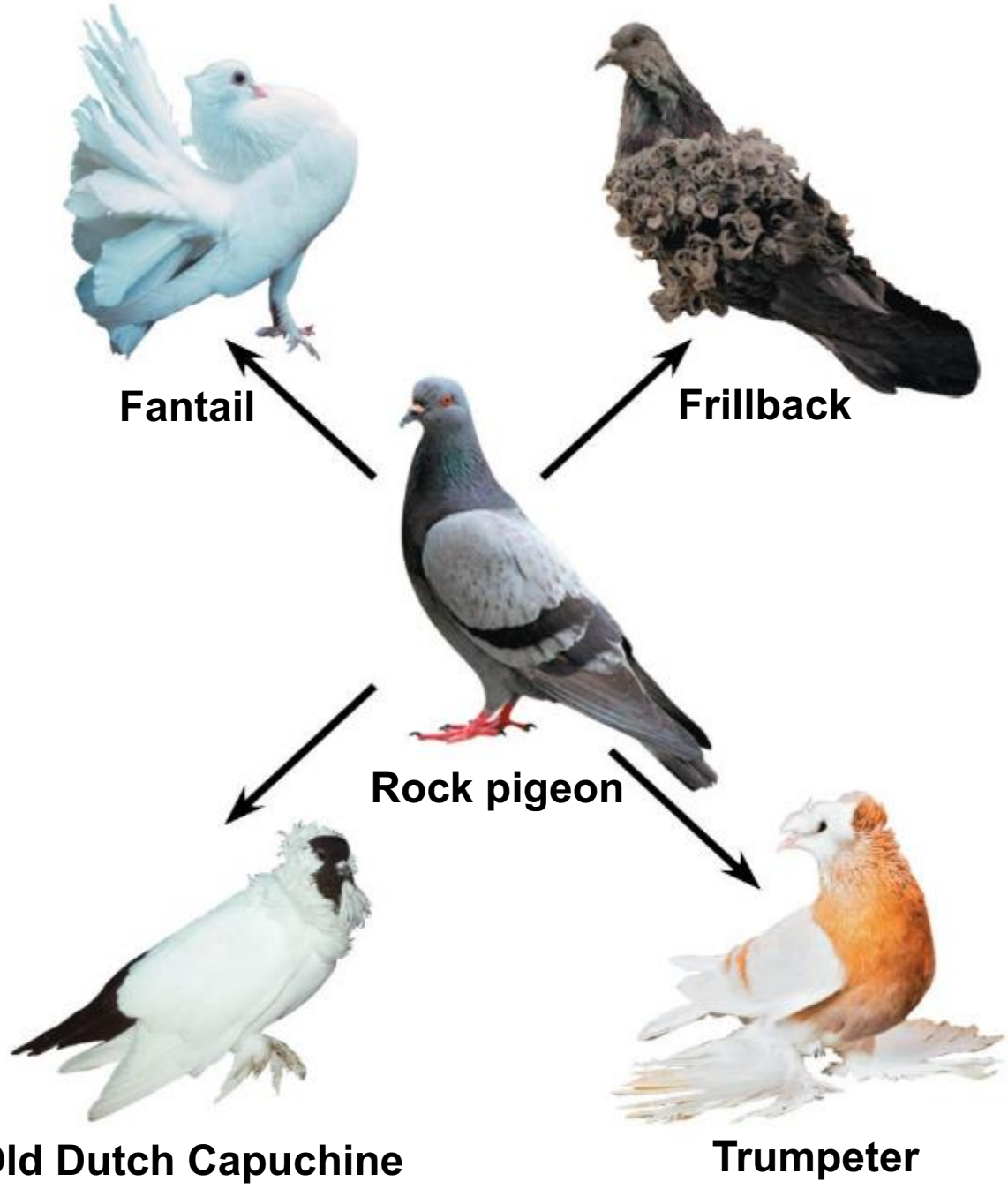
https://www.youtube.com/watch?v=0jFGNQScRNY

- Is this behavioral change genetic?
- Where does the variation come from?
- Is behavior the only trait responding to selection?

The silver fox experiment

- 1959
- First generation: from local fur farms
- Two opposite directions of selection
- Swap babies with mothers: mothers' behavior does not affect the cubs'
- Even transplanted embryos
- Selection on behavior, but morphology also changed
- Selecting for a prolonged juvenile stage?

Figure 13.6-0



Malaria & Silver fox

- To evolve and respond to selection, the phenotypic variation of a trait has to be determined by genetic variation.

- Where does genetic variation come from?
  - Mutation
  - Standing variation

Figure 13.0-2

Chapter 13: Big Ideas

Darwin's Theory of Evolution

The Evolution of Populations

Mechanisms of Microevolution

DARWIN'S THEORY OF EVOLUTION

13.1 A sea voyage helped Darwin frame his theory of evolution

- *On the Origin of Species*
  by Means of Natural Selection

- At that time:
- Most scientists accepted: species are fixed, permanent forms that do not evolve.
- Christian: Earth is ~6,000 years old.
- Genesis 創世紀: each form of life is individually created in its present-day form. Nothing changes.

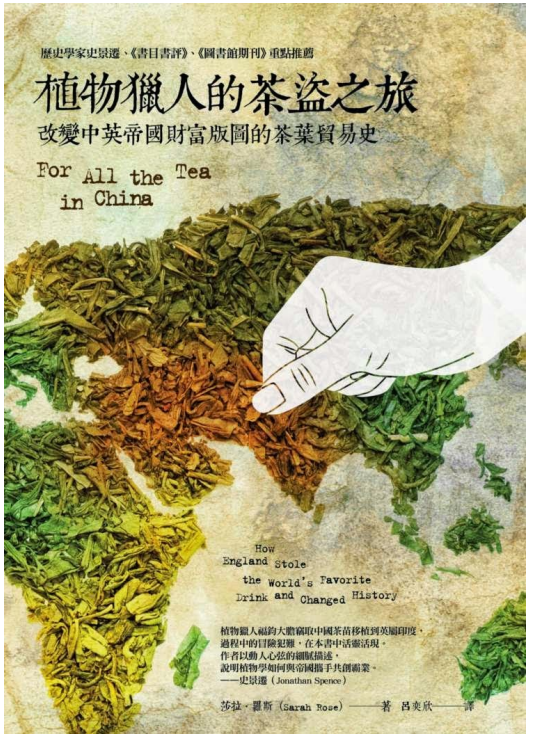
- Christian:
- God made the world, and then nothing changed.

- Evolution:
- Organisms can change through time.

13.1 A sea voyage helped Darwin frame his theory of evolution

- 1831-1836
- At the age of 22, Darwin took a position on HMS *Beagle*
- HMS means what?
  - Her Majesty's Ship
- As the ship's naturalist (field biologist), Darwin
  - spent most of his time on shore collecting thousands of specimens of fossils and living plants and animals and
  - kept detailed journals of his observations.

- At 19th century, UK naturalists collected many plant species around the world
- Mostly for economic and strategic reasons
- East India Company 1600-1874
- Kew garden



