Cambridge Assessment International Education

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Chapter 17

Selection & Evolution

Chapter Outline

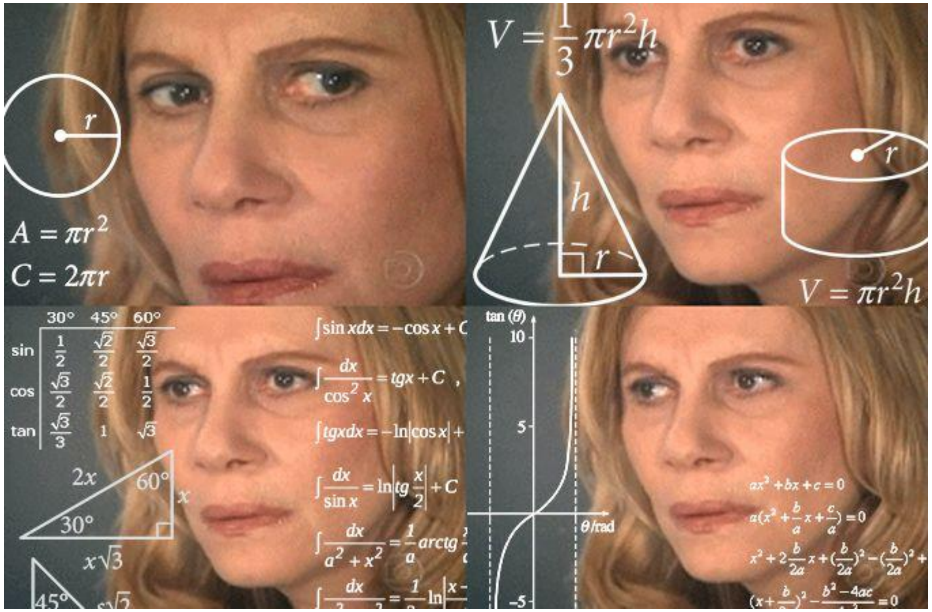
3 Parts

1. Variation
2. Natural Selection
3. Evolution and Speciation

Chapter Outline

Part I: Variation

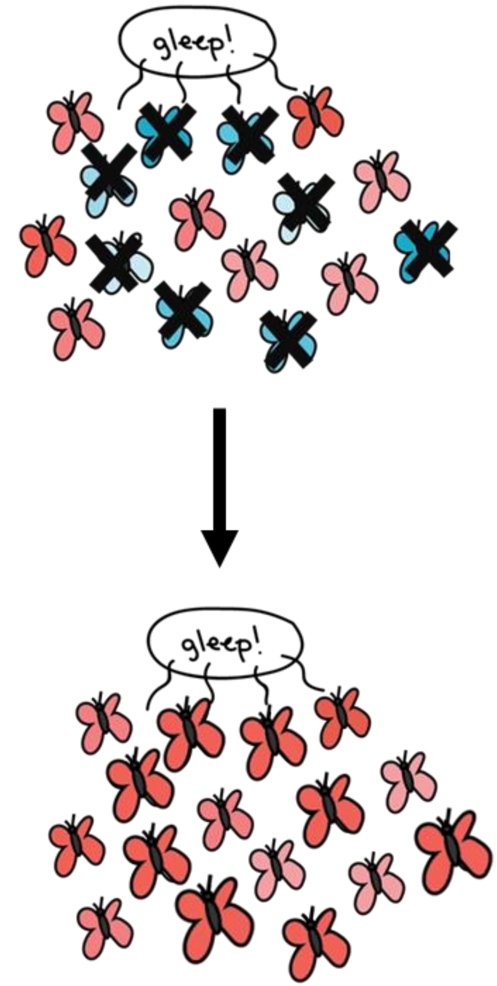
- Phenotype results from interaction of genotype and environment
- Continuous vs Discontinuous Variation
- Examples on how the environment influences phenotype
- **P5:** std dev, std error and error bars, t-test



Chapter Outline

Part II: Natural Selection

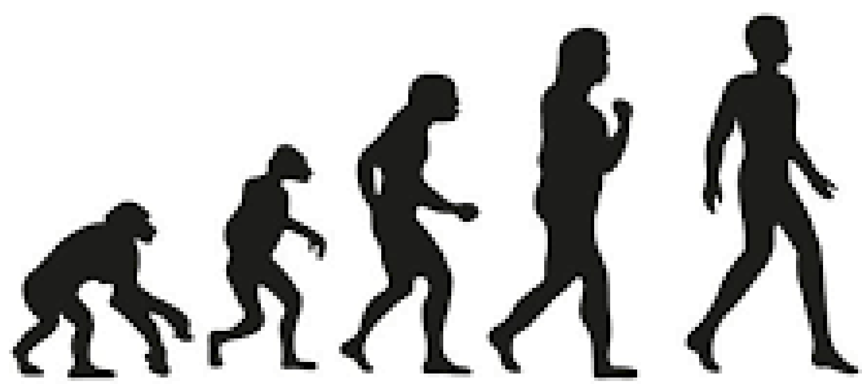
- Importance of genetic variation in selection
- Stabilising, disruptive and directional selection
- Examples for evolution by natural selection
    - Antibiotic resistance in bacteria
    - Industrial melanism in peppered moth
    - Sickle cell anaemia
- The Hardy-Weinberg principle
- Genetic drift and founder effect
- Selective breeding / Artificial selection
    - Milk yield of dairy cattle
    - Disease resistance in varieties of wheat and rice
    - Incorporation of mutant alleles for gibberellin synthesis into dwarf varieties
    - Inbreeding and hybridisation of maize



Chapter Outline

Part III: Evolution and Speciation

- Molecular evidence for evolution
- Allopatric vs sympatric speciation
- Extinction



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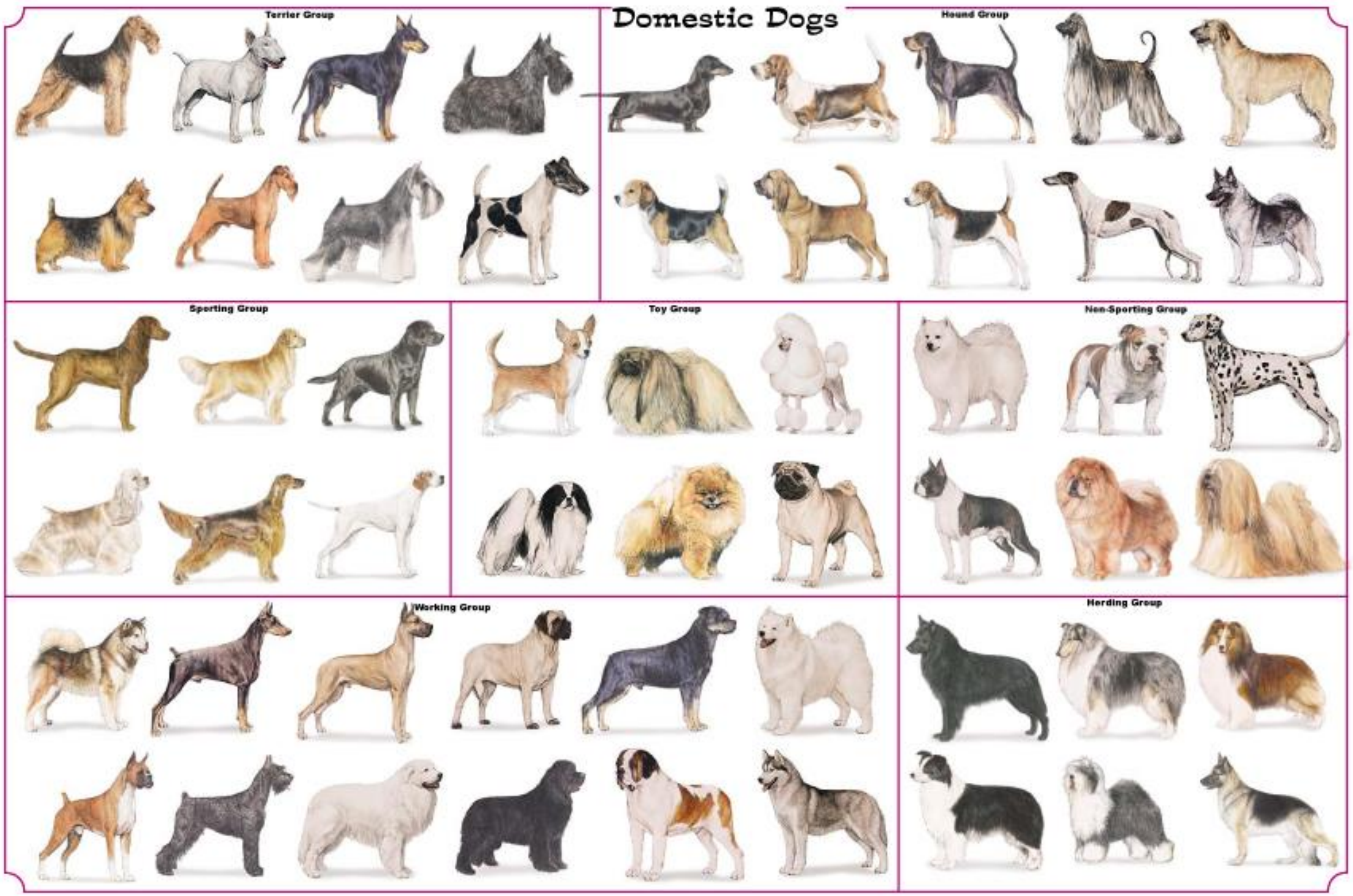
Chapter 17

Selection & Evolution

Part 1: Variation



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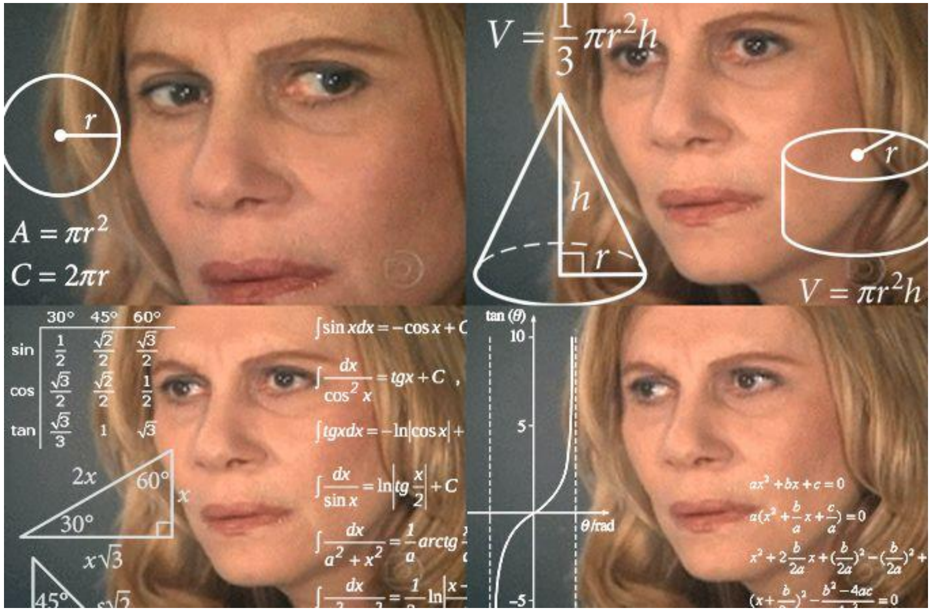

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Variation

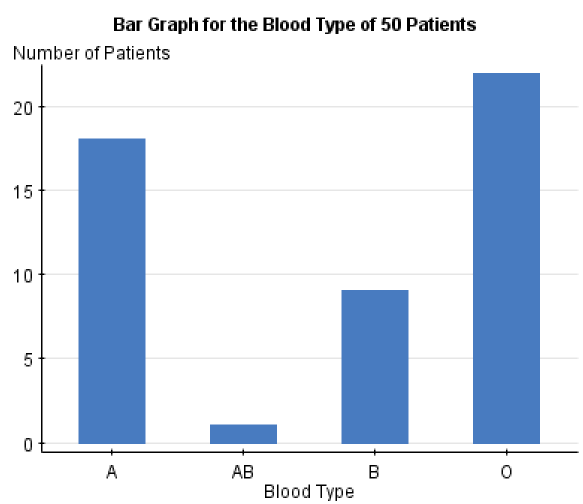
- Variation = presence of different characteristics
- **Phenotype** results from interaction of **genotype and environment**

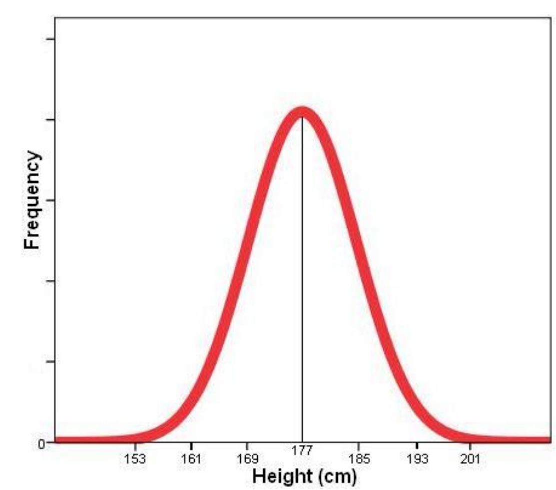
Phenotypic variation = Genetic variation + Environmental variation

$$V_P = V_G + V_E$$

- Two types of variation:

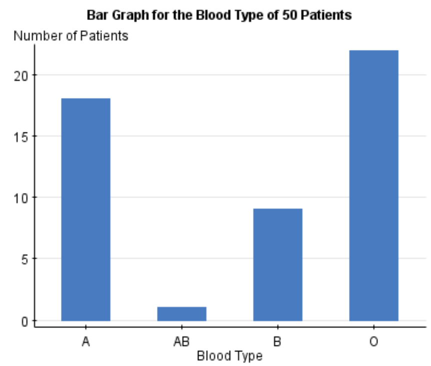
1. Discontinuous variation
2. Continuous variation

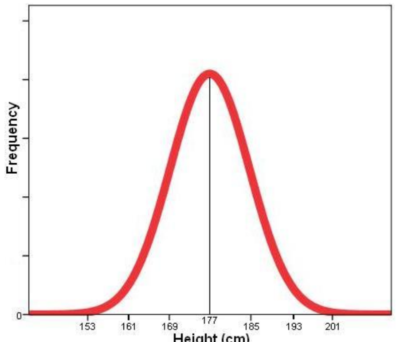




Continuous variation vs Discontinuous variation

Feature	Discontinuous Variation	Continuous Variation
Type of distribution	Discontinuous distribution	Normal distribution
Number of genes controlling phenotype	One / few genes (Monogenic)	**Many genes** (Polygenic)
Effect of diff alleles at single gene locus	Large Diff genes have diff effects	Small **Genes have an additive effect**
Type of data	Qualitative	Quantitative
No. of categories / intermediates	Discrete categories, no intermediates	**Range of phenotypes**, many intermediates
Effect of environment on phenotype	Little or none	**Environment has effect** Helps smooth the curve
Examples	Albinism, sickle cell anaemia, haemophilia, Huntington's disease	Height, mass





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Genetic Variation

Phenotype results from interaction of **genotype and environment**

Main source of genetic variations:

1) **Meiosis and fertilization**
(refer to Chap 16)

- Crossing over @ Prophase I
- Independent assortment @ Metaphase I
- Random fertilization / mating

2) **Mutations!**

- Primary source of variations
- Results in new alleles

How the environment influences phenotype

Phenotype results from interaction of **genotype and environment**

Environmental factors that can influence phenotypes:

- Nutrients / diet
- Water availability
- Light intensity
- Disease / parasites
- Temperature
- Chemicals / mutagens
- Lifestyle and culture etc.

- Environment effect usually greater on **polygenes**

→ Polygenes = many genes controlling one trait

→ Phenotypes affected by environment often show **continuous variation**

How the environment influences phenotype

How does the environment influence phenotype?

The environment may….

1. Limit / modify gene expression

- Size / mass / height

2. Trigger / switch on gene

- Examples:

a) Low temp and change in animal colour
b) High temp and gender in croc / curly wing in Drosophila
c) UV light and melanin production
d) Wavelength of light and plant growth

3. Induce mutation which affects phenotype

a) Low temp and change in animal colour

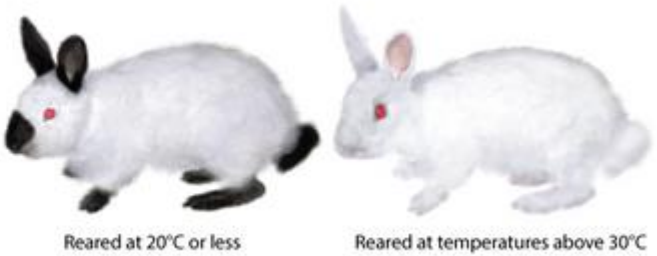
- Dark pigmentation in Himalayan rabbits

→ Controlled by both genotype and environment

At low temp:

- Allele for dark pigment expressed
- Forming dark tips at ears, paws, nose & tail

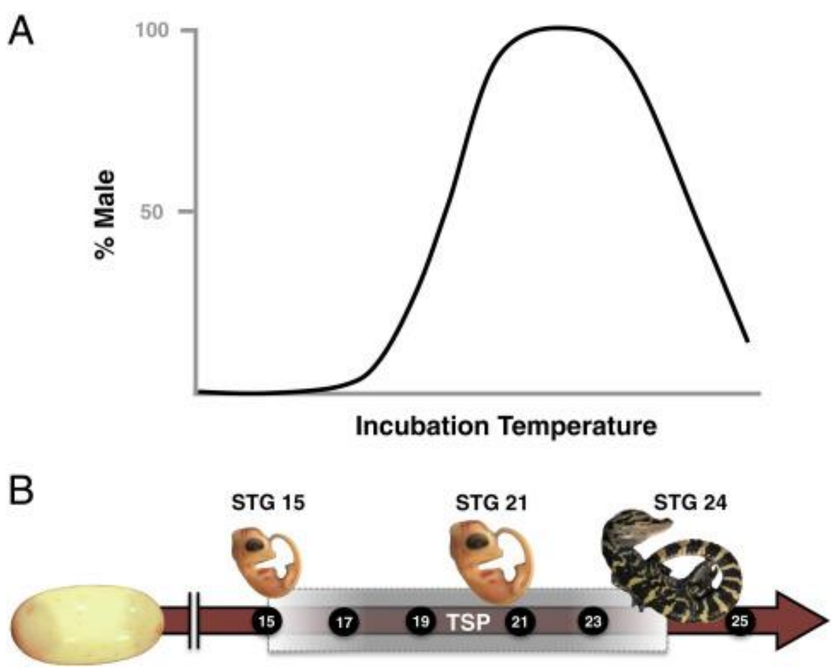
→ Coldest parts of rabbit



b) High temp and gender in crocs / curly wing in *Drosophila*

Gender of crocodiles depend on temperature of eggs!

- Temp of 32-34°C= Males
- Below 32°C / above 34°C = Females



(thermosensitive period)

In fruit flies with the curly wing mutation…

- Temp of 19°C = straight wings

- Temp of 25°C = curly wings

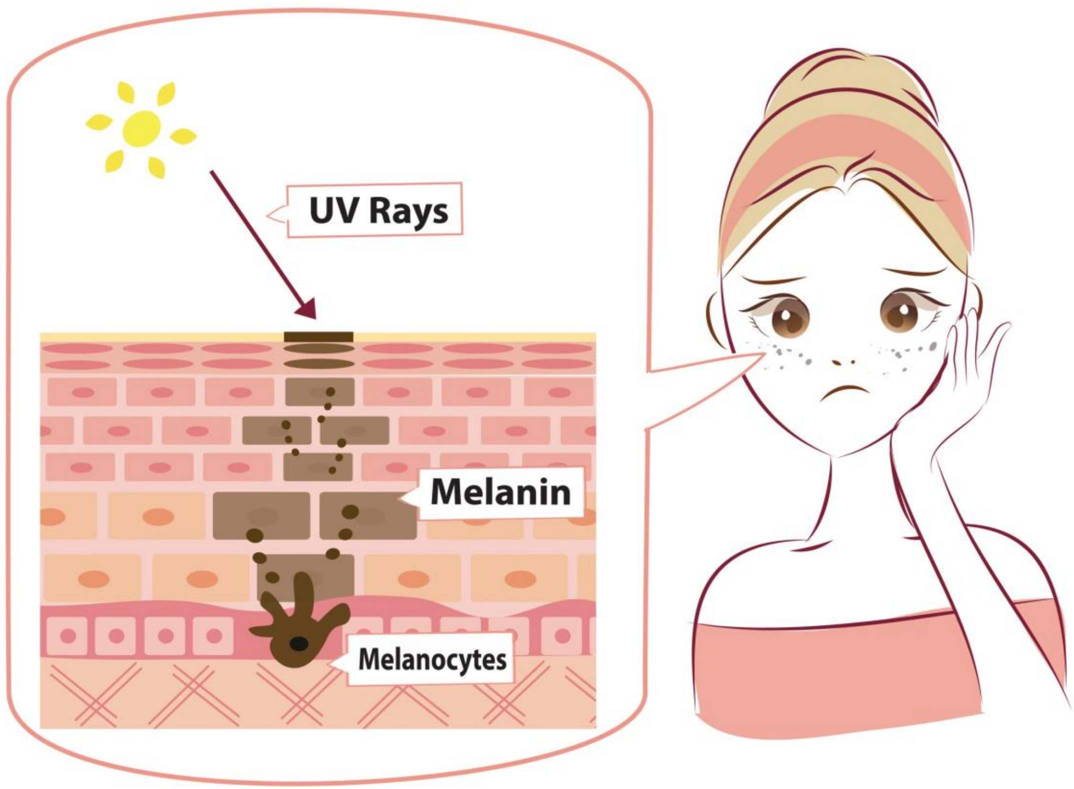
c) UV light and melanin production

After a few hours of exposure to UV radiation:

- Melanocytes produce melanin in skin

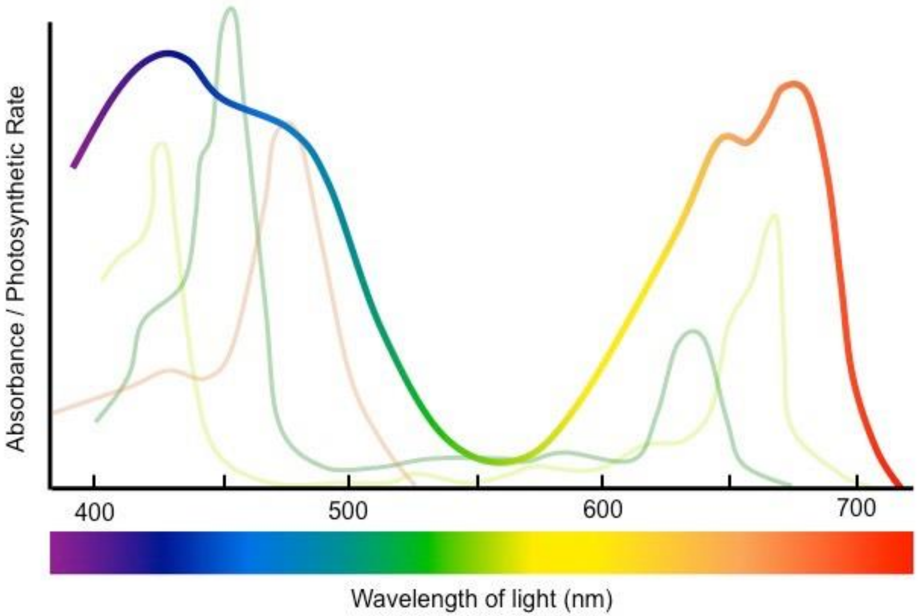
→ Causing skin to tan / form dark spots / freckles

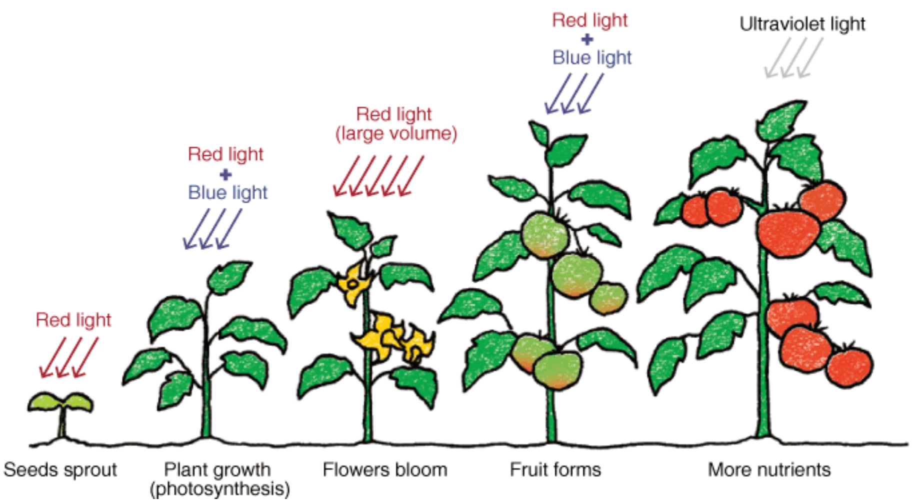
→ Protecting cells from DNA damage



d) Wavelength of light and plant growth

- Red and blue light are most effective for plant growth
- Blue light = helps with seed germination
- Red light = helps flowers bloom, but leaves will have stretched and elongated appearance