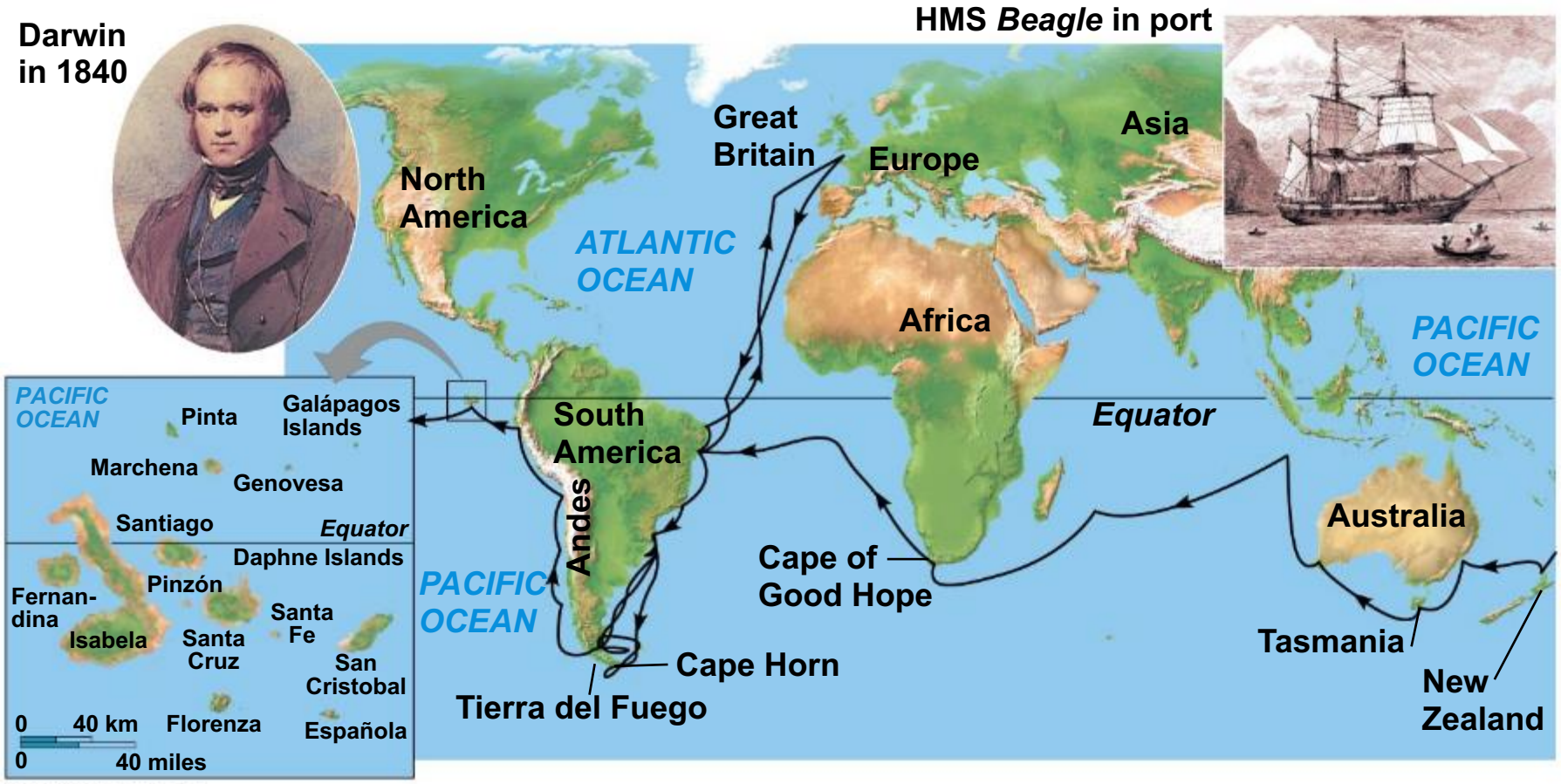
- Tea: Robert Fortune 1848-1851 from China
- Opium Poppy
- Taiwan: Robert Swinhoe

Robert Swinhoe

- 郇和, 史溫侯, 斯文侯, 斯文豪
- “現在台灣記錄的鳥種中，有超過三分之一是郇和首先報導的。” (Wikipedia)
- 英國駐打狗 (高雄) 第一任領事

- 臺灣水鹿 *Rusa unicolor* swinhoei
- 藍腹鷴 *Lophura swinhoii*
- 斯文豪氏攀蜥 *Japalura swinhonis*
- 斯文豪氏游蛇 *Natrix swinhonis*
- 斯文豪氏赤蛙 *Odorrana swinhoana*

Figure 13.1a-0



13.1 A sea voyage helped Darwin frame his theory of evolution

- Darwin was particularly intrigued by the geographic distribution of organisms on the Galápagos Islands, including
  - marine iguanas and
  - giant tortoises.

13.1 A sea voyage helped Darwin frame his theory of evolution

- Christian: Earth is about 6,000 years old

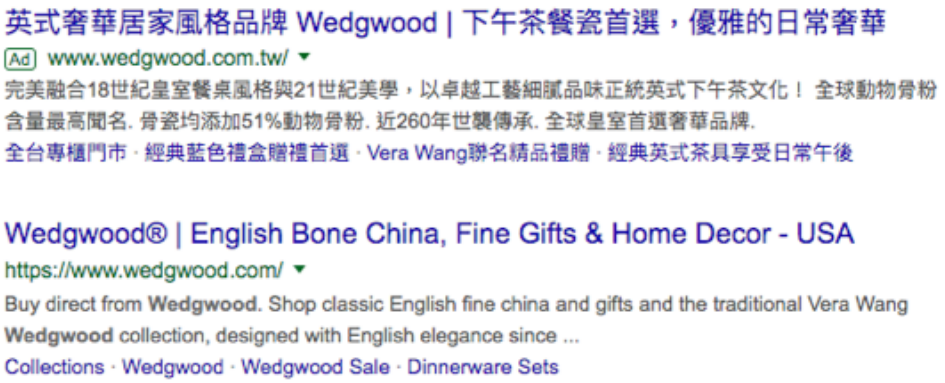
- *Principles of Geology*
  by Scottish geologist Charles Lyell.
  - The book presented the case for an ancient Earth sculpted over millions of years by gradual geologic processes that continue today.

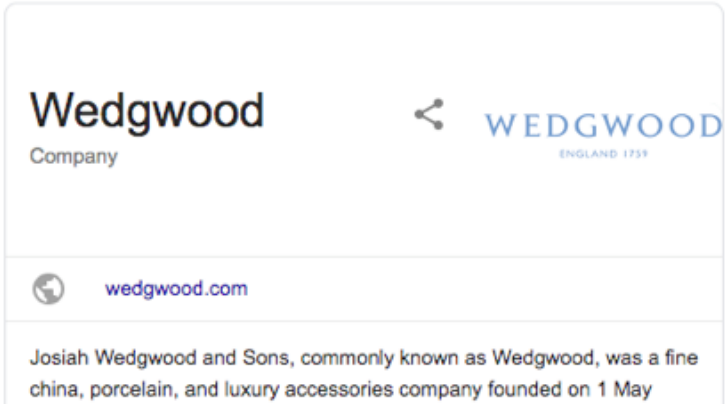
13.1 A sea voyage helped Darwin frame his theory of evolution

- His idea:
- Descendants of a remote ancestor spread into various habitats
- Over millions and millions of years
- They accumulated diverse modifications, that fit them to specific ways of life in their environment (**adaptation**).

Based on Wikipedia

- 祖父伊拉斯謨·達爾文是英國醫學界權威
- 父親羅伯特·達爾文是當地小有名氣的醫生
- 外祖父喬賽亞·韋奇伍德是工業革命時代美術瓷器的創始者 (Wedgwood)





13.1 A sea voyage helped Darwin frame his theory of evolution

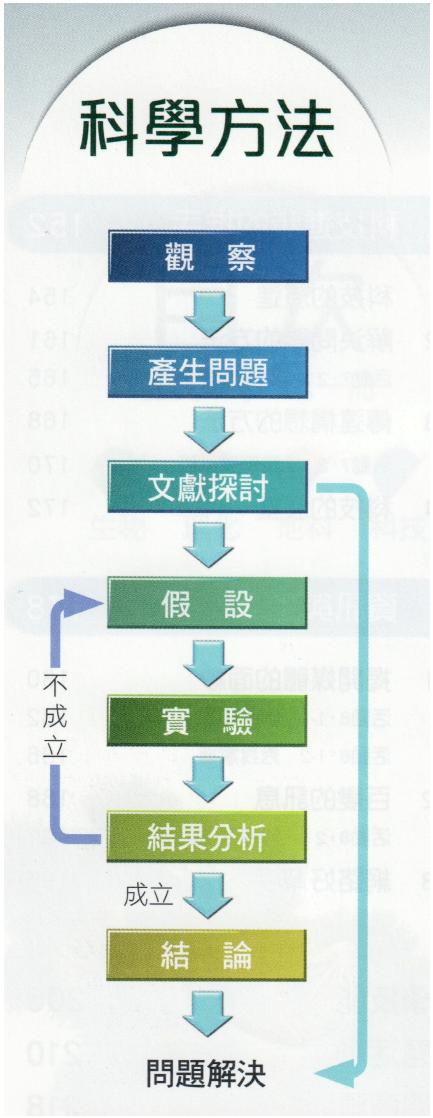
- Voyage of the Beagle: 1831-1836
- By the early 1840s, Darwin had a draft
- Keep compiling evidences
- Published it in 1859

https://www.visitlondon.com/things-to-do/place/147133-english-heritage-down-house-home-of-charles-darwin

https://www.nature.com/articles/548389a

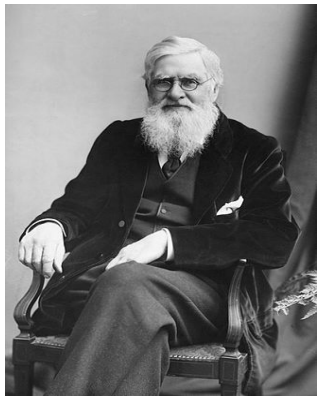
13.1 A sea voyage helped Darwin frame his theory of evolution