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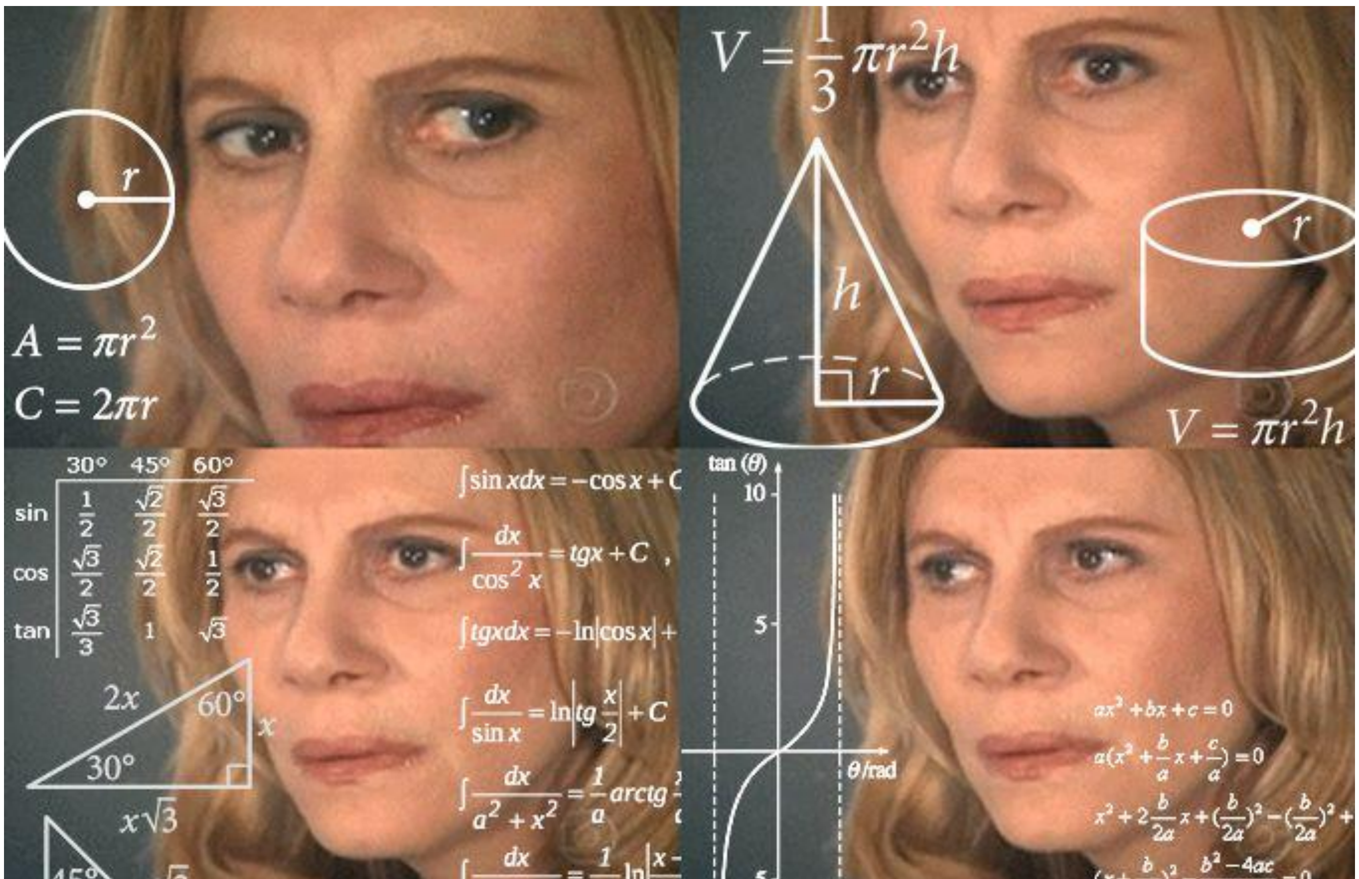
Statistics in Biology



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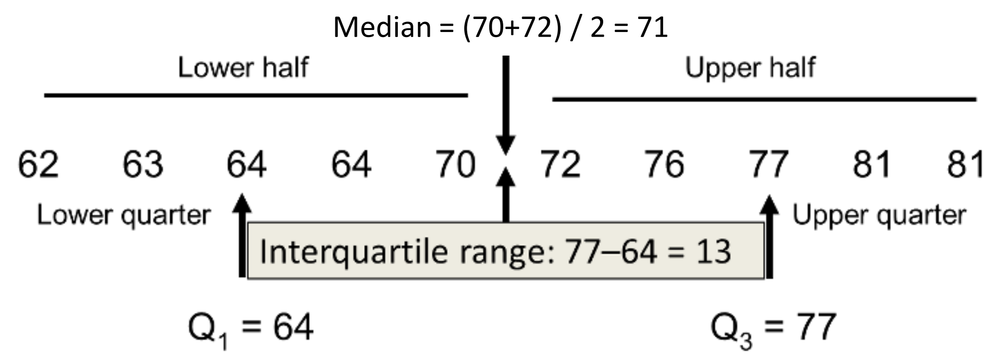
Maths Skills Required!

- **Mean,** $\overline{x} = \frac{\sum x}{n}$
- **Median**
- **Mode**
- **Range**
- **Interquartile range**

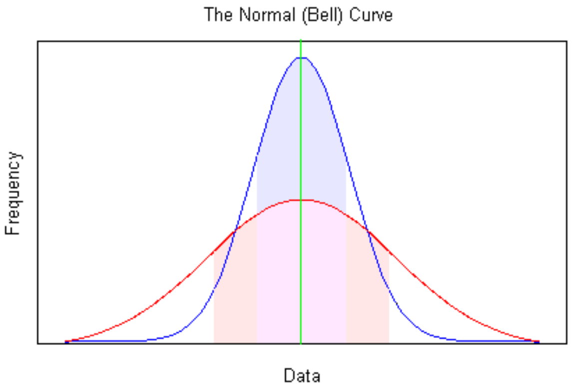


Mean = 710/10 = 71
Mode = 64 and 81
Range = 81-62 = 19

- **Standard deviation, s**
- **Standard error, S_M**
- **95% Confidence Interval = ± $2S_M$**

Standard Deviation, s

- **To show the spread of data about the mean, $\bar{x}$,** in a sample that is normally distributed
- **Indicates reliability of data**



- **If s = small value**

→ Data is less scattered, **more consistent and reliable**

$$\sqrt{\frac{\Sigma(X - \bar{X})^2}{(n - 1)}}$$

- **If s = large value**

→ Data is widely spread, results are **less reliable**

where:

X = each score
$\bar{X}$ = the mean or average
n = the number of values
Σ means we sum across the values

Other functions:

- To **calculate standard error, and put error bars of a graph**
- To calculate **t-test value**

P/S: it's different from what you learn in maths!
*In maths, you learn standard deviation of a **population**, whereas in bio, we learn s.d. of a **sample***

Standard Deviation, s

$$\sqrt{\frac{\Sigma(X - \bar{X})^2}{(n - 1)}}$$

where:

X = each score
$\bar{X}$ = the mean or average
n = the number of values
Σ means we sum across the values

E.g. The student measured the petal length of 12 flowers in the woodlands. These were the results in mm:

2.5 4 9 1.75 3 7 2 3 6 8 1.5 6.5

The student then measured petal lengths of another 10 flowers in the garden.

These were the results in mm:

2 2.5 2.5 2.5 2.5 3 2.5 2.5 1 2.5

a) State the null hypothesis for this experiment.

b) Find the mean, $\bar{x}$ and the standard deviation, s for both these sets of data.

c) Determine whether the 2 sets of data are significantly different by:

1. plotting a bar chart with error bars
2. conducting a t-test

$\overline{x} = \frac{\sum x}{n}$ = 54.24 / 12 = 4.52

x	$x - \overline{x}$	$(x - \overline{x})^2$
2.5		
4		
9		
1.75		
3		
7		
2		
3		
6		
8		
1.5		
6.5		
$\sum(x - \overline{x})^2$		
$s = \sqrt{\frac{\sum(x - \overline{x})^2}{n-1}}$		

P5

Standard Error, S_M

- To show how close the mean of sample calculated is from the true mean of the population
- S_M shows **the reliability of the mean**
- Used to put **error bars on graphs**

$$S_M = \frac{s}{\sqrt{n}}$$

- **Small value** of standard error shows:

→ The sample mean value is **closer to the actual mean**

→ Mean is more reliable

- S_M value is between 0 and 1

P5

Standard Error, S_M

E.g. The student measured the petal length of 12 flowers in the woodlands and 10 flowers in the garden.

Standard deviation calculated from previous example:

woodlands: $s = 2.638$

garden: $s = 0.530$

Calculate the standard error for both sets of data.

woodlands: $S_M = 2.638/\sqrt{12} = 0.761$

garden: $S_M = 0.530/\sqrt{10} = 0.168$

→ now we can plot a bar chart with error bars!

E.g. The student measured the petal length of 12 flowers in the woodlands and 10 flowers in the garden.

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garden: $S_M = 0.530/\sqrt{10} = 0.168$

→ now we can plot a bar chart with error bars!

Bar Charts with Error Bars

P5

Requires:

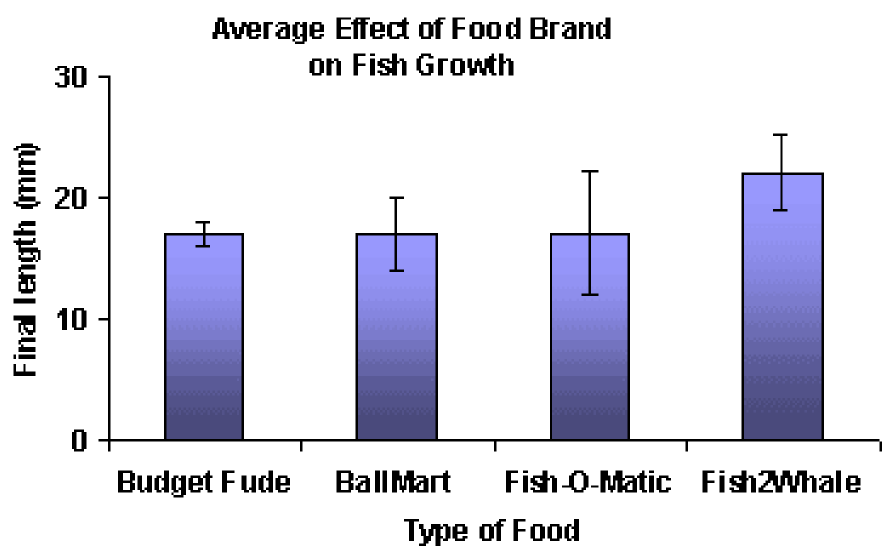
1) Mean, $\overline{x}$ = value for y coordinates

2) Standard error, **S_M**

3) Error bars = lines on bar charts

- To draw error bars, we use upper and lower limits of a **95% confidence interval**, that is **mean ± 2 S_M**
- Function of error bars:

  → To **see if there is a significant difference between two means**



Upper & Lower Limits in Normal Distribution's Curve

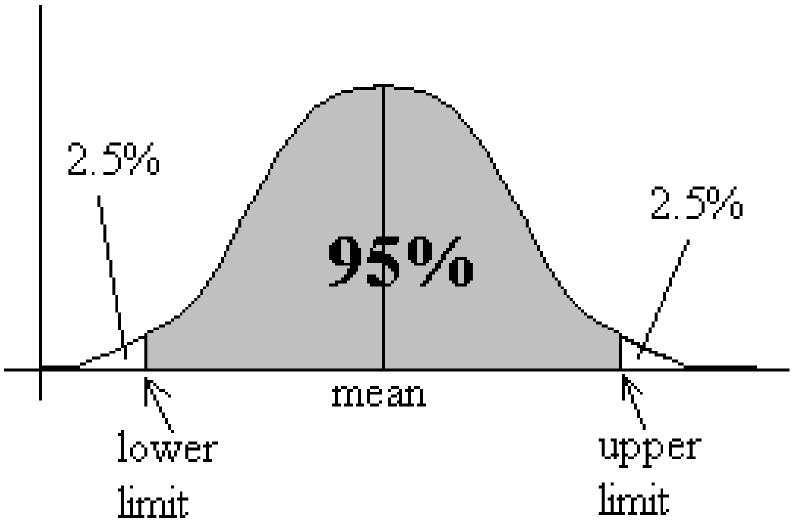
95% confidence interval =

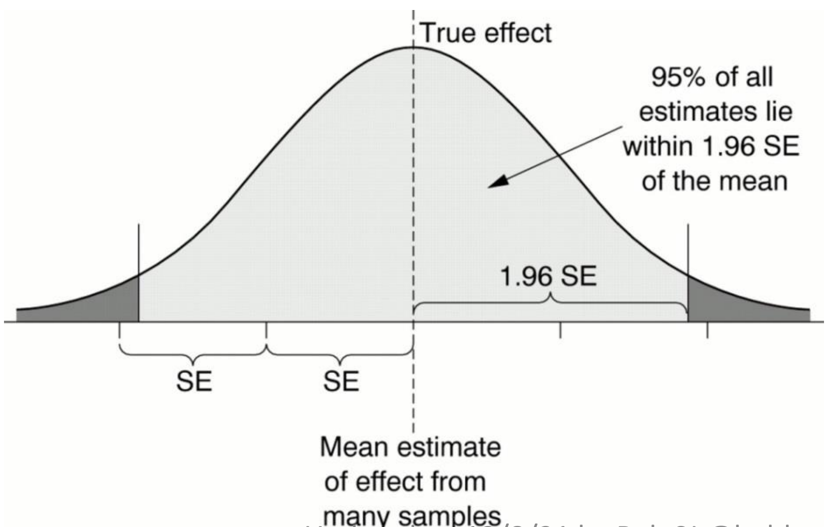
Interval where 95% of the sample's data lies around the mean

- Upper & lower limits of 95% confidence interval

→Min and max limit of the 95% interval

→Is calculated by **mean ± $2S_M$**





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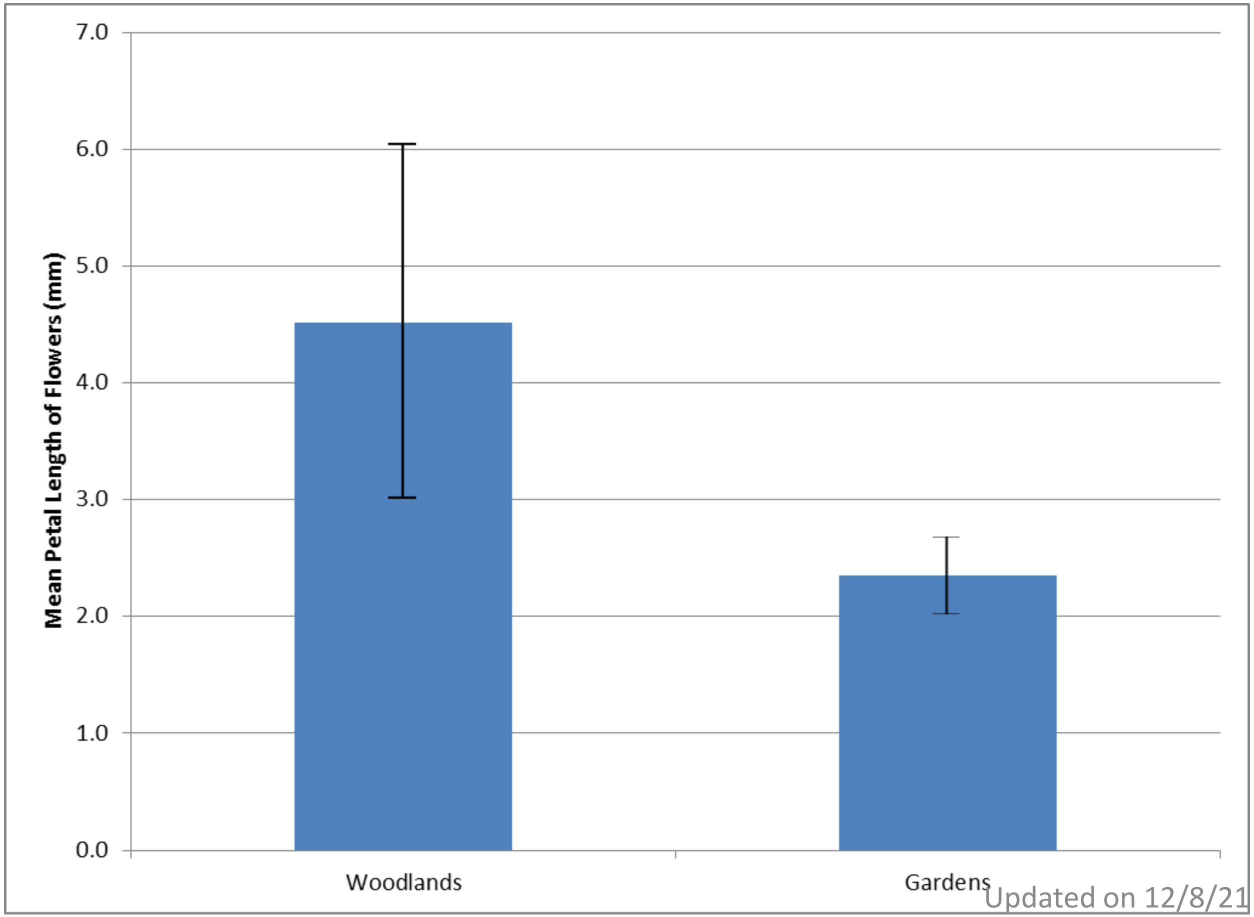
Bar Charts with Error Bars

E.g. The student measured the petal length of 12 flowers in the woodlands and 10 flowers in the garden.

Woodlands:	$\bar{x} = 4.520$	$S_M = 0.761$	$2S_M = 1.522$
Gardens:	$\bar{x} = 2.350$	$S_M = 0.168$	$2S_M = 0.336$



Error Bars Results Interpretation

- **Error bars overlap**

- The two means are **not significantly different**

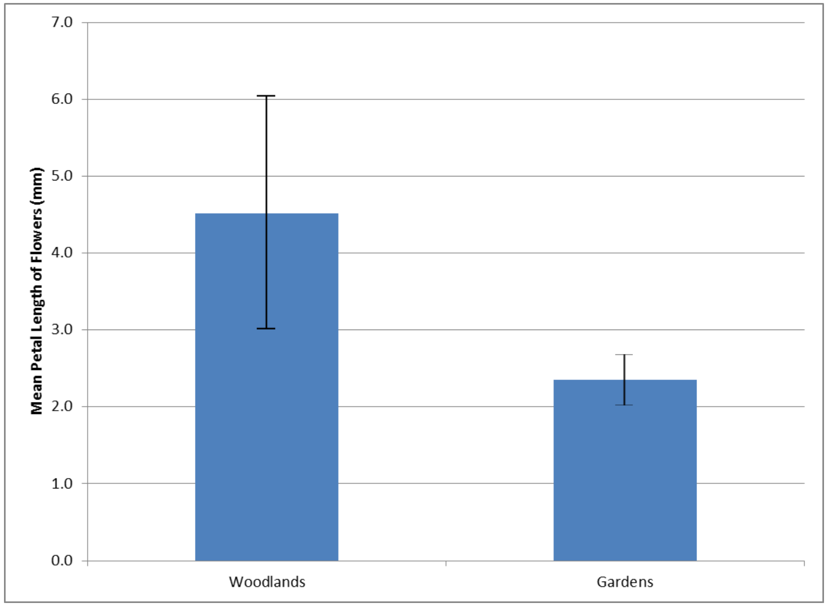
- Null hypothesis is accepted

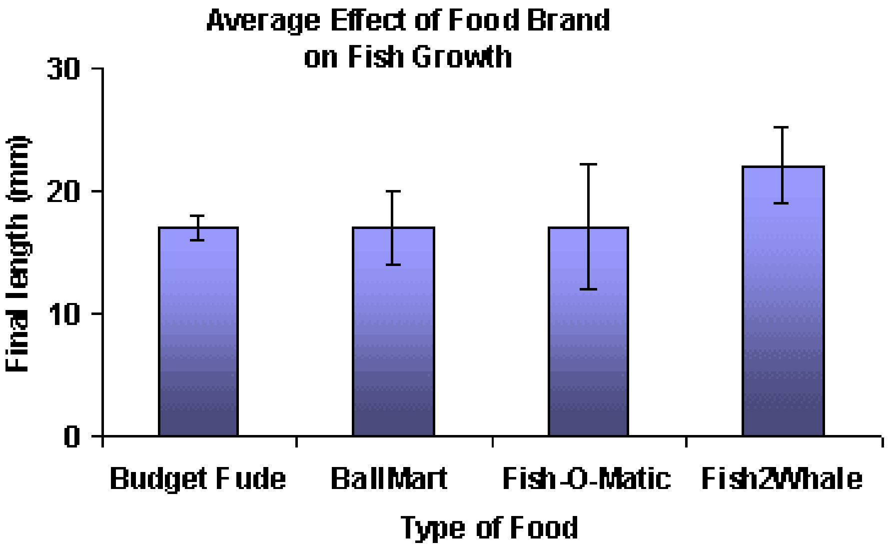
→ ***double check with t-test***

- **Error bars don't overlap**

- The two means are **significantly different**

- Null hypothesis is rejected





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P5: Student's t-test

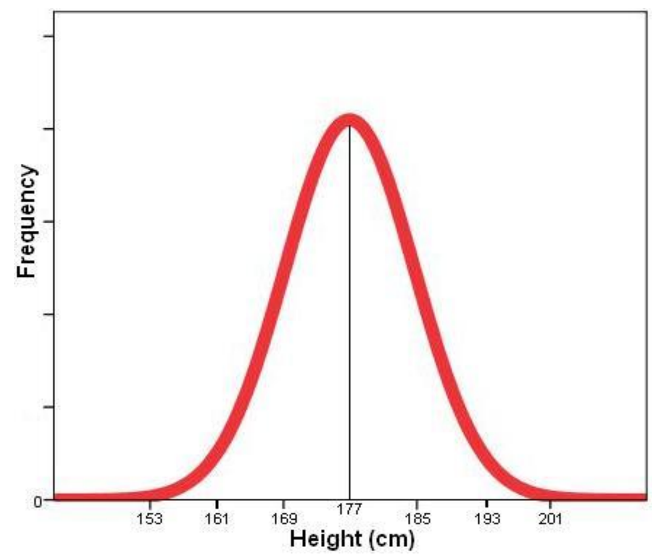
t-test

- To test whether data from **2 samples**
- Are significantly different

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Requirements:

- **Continuous / interval data**
- Data is **normally distributed**
- **Standard deviations are approx. the same**
- Two samples have <30 values each



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Example #1

E.g. Petal length of flowers in the woodlands

$\bar{x}_1$= 4.520

s_1 = 2.638

n_2 = 12

Petal length of flowers in the gardens

$\bar{x}_2$ = 2.350

s_2 = 0.530

n_2 = 10

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Determining significance difference in t-test

1) Calculate t **value** using formula

2) Calculate total degrees of freedom for t-test

→**$v = (n_1 - 1) + (n_2 - 1) = n_1 + n_2 - 2$**

→In this case, v = 12 + 10 - 2 = 20

3) Check critical value at **$p = 0.05$**

4) Check if **critical value** in t-test table is lower/higher compared to t-test value calculated

P5

t-test table

- Critical value = 2.09
- t = 2.78

Degrees of Freedom	p=0.05	p=0.025	p=0.01	p=0.005
1	12.71	25.45	63.66	127.32
2	4.30	6.20	9.92	14.09
3	3.18	4.17	5.84	7.45
4	2.78	3.50	4.60	5.60
5	2.57	3.16	4.03	4.77
6	2.45	2.97	3.71	4.32
7	2.36	2.84	3.50	4.03
8	2.31	2.75	3.36	3.83
9	2.26	2.68	3.25	3.69
10	2.23	2.63	3.17	3.58
11	2.20	2.59	3.11	3.50
12	2.18	2.56	3.05	3.43
13	2.16	2.53	3.01	3.37
14	2.14	2.51	2.98	3.33
15	2.13	2.49	2.95	3.29
16	2.12	2.47	2.92	3.25
17	2.11	2.46	2.90	3.22
18	2.10	2.44	2.88	3.20
19	2.09	2.43	2.86	3.17
20	2.09	2.42	2.84	3.15

Making Conclusions in t-test

P5

1) If t value calculated is **higher** than value in table:

→The two data sets are **significantly different**

→**Reject** null hypothesis

→Differences are NOT due to random error/chance

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

2) If t value calculated is **lower** than value in table:

→The means of the data are **not significantly different**

→**Accept** null hypothesis

→Any differences are due to chance/random error

P5

Example #2

Table 1.2 shows the students' results from the colorimeter measurements made on 10 samples of each of the four types of leaf.

Table 1.2

type of leaf	ivy	geranium	spiderwort	sorghum
mean absorbance $\pm s$	0.28 ± 0.08	0.32 ± 0.1	0.43 ± 0.18	0.39 ± 0.21

Use the information above to conduct a t-test to determine the significance of difference between the mean absorbance of **ivy** and **geranium**.

The formula is given below. Show that the t value is 0.9877.

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

P5

t-test table

- Critical value = 2.10
- t = 0.9877 (< 2.10)
- What conclusions do you draw from the data?