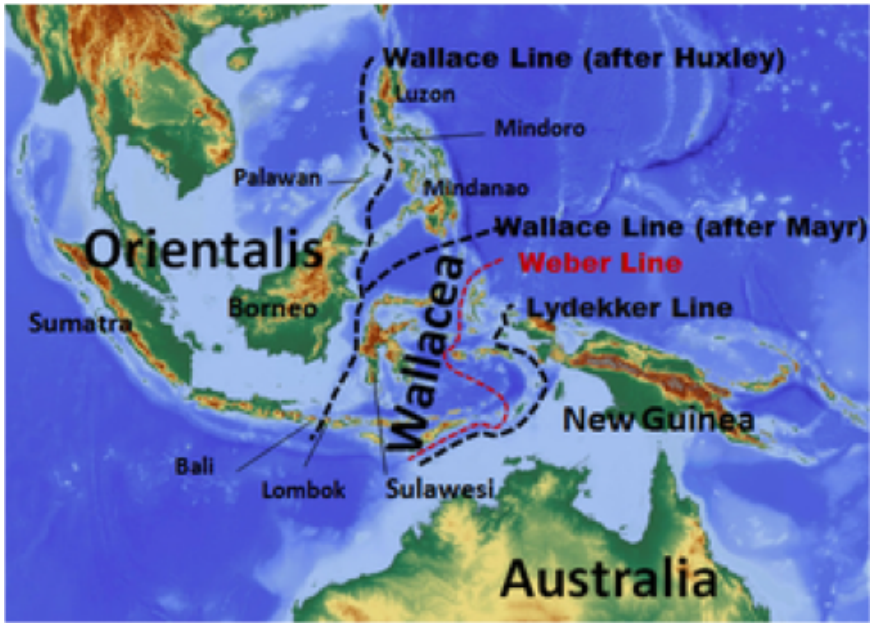
- Voyage of the Beagle: 1831-1836
- By the early 1840s, Darwin had a draft
- Keep compiling evidences
  - To support his “hypothesis”
- Published it in 1859



13.1 A sea voyage helped Darwin frame his theory of evolution

- Why did he finally decide to publish it?
- Alfred Wallace
- “Wallace line”





Wiki

13.2 The study of fossils provides strong evidence for evolution

- The sequence in which fossils appear within **strata (地層)**, layers of sedimentary rocks, is a historical record of life on Earth.

13.4 Homologies provide strong evidence for evolution

- Evolution is a process of descent with modification.
  - Characteristics present in an ancestral organism are altered over time by natural selection (?) as its descendants face different environmental conditions.
  - Related species can have characteristics that have an underlying similarity yet function differently.
  - Similarity resulting from common ancestry is known as **homology (同源)**.

Figure 13.3b

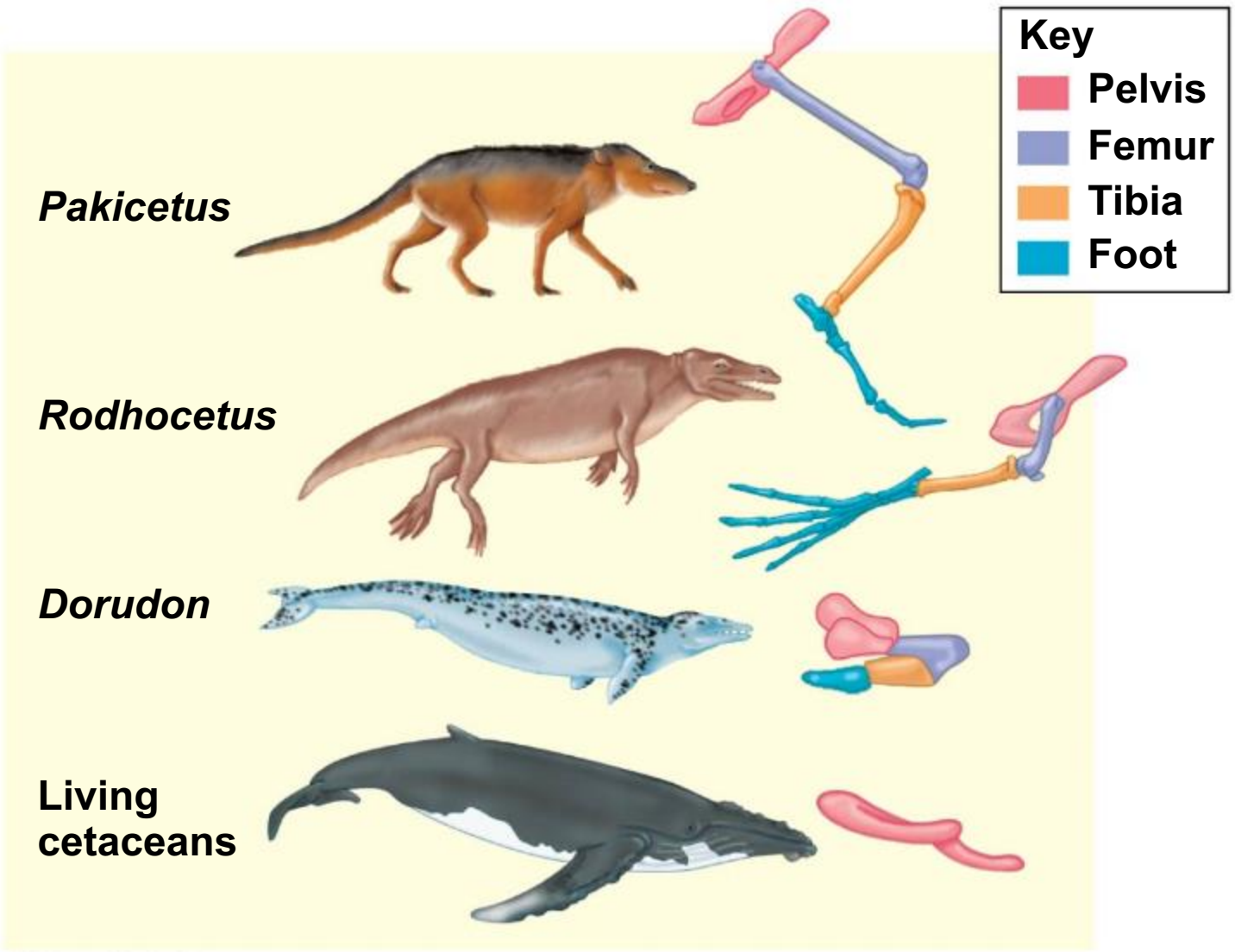
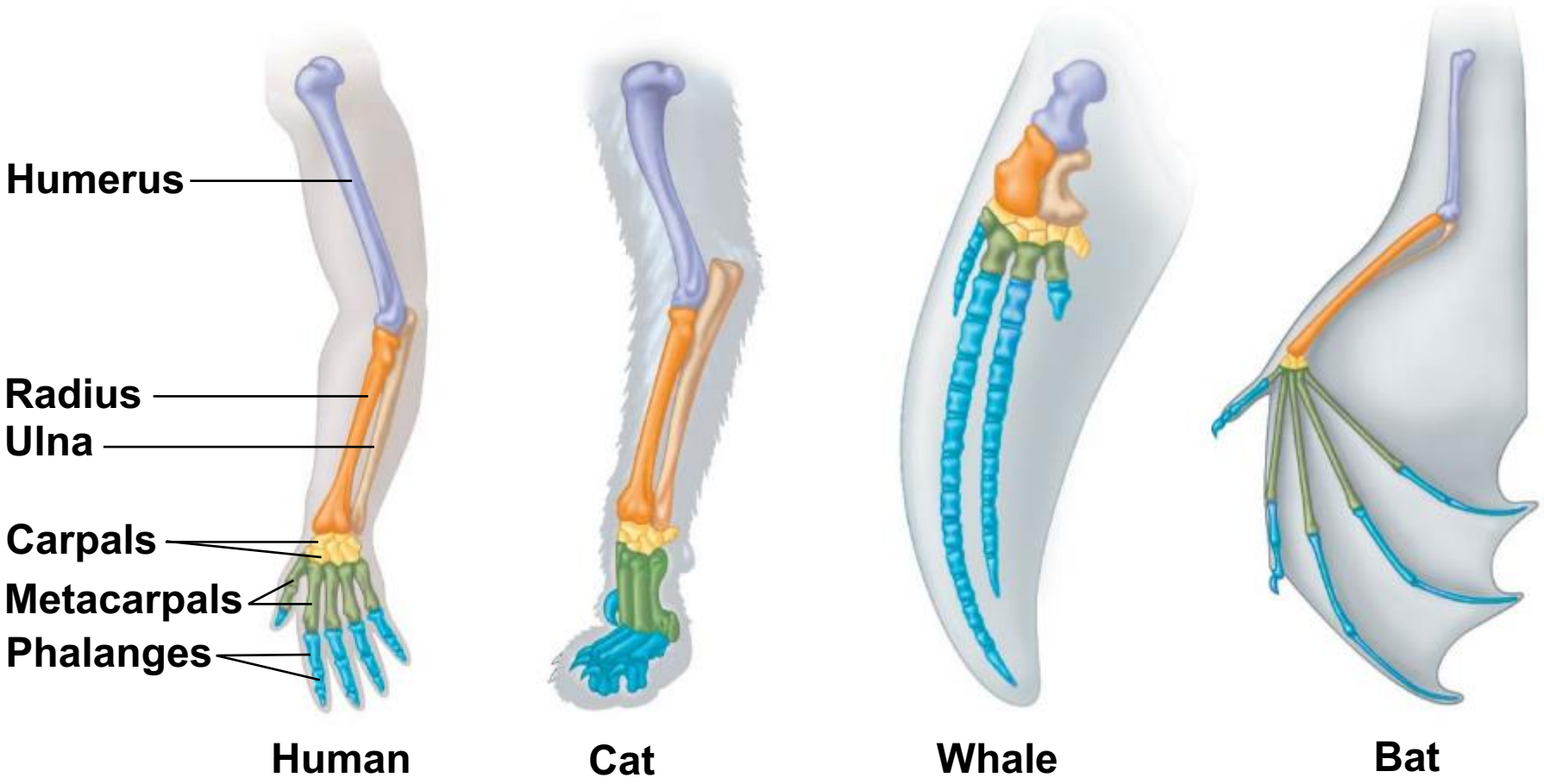


Figure 13.4a



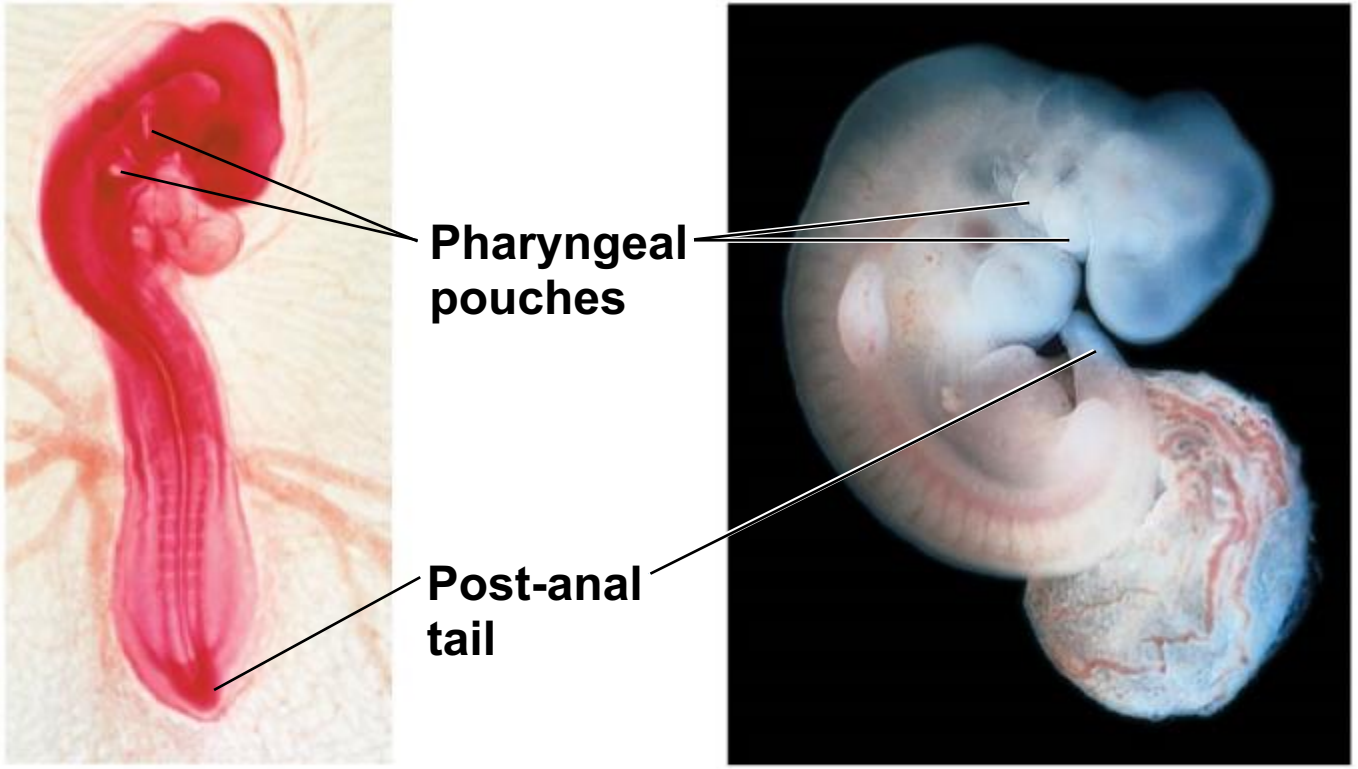
13.4 Homologies provide strong evidence for evolution

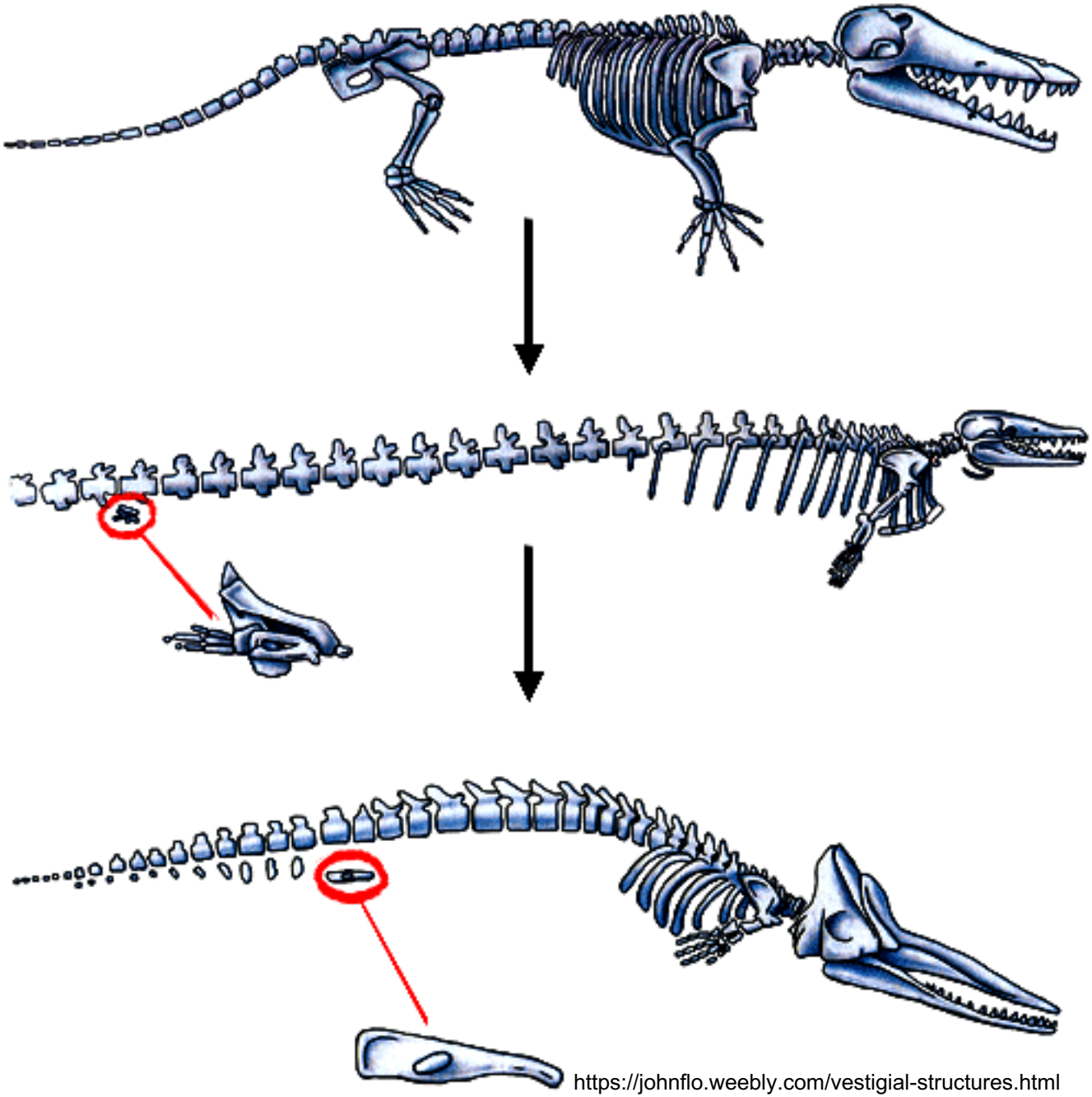
- Darwin's boldest hypothesis was that all life-forms are related. Molecular biology provides strong evidence for this claim.
  - All forms of life use the same genetic language of DNA and RNA.
  - The genetic code—how RNA triplets are translated into amino acids—is essentially universal.