Degrees of Freedom	p=0.05	p=0.025	p=0.01	p=0.005
1	12.71	25.45	63.66	127.32
2	4.30	6.20	9.92	14.09
3	3.18	4.17	5.84	7.45
4	2.78	3.50	4.60	5.60
5	2.57	3.16	4.03	4.77
6	2.45	2.97	3.71	4.32
7	2.36	2.84	3.50	4.03
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13	2.16	2.53	3.01	3.37
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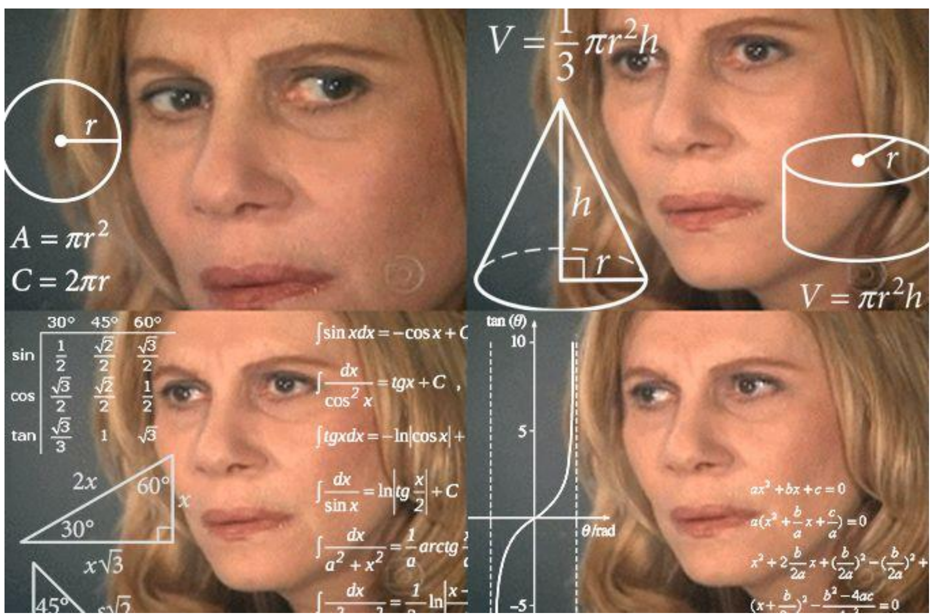

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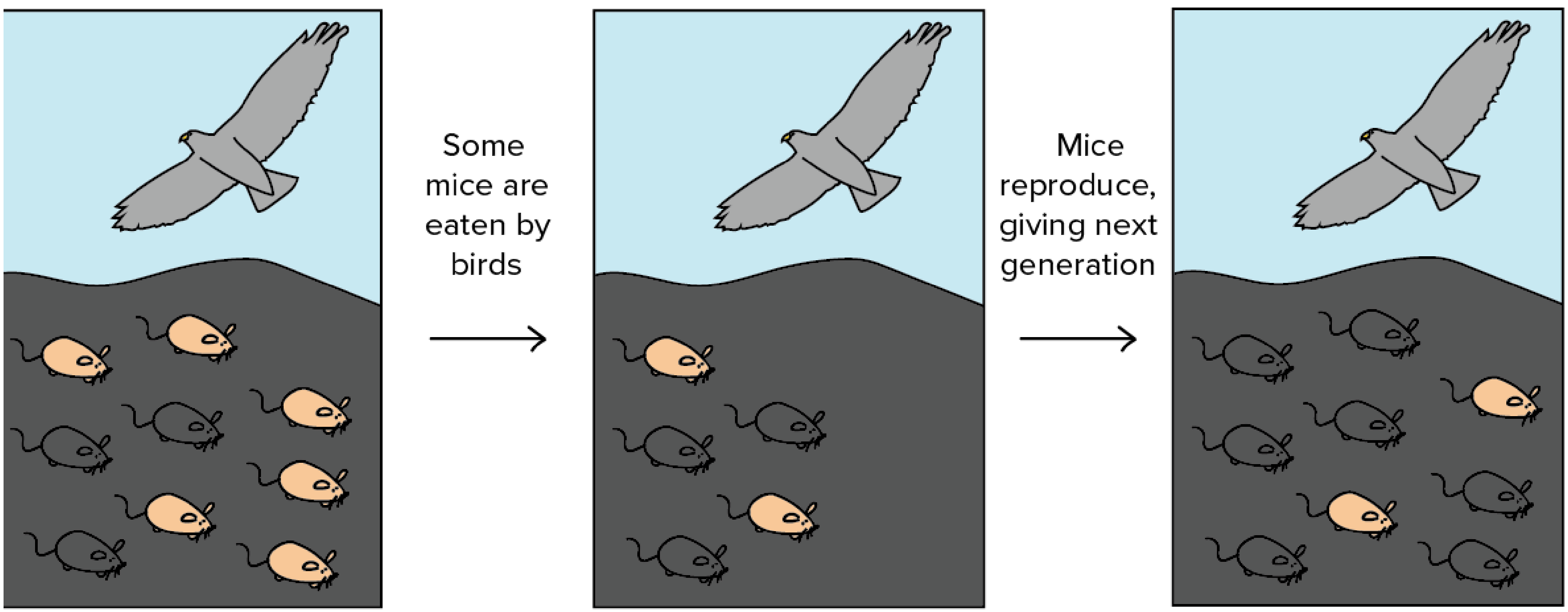

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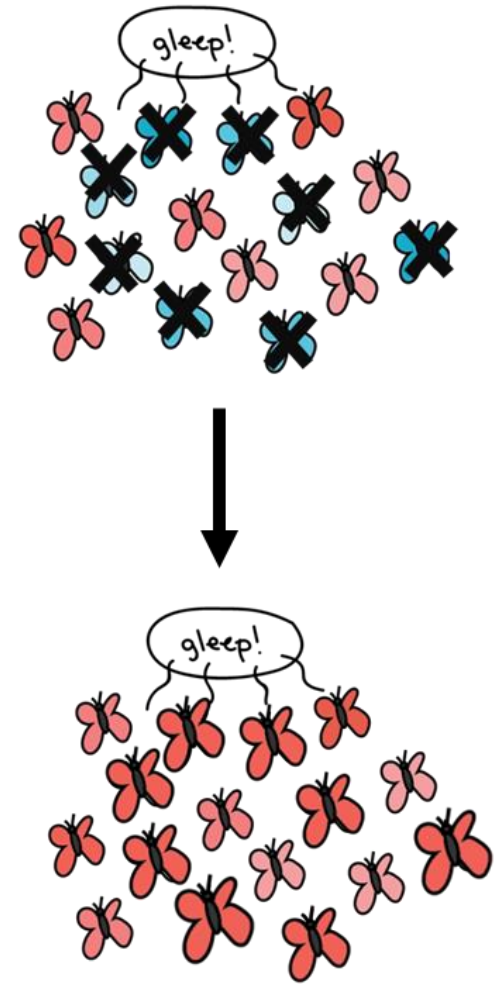


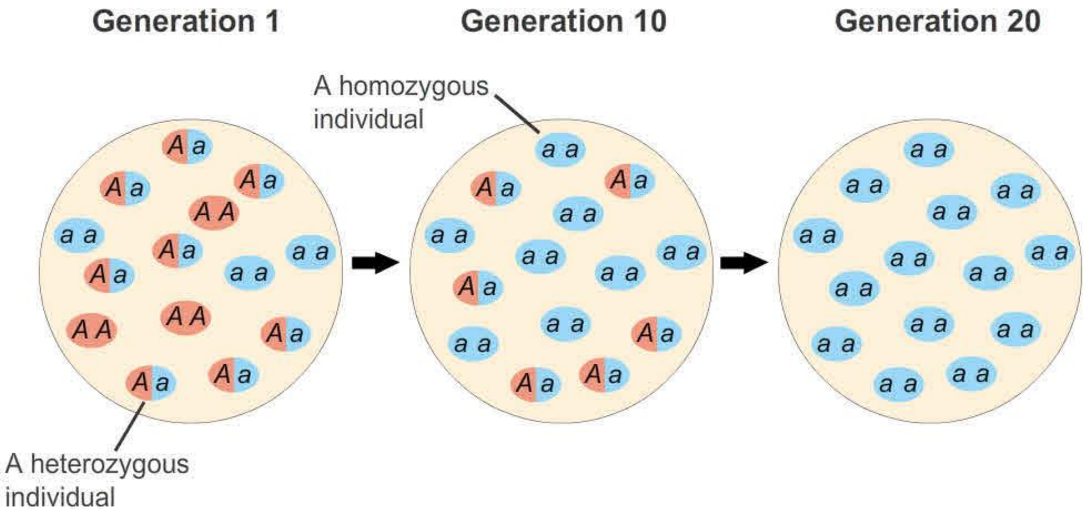
Intro to Natural Selection

Population = group of individuals of the same species living in the same area that can interbreed

Alleles = different forms of a gene

Allele frequency = the number of occurrences of an allele in a population

Gene pool = all genes / alleles present in a population



Gene pool of a population over the generations

Intro to Natural Selection

- Theory of **evolution** = idea that **organisms change over time**
- Forms new varieties and species of organisms over time
- Due to **change in allele frequencies**

- **Natural selection** is one ***mechanism*** by which evolution occurs
- The theory of evolution by natural selection is proposed by Charles Darwin and Alfred Russel Wallace independently in 1858
- Darwin published the famous “On the Origin of Species” the following year

Updated on 12/8/21 by Beh SJ @behlogy

Natural Selection

Observation 1: Overproduction

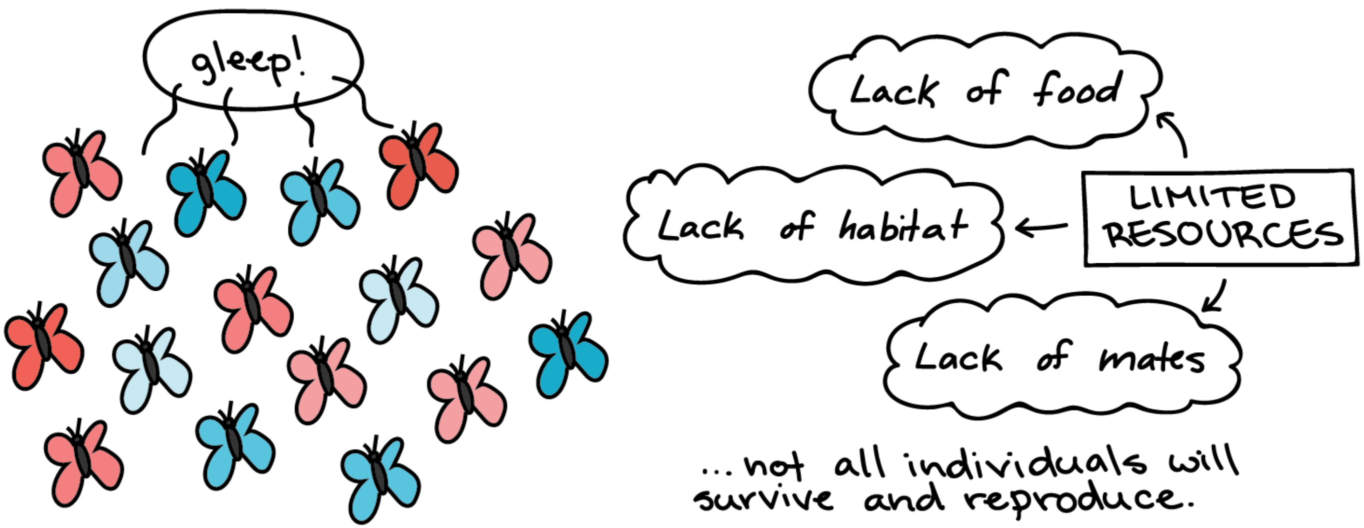
- Organisms produce many offspring

→Organisms have great **reproductive potential**

→ Reproduce more than is necessary to maintain population

→ Reproduce more than can be supported by food supply / space

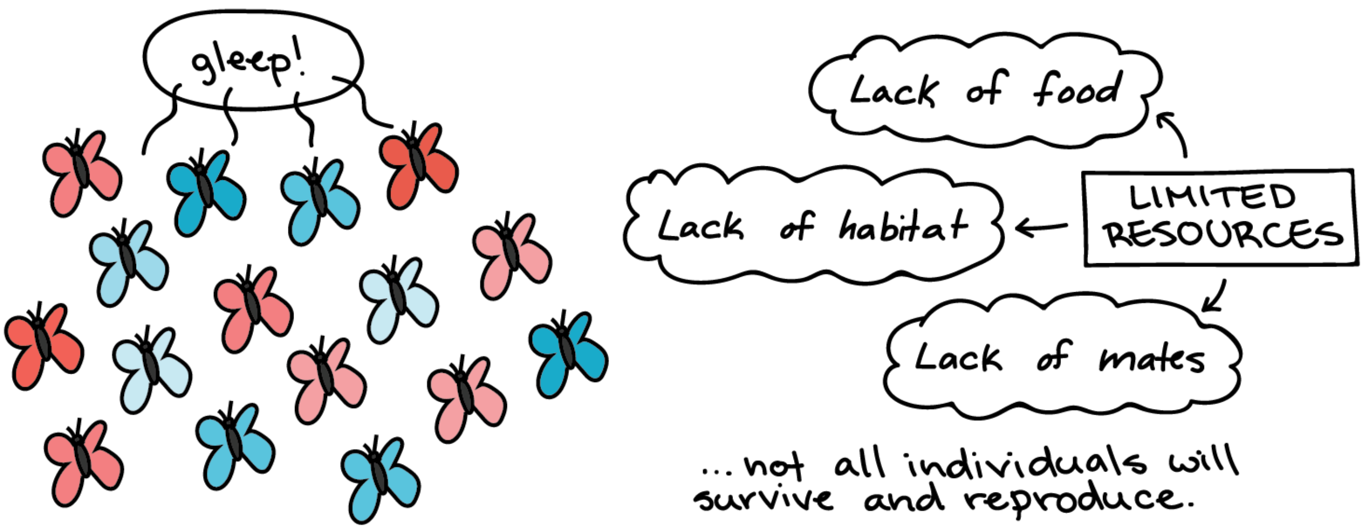
- BUT **population size is constant over time**