13.4 Homologies provide strong evidence for evolution

- Some of the most interesting homologies are “leftover” structures that are of marginal or perhaps no importance to the organism.
- These **vestigial structures (痕跡構造?)** are remnants of features that served important functions in the organism’s ancestors.

Figure 13.4b-0





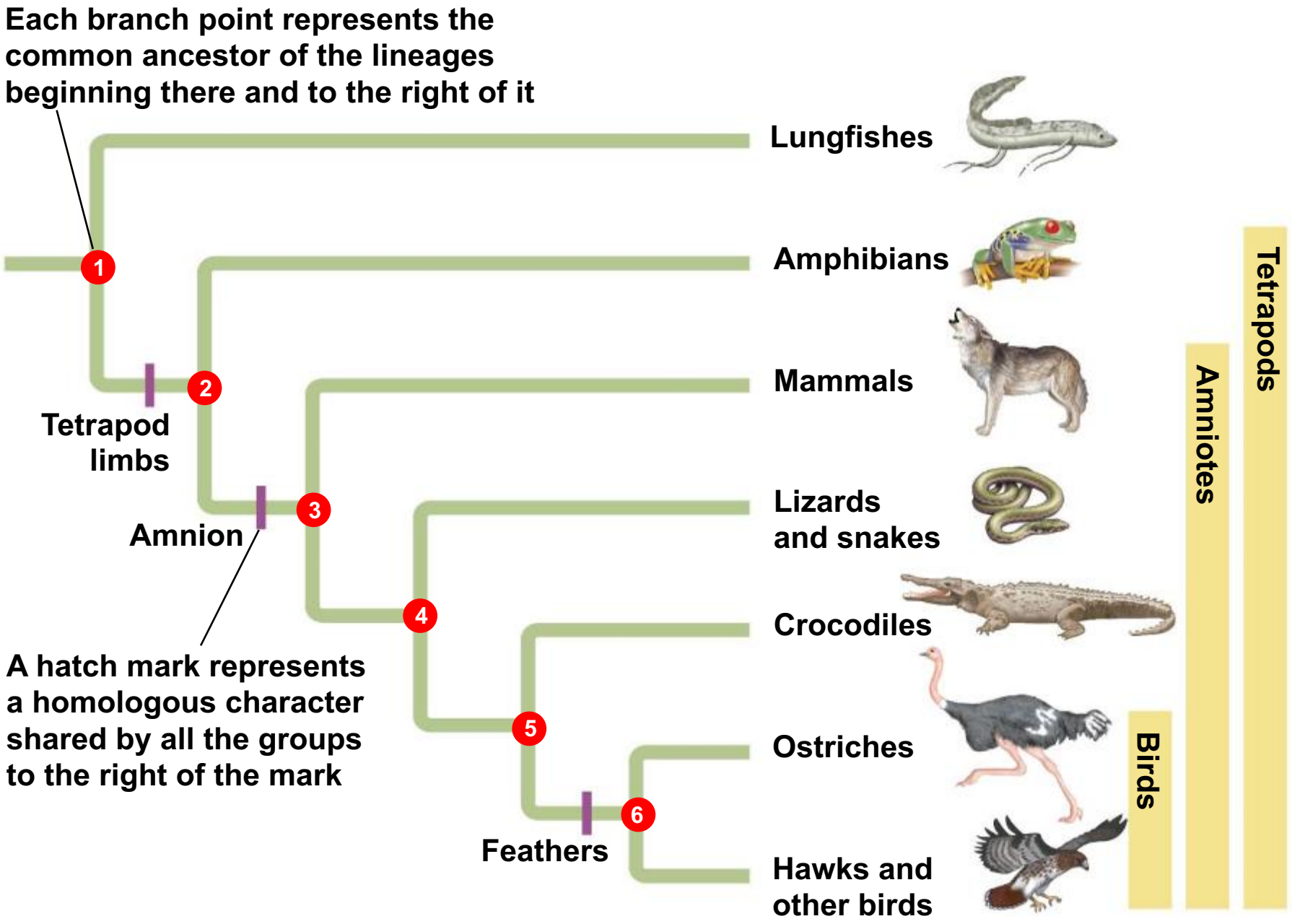
https://johnflo.weebly.com/vestigial-structures.html

13.5 Homologies indicate patterns of descent that can be shown on an evolutionary tree

- Evolutionary tree

- Homologous structures can be used to determine the branching sequence of an evolutionary tree.
- These homologies can include
  - anatomical structure and/or
  - molecular structure.

Figure 13.5



創造論者: 一切都是達爾文和你們在腦補.
Where is evidence?

- Homology & vestigial organs?
- Do you have proof that a normal leg can shrink, as in whales?

- Evolution is a science, which needs evidences and experimental proof.
- What is the critical evidence?
- Can we SEE species change their appearance?