Natural Selection

Deduction 1: "Struggle for existence"

- Individuals / members of the same species **compete for survival** (intraspecific competition)
- Many die due to environmental factors and therefore do not reproduce
- **Selection pressure** occurs = environmental factor causes difference in survival between individuals with diff traits



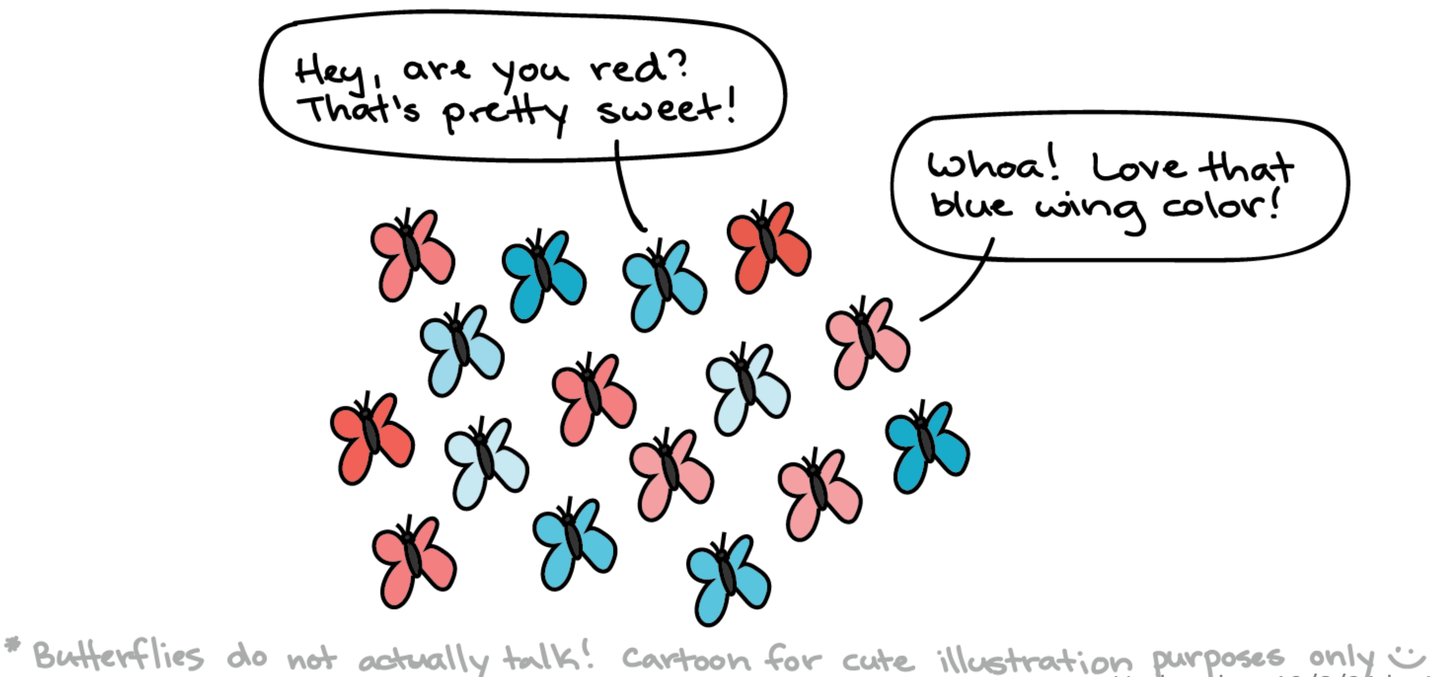
Natural Selection

Observation 2: **Variation**

- Within a species there is variation in phenotype

→ Due to **genetic variation**

→ Primarily caused by **mutations**, that introduces new alleles



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Natural Selection

Deduction 2: "Survival of the fittest"

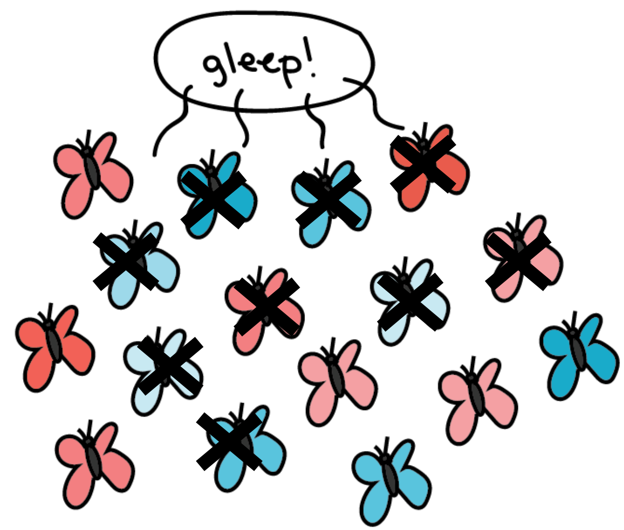
- Some individuals have advantageous **alleles**

→ Better **adapted** to survive / have selective advantage

→ Have higher **fitness** = more likely to **survive and reproduce** more (i.e. have more offspring)

→ **Pass on advantageous alleles to next generation**

- Advantageous alleles are **selected for**
- Disadvantageous alleles are **selected against**



P/S: pay attention to the wording – "more likely"

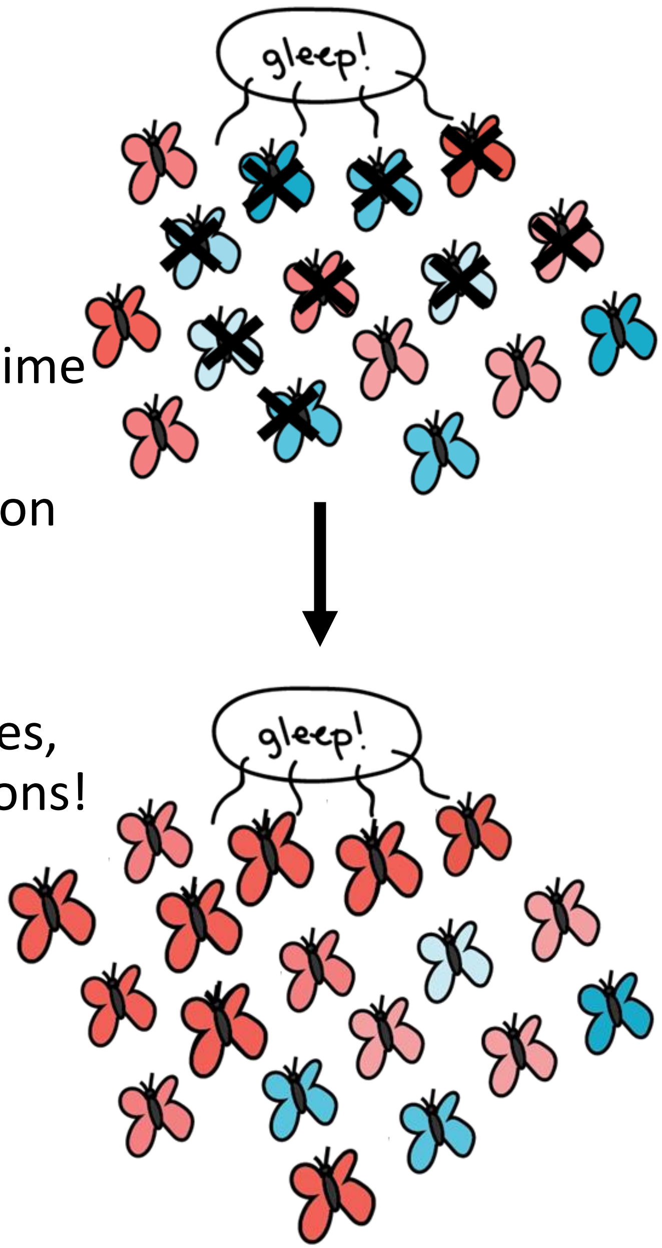
Natural Selection

Over time… Over many many generations…

- This cause **changes in allele frequency** / gene pool

→ Frequency of advantageous alleles increase over time

→ Result in **adaptation** = structure / behaviour / physiological trait that is a result of natural selection over time, in a species of a population

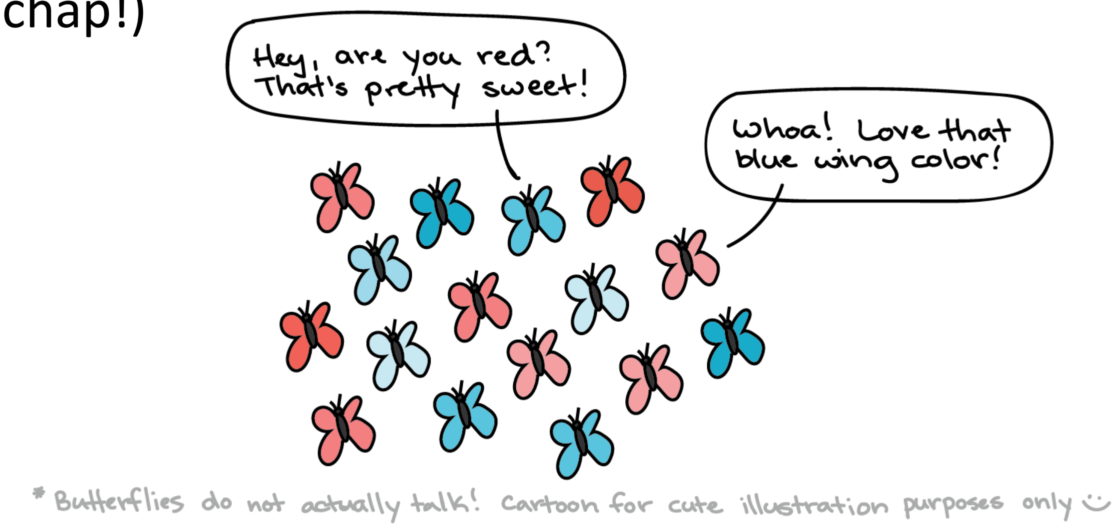


→ Can lead to **speciation** = formation of a new species, if it is reproductively isolated from other populations! (More on this later)

Importance of Variation

- Variation means the presence of different characteristics
- Resulting in different survival rates
- Leads to either reproductive success or failure
- Allow some individuals within a population to adapt to the changing environment

- **Enables a population to survive despite a changing environment**
- Low genetic diversity = susceptible to disease / environmental changes (more on this next chap!)



Types of Natural Selection

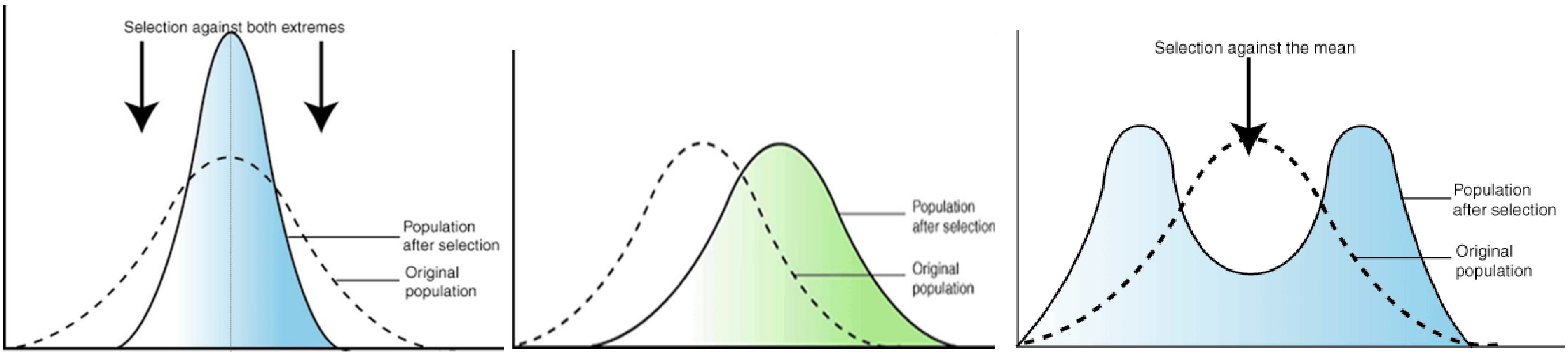
- When there is selection pressure, natural selection occurs

→ The favourable allele will be always **selected for**

→ Less favourable allele will be **selected against**

→ Leads to changes in allele frequency

- 3 types of natural selection:



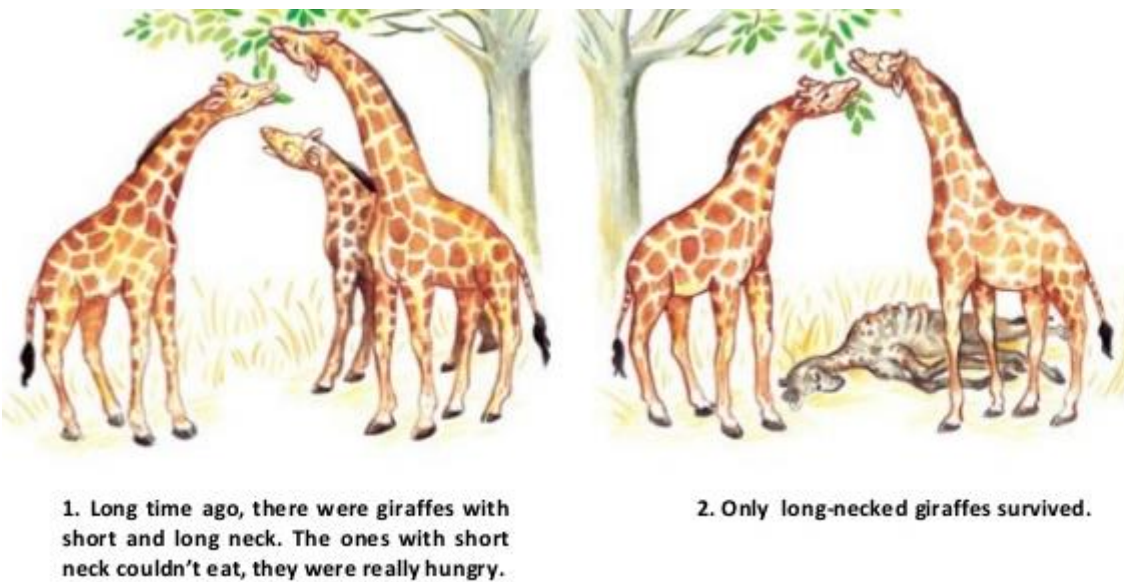
Stabilising Selection	Directional Selection	Disruptive Selection
Intermediate phenotypes are selected for	One extreme characteristic is selected for	Both extreme traits are selected for
Extremes of the phenotype are selected against	The other extreme and intermediate phenotype are selected against	Intermediate traits are selected against

Types of Natural Selection

1. Stabilising Selection

Short flowers die: No sunlight
Medium flowers live: Perfect conditions
Tall Flowers die: Wind damage

2. Directional Selection



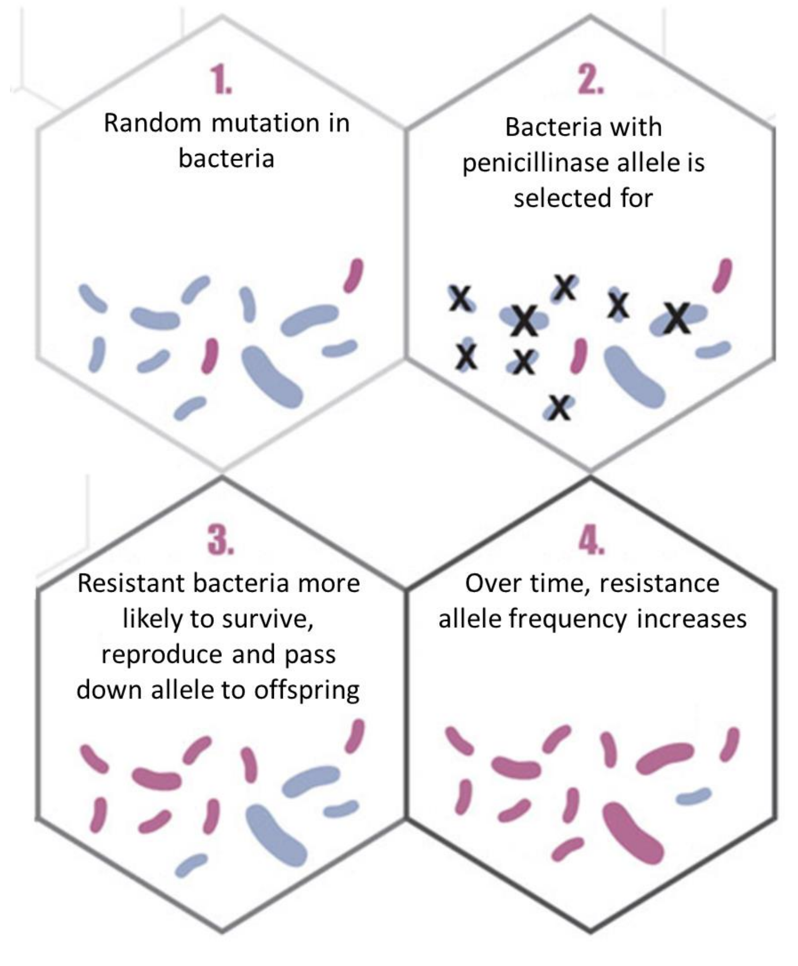
3. Disruptive Selection

Examples of Natural Selection

a) Antibiotic resistance in bacteria

b) Industrial melanism in peppered moth

c) Sickle cell anaemia



a) Antibiotic Resistance

Chap 10 Recap

- When antibiotics are no longer effective against bacteria
- Antibiotic resistance can be spread from bacteria to bacteria

E.g.

- Penicillin inhibits cross-link formation btwn peptidoglycans in bacteria's cell wall
- Many bacteria have **penicillinase** enzymes can break down penicillin
- Become **resistant to penicillin**

Caused by:

1. Spontaneous/random **mutation** in some bacteria

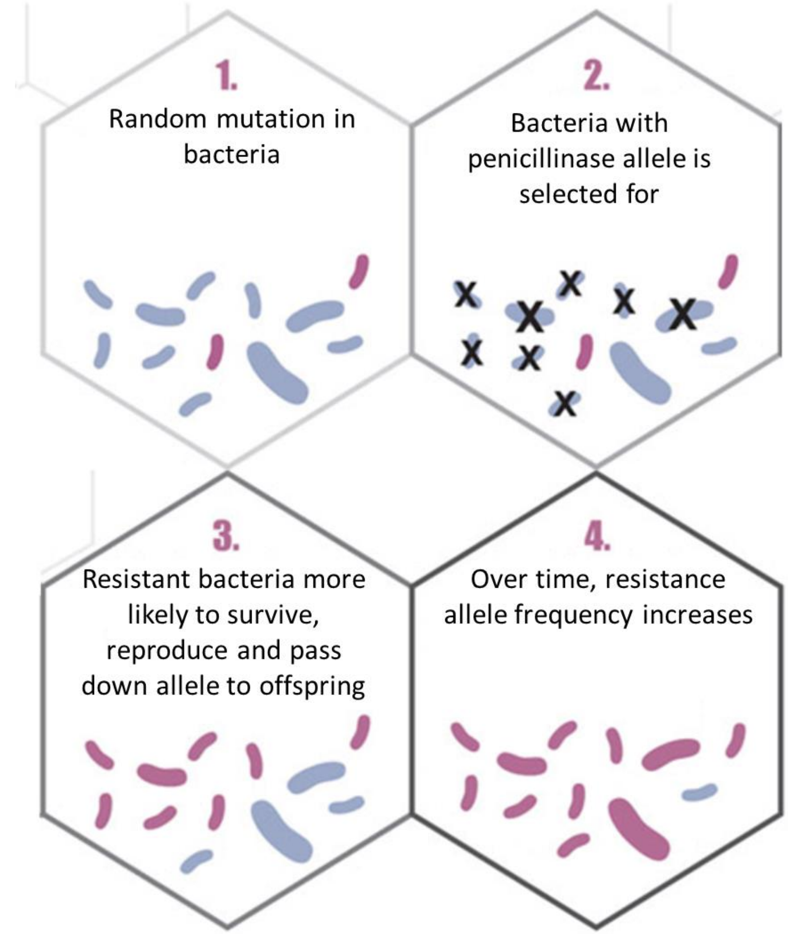
- Mutation cause change in protein/production of new protein that cannot be targeted by antibiotics

a) Antibiotic Resistance

Natural selection enables resistance genes to spread

2. **Antibiotic is the selection pressure**

- Bacteria with allele coding for penicillinase has **selective advantage**
- Antibiotics only kill bacteria that are non-resistant



3. Resistant bacteria more likely to **survive and reproduce**

- More likely to **pass down allele** to offspring via binary fission

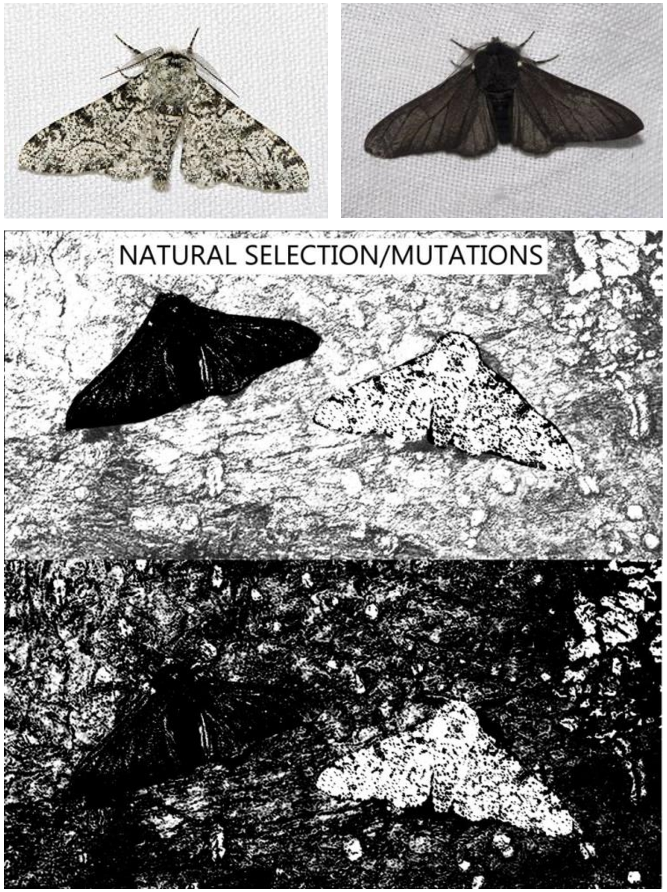
4. Over time, resistance **allele frequency** increases

b) Industrial Melanism

- Peppered moth (*Biston betularia*)
- Spends the day resting on tree barks / branches / trunks
- Camouflages to protect itself against its predator (birds)

- Before 1849, moths with a **speckled appearance** was most common
- No. of moths with a **melanic / black appearance increased in industrial areas**
- BUT other places speckled form still more common

→ Natural selection caused change in allele frequencies



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b) Industrial Melanism

1. Variation present

- Black moths and speckled moths

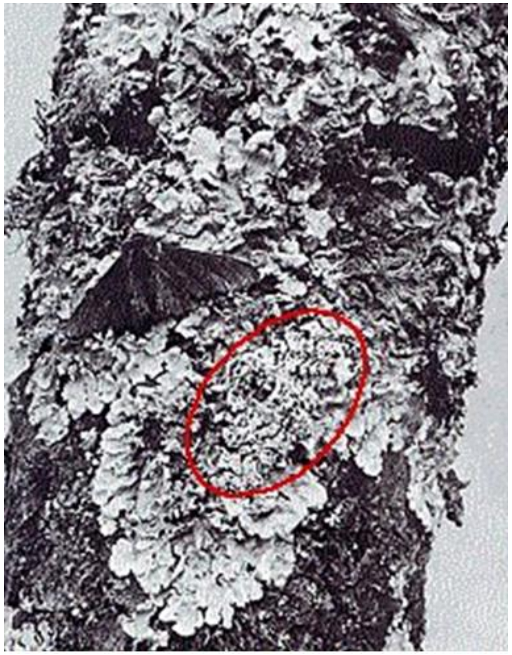
2. **Selection pressure = Predation by birds**

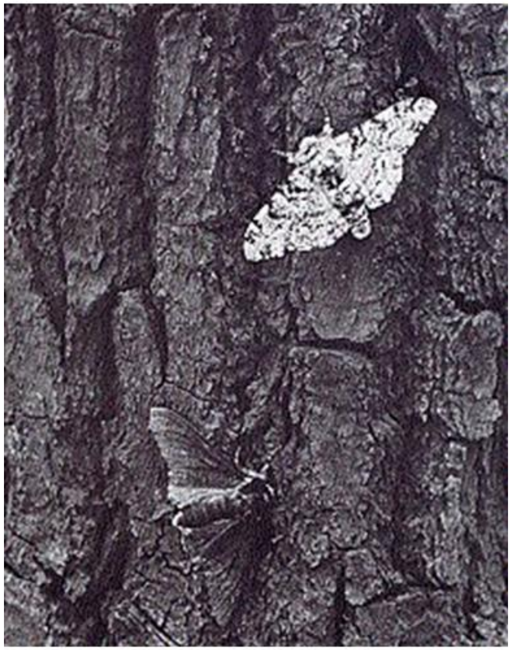
- Industrial cities' tree barks has a darker shade due to high pollutants
- Black moths have **selective advantage** as they were more camouflaged
- White moths are selected against