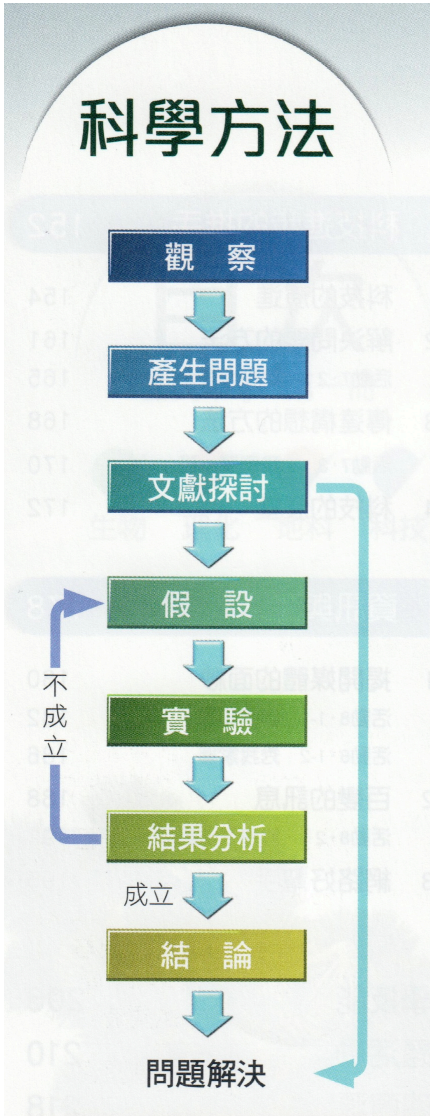
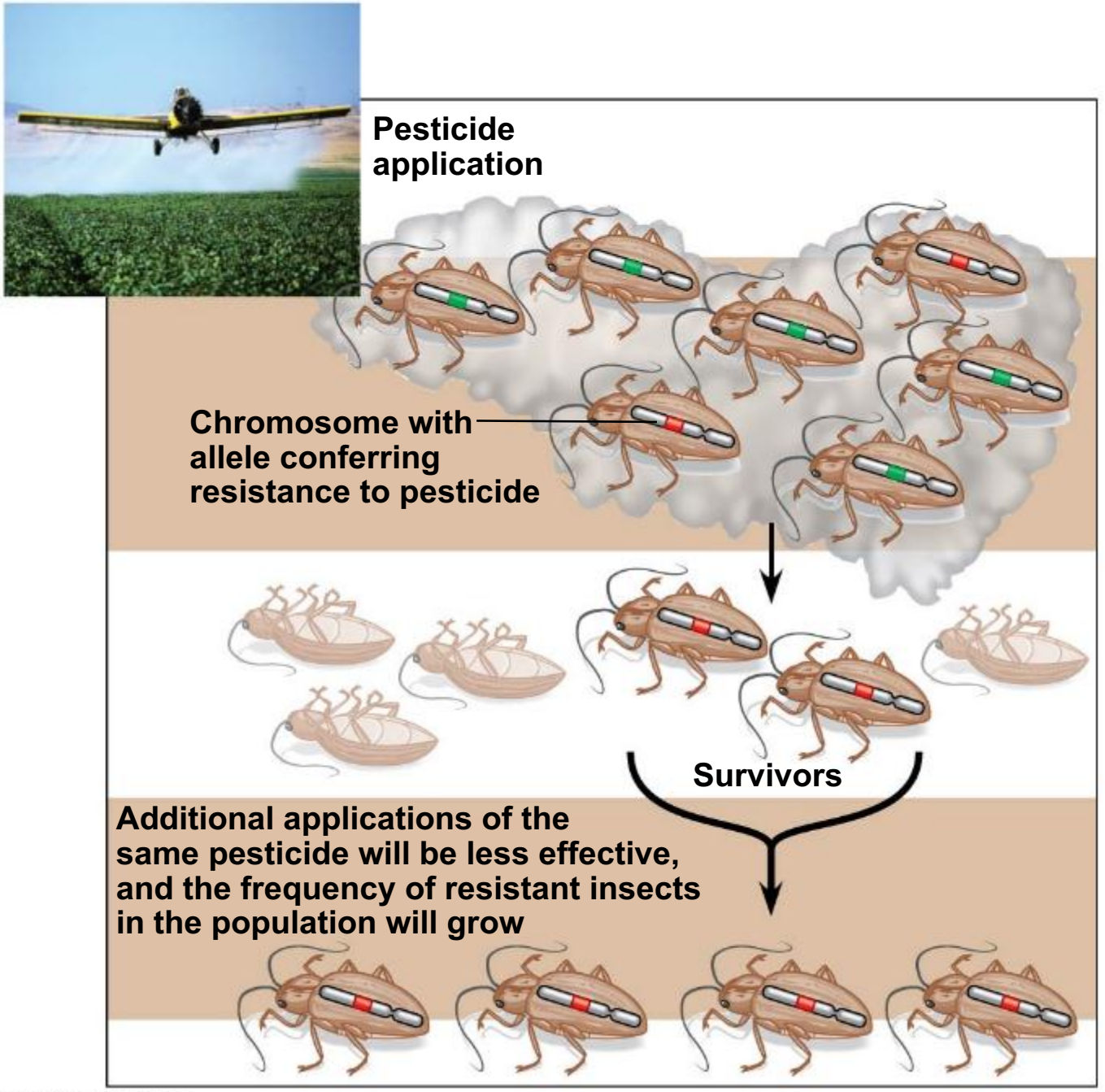
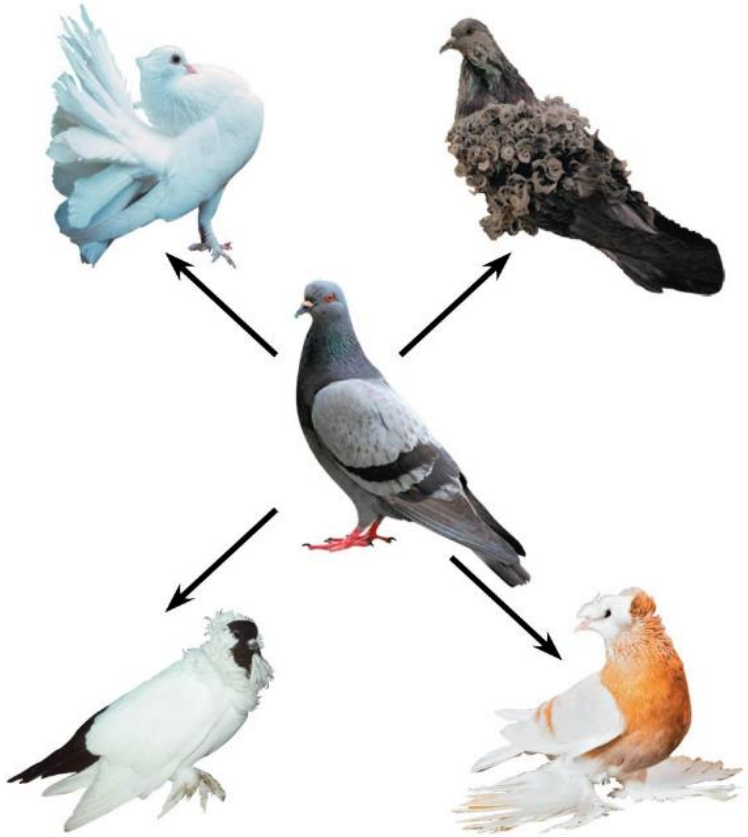


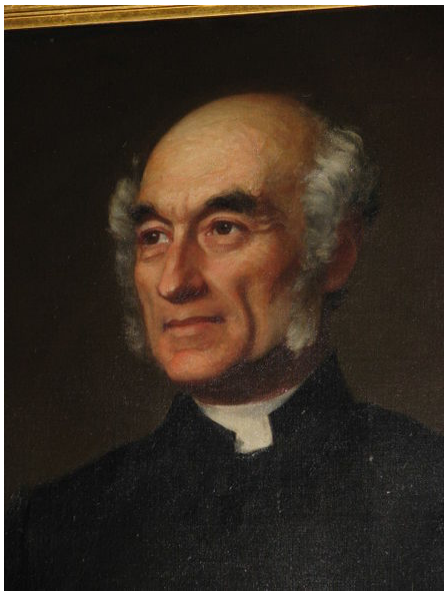
Figure 13.7-0



創造論者: 一切都是達爾文和你們在腦補.
Where is evidence?

- Best evidence at that time? domestication





Wiki

Joel McGlothlin on Twitter:

"If you ever get frustrated by peer review, remember Whitwell Elwrin, who upon reviewing the first 3 chapters of Darwin's Origin, said that it should focus more on pigeons, because "every body is interested in pigeons.""

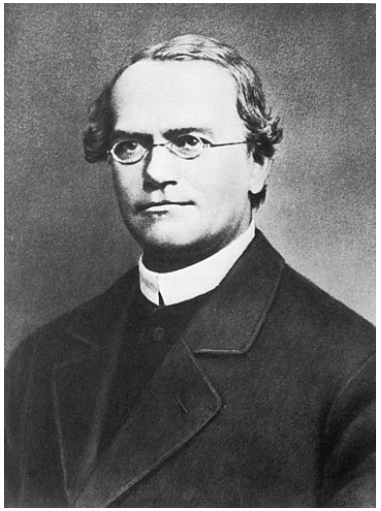
Was he wrong?

創造論者: 一切都是達爾文和你們在腦補.
Where is evidence?

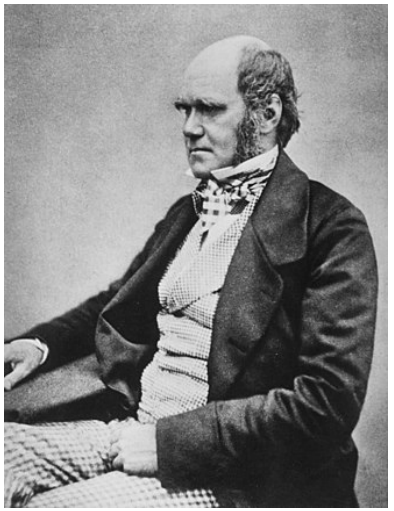
- Evolutionary genetics
- Using molecular genetics to investigate mechanisms and causes of evolution

https://www.youtube.com/watch?v=Pv4Ca-f4W9Q

THE EVOLUTION OF POPULATIONS



Population genetics



- 1859: “On the origin of species” by Charles Darwin
- 1866: Gregor Mendel published his work
- 1900: Re-discovery of Mendel’s work

- “Evolution is an outdated research field because Darwin does not understand genetics.”
- Is this statement correct?

Four major elements of evolution

- **Mutation** creates genetic variation
- **Selection** filters genetic variation
- **Migration** exchanges genetic variation
- **Drift** randomly changes genetic variation

Evolution. 2013. Futuyma

13.9 Evolution occurs within populations

- A **population** is a group of individuals of the same species, that live in the same area, and interbreed.
- **Microevolution** is
  - change in the relative frequencies of alleles in a population over a number of generations

Figure 13.10b

Hardy-Weinberg Equilibrium

Phenotypes			
Genotypes	***WW***	***Ww***	***ww***
Number of animals (total = 500)	**320**	**160**	**20**
Genotype frequencies	$\frac{320}{500} = 0.64$	$\frac{160}{500} = 0.32$	$\frac{20}{500} = 0.04$
Number of alleles in gene pool (total = 1,000)	**640 *W***	**160 *W* + 160 *w***	**40 *w***
Allele frequencies	$\frac{800}{1{,}000} = 0.8\ W$		$\frac{200}{1{,}000} = 0.2\ w$

Why do we calculate this?

Figure 13.10c

Gametes reflect allele frequencies of parental gene pool

Eggs \ Sperm	*W* $p = 0.8$	*w* $q = 0.2$
W $p = 0.8$	*WW* $p^2 = 0.64$ 	*Ww* $pq = 0.16$ 
w $q = 0.2$	*wW* $qp = 0.16$ 	*ww* $q^2 = 0.04$ 

Genotype & allele frequency vs. previous generation?

Next generation:

Genotype frequencies	0.64 *WW*	0.32 *Ww*	0.04 *ww*
Allele frequencies	0.8 *W*	0.2 *w*	

13.10 The Hardy-Weinberg equation can test whether a population is evolving

- Even if the original population is not in Hardy-Weinberg equilibrium (HWE), we only need one generation of random mating to get HWE
- If a population is in HWE, allele and genotype frequencies will remain constant, generation after generation = no evolution
- Something other than the reshuffling processes of sexual reproduction is required to change allele frequencies in a population.

13.10 The Hardy-Weinberg equation can test whether a population is evolving

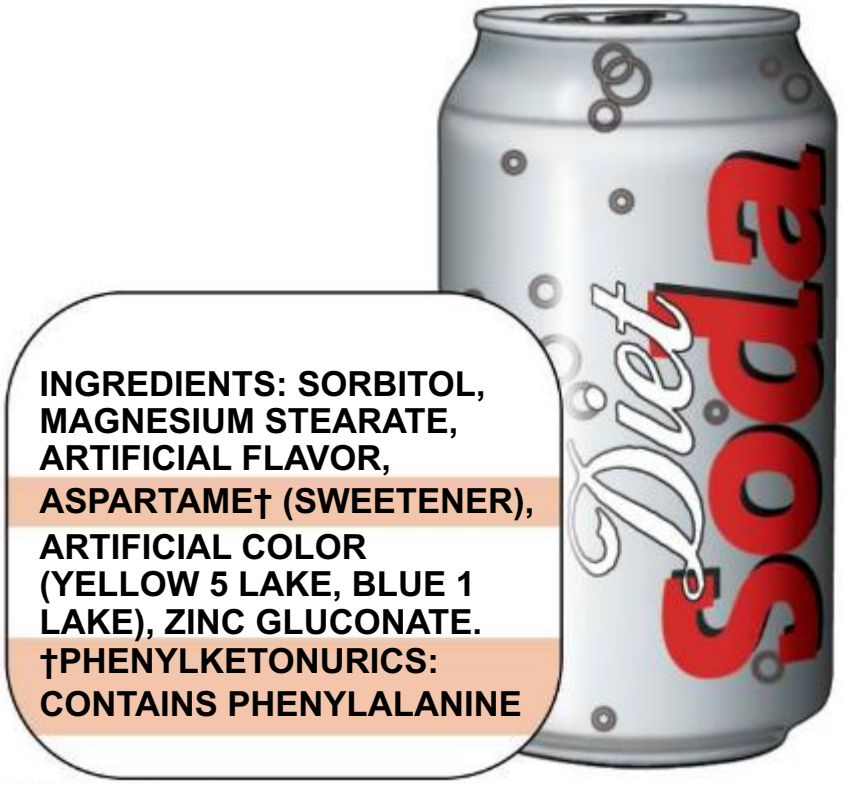
- For a population to be in Hardy-Weinberg equilibrium, it must satisfy five main conditions. There must be
  1. a very large population,
  2. no gene flow between populations,
  3. no mutations,
  4. random mating, and
  5. no natural selection.

The major elements of evolution discuss these forces.

13.11 CONNECTION: The Hardy-Weinberg equation is useful in public health science

- Public health scientists use the Hardy-Weinberg equation to estimate how many people carry alleles for certain inherited diseases.
- One out of 10,000 babies born in the United States has phenylketonuria (PKU), an inherited inability to break down the amino acid phenylalanine.
- The health problems associated with PKU can be prevented by strict adherence to a diet that limits the intake of phenylalanine.

Figure 13.11



13.11 CONNECTION: The Hardy-Weinberg equation is useful in public health science

- PKU is a recessive allele.
- The frequency of the recessive allele for PKU in the population, *q*, equals the square root of 0.0001, or 0.01.
  - The frequency of the dominant allele would equal 1 – *q*, or 0.99.
  - The frequency of carriers = $2pq$ = 2 x 0.99 x 0.01 = 0.0198 = 1.98% of the U.S. population.
  - Thus, the equation tells us that about 2% (actually 1.98%) of the U.S. population are carriers of the PKU allele.

Mechanisms of Microevolution

Natural selection is not the only force

13.12 Natural selection, genetic drift, and gene flow can cause microevolution

Genetic drift

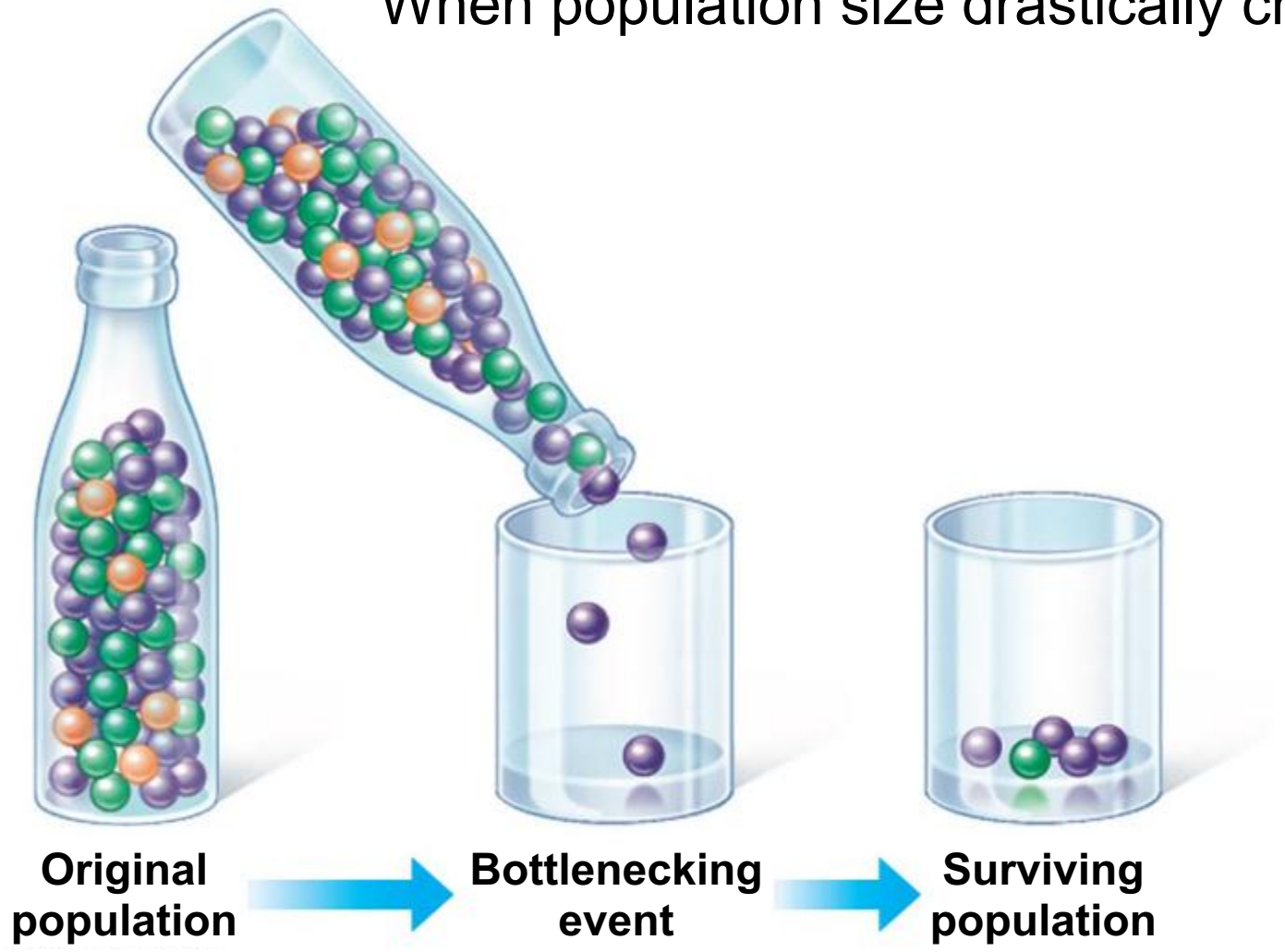
- Chance events can cause allele frequencies to fluctuate unpredictably
- The smaller the population, the more impact genetic drift is likely to have.

https://evolution.berkeley.edu/evolibrary/article/evo_24

Figure 13.12a-3

The bottleneck effect

When population size drastically changed



13.12 Natural selection, genetic drift, and gene flow can cause microevolution

- Genetic drift is also likely when a few individuals colonize an island or other new habitat, producing what is called the **founder effect**.
- By chance, the originally rare & bad allele may greatly increase its frequency
- The founder effect explains the relatively high frequency of certain inherited disorders among some human populations established by small numbers of colonists.

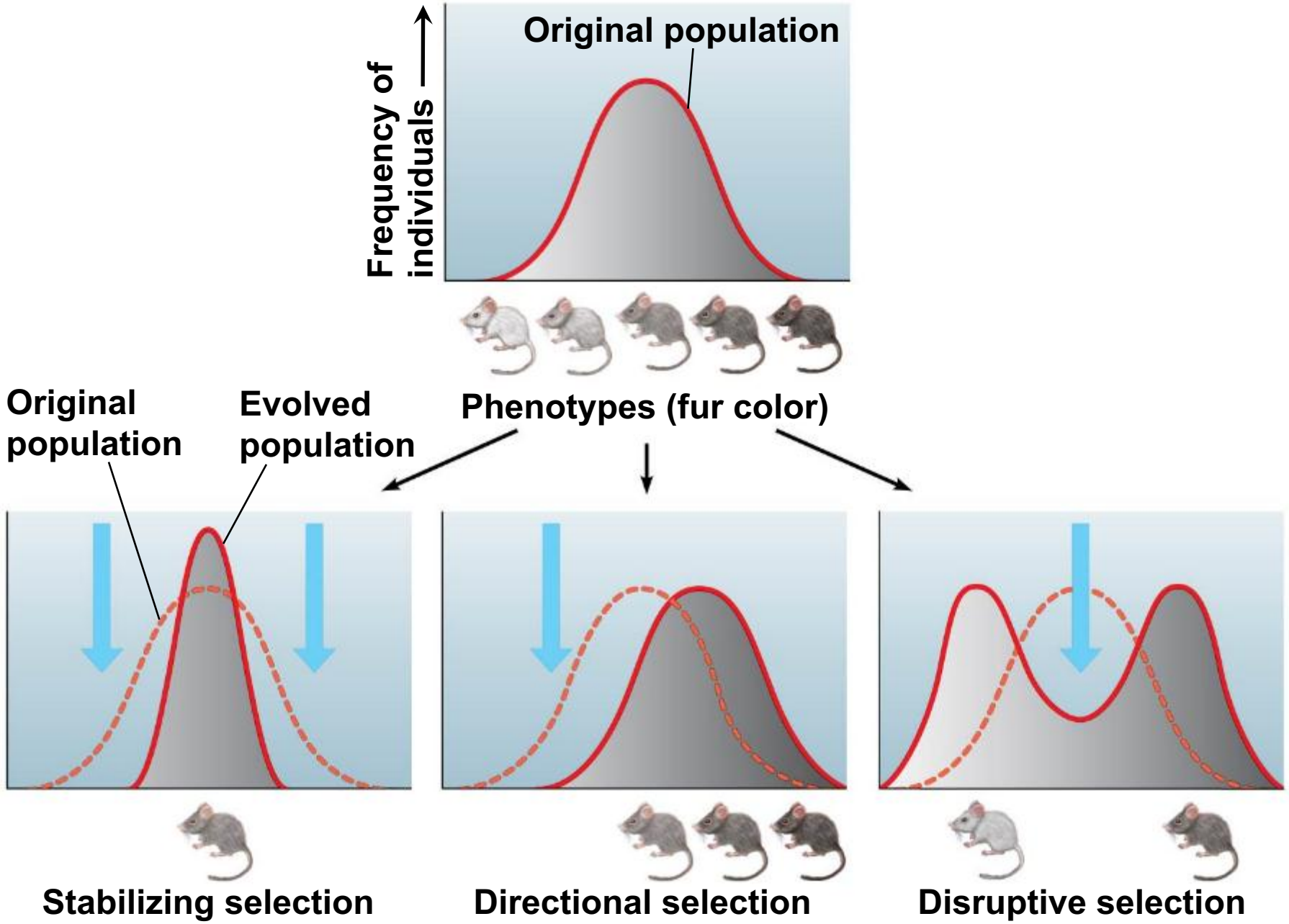
“Pure blood”

https://www.peta.org/wp-content/uploads/2015/02/German-Shepherd-Dog.png

13.14 Natural selection can alter variation in a population in three ways

- Natural selection can affect the distribution of phenotypes in a population.
  - **Stabilizing selection** favors intermediate phenotypes.
  - **Directional selection** shifts the overall makeup of the population by acting against individuals at *one* of the phenotypic extremes.
  - **Disruptive selection** typically occurs when environmental conditions vary in a way that favors individuals at *both* ends of a phenotypic range over individuals with intermediate phenotypes.

Figure 13.14



13.15 Sexual selection may lead to phenotypic differences between males and females

- **Sexual selection** is a form of natural selection in which individuals with certain characteristics are more likely than other individuals to obtain mates.
- In many animal species, males and females may have secondary sexual characteristics, noticeable differences not directly associated with reproduction or survival, called **sexual dimorphism**.

Figure 13.15a

Figure 13.15b

13.15 Sexual selection may lead to phenotypic differences between males and females

- The advantage to females of being choosy?
- One hypothesis is that females prefer male traits that are correlated with "good genes."
  - In several bird species, research has shown that traits preferred by females, such as bright beaks or long tails, are related to overall male health.
  - The "good genes" hypothesis was also tested in gray tree frogs. Female frogs prefer to mate with males that give long mating calls.

Figure 13.15c

13.15 Sexual selection may lead to phenotypic differences between males and females

- Peacock spider
- https://www.youtube.com/watch?v=d_yYC5r8xMI

- Are those traits beneficial to the survival of an individual? Are they beneficial to the population?
- Why do they spread to the whole species?
- The antagonistic effect among different forces
  - Reproductive benefit vs. survival

13.17 Diploidy and balancing selection preserve genetic variation

- Directional selection selects for the good allele
- Why do we still see variation?
- Drift & migration

- Other forms of selection maintaining variation
- **Balancing selection** occurs when natural selection maintains stable frequencies of two or more phenotypic forms in a population.

13.17 Diploidy and balancing selection preserve genetic variation

- **Heterozygote advantage** : heterozygous individuals have greater reproductive success
- **Negative frequency-dependent selection**: selection that maintains two different phenotypic forms in a population.