3. Black moths more likely to **survive and reproduce**

- More likely to **pass down allele** to offspring

4. Over time, allele for black colour increased in **frequency** in industrial cities

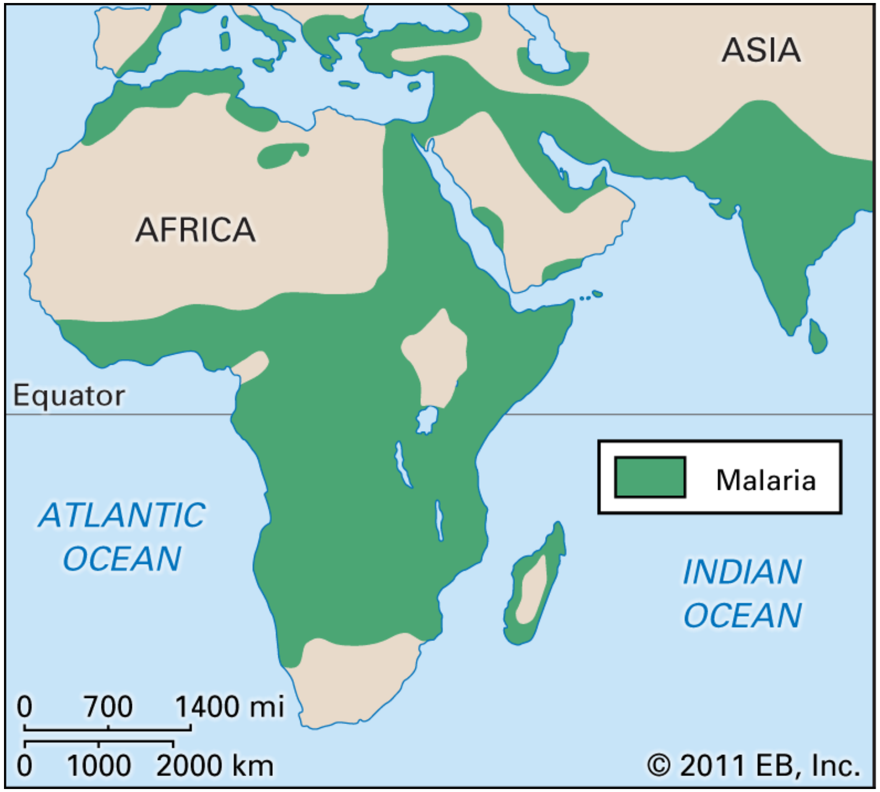


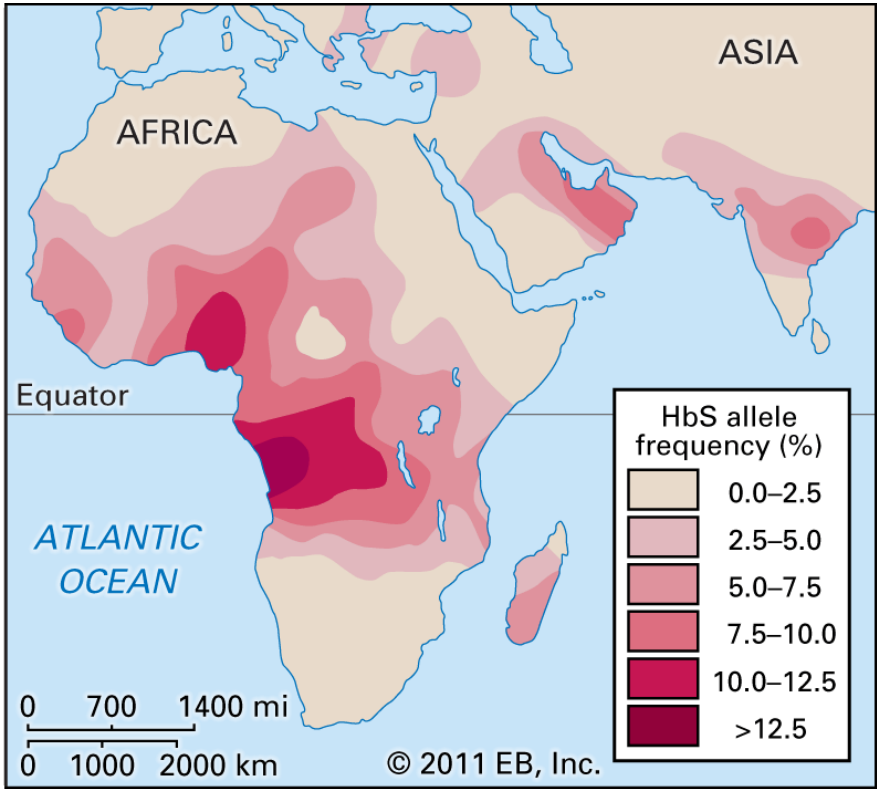


c) Sickle Cell Anaemia

- **Frequency of sickle cell anaemia is highest in areas where malaria is common**

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





c) Sickle Cell Anaemia & Malaria

Selection pressure: SCA and malaria

3 genotypes:

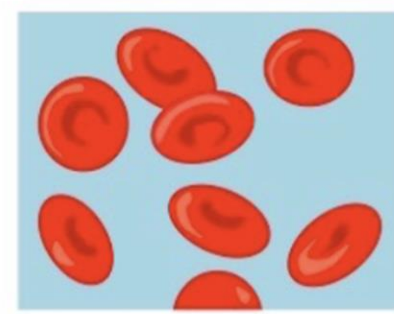
1. H^SH^S : Homozygous for sickle cell alleles

- RBC cannot carry oxygen very well, may die from SCA
- **SCA selects against H^SH^S**

H^SH^S
Resistant to malaria
but has fatal sickle cell disease

2. H^NH^N : Homozygous for normal Hb allele

- No SCA
- *Plasmodium* parasite affects RBC
- Malaria is lethal, so more likely to die from malaria
- **Malaria selects against H^N H^N**



H^NH^N
Susceptible to malaria
but no sickle cell disease

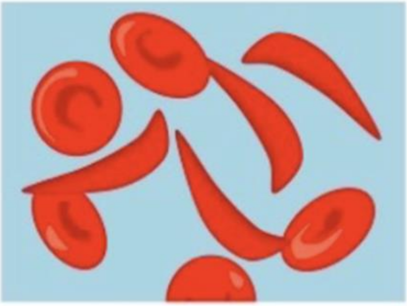
c) Sickle Cell Anaemia & Malaria

3. H^NH^S : Heterozygous for sickle cell allele

- Have sickle cell trait
- Do not die from SCA

- Less likely to suffer severe effects of malaria
- Contains less *Plasmodium* in their blood

- Has **selective advantage**
- More likely to **survive and reproduce**
- More likely to **pass on** both H^N and H^S
- **Sickle cell allele is maintained within population** because of sickle cell trait individuals



H^NH^S
Resistant to malaria
and only mild sickle cell disease

The Hardy-Weinberg Principle

- **Used to calculate allele, genotype and phenotype frequencies in populations**

5 requirements of the principle:

1. The population is large
2. There is random mating within a population
3. No immigration or emigration
4. No mutations
5. No selection pressure against one genotype

- If frequencies in real life are not as expected, this may mean that one of the assumptions above does not apply

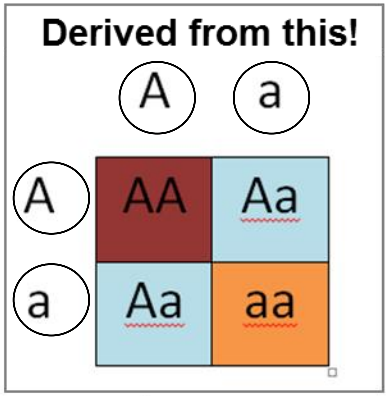
The Hardy-Weinberg Equations

- **Equation 1 – for alleles**

Frequency of dominant allele (A)

Frequency of recessive allele (a)

$$p + q = 1$$



- **Equation 2 – for genotypes**

Heterozygous (Aa)

$$p^2 + 2pq + q^2 = 1$$

Homozygous dominant (AA)

Homozygous recessive (aa)

Example #1

Given that the incidence of the genotype aa is 16%, calculate the frequency of dominant allele A and the frequency of homozygous dominant individuals and heterozygous individuals.

Frequency of genotype aa = q^2 = 16% = 0.16

$$p + q = 1$$

$$p^2 + 2pq + q^2 = 1$$

Find....

Frequency of dominant allele A =

Frequency of genotype AA =

Frequency of genotype Aa =

Example #2

[CIE, Nov 2018, P42, Q2]

Lactose intolerance and lactose persistence were investigated in a test population in Europe.

The mutation which causes lactose persistence is in a regulatory gene (**T**/**t**).

- People with lactose intolerance have the genotype **tt**.
- People with lactose persistence have the genotypes **TT** and **Tt**.
- 166 people were tested for their genotype.
- 58 people were found to have lactose intolerance.

Calculate the frequency of allele T.

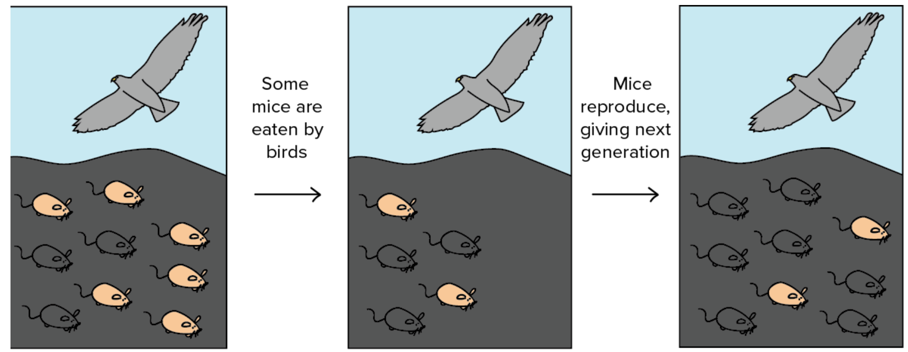
Show your working.

$$p + q = 1$$

$$p^2 + 2pq + q^2 = 1$$

What processes can change allele frequency?

1. **Natural selection**



2. **Genetic drift**
   - Founder effect
   - Bottleneck effect

3. **Artificial Selection**

Genetic Drift

- **Random** process due to chance, unlike natural selection

→ **Changes in allele frequencies fluctuate** due to random events

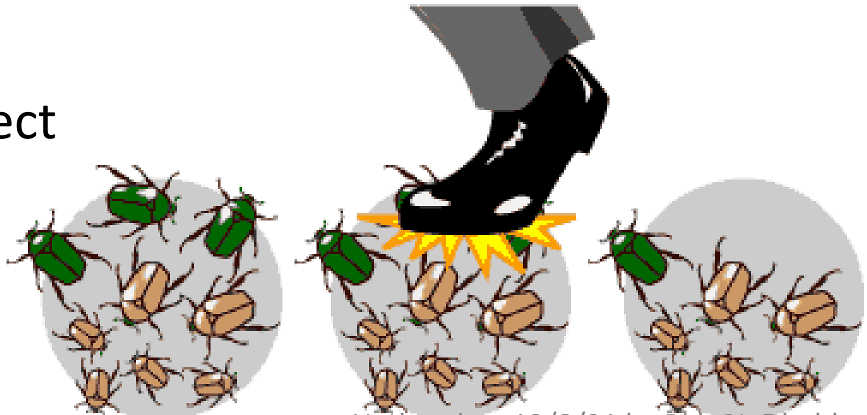
→ Cannot be predicted

- Affects **small populations** more than large populations

→ Higher chance that allele will be lost from population

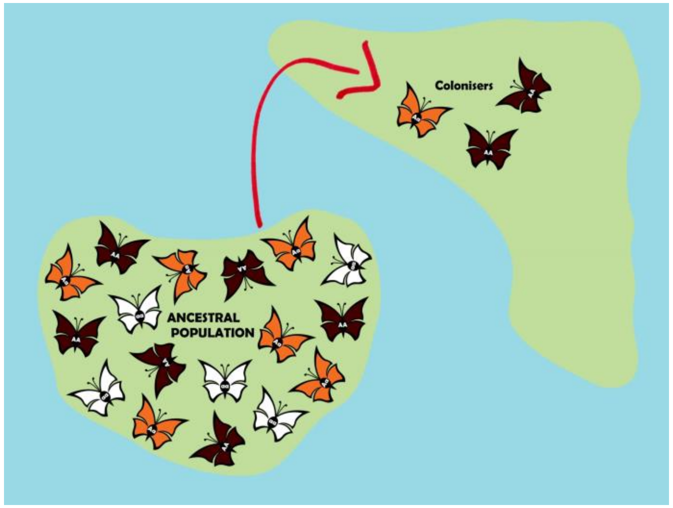
- Random events usually cause small effects only
- Unless…there is:

1. Migration → Founder effect
2. Natural disaster → Bottleneck effect



Genetic Drift

Founder Effect



- Due to **migration**
- Few individuals move to a new region

→ Become geographically isolated from the larger population

- New population is established by a **small number** of individuals

→ Only carry a **fraction of the alleles** of the original population

→ **Gene pool may not be representative** of gene pool of original population

→ Lower genetic diversity than original population

- Over time, population may become genetically distinct from original population

→ May develop into separate species = **speciation**

Genetic Drift
Bottleneck Effect

- **Large decease in genetic diversity**

→ Due to **large decrease in population numbers**

→ Common when **natural disasters** occur

→ But can occur due to overhunting / human activities too!

- Small group of survivors

→ **Gene pool will not be representative** of gene pool of original population

→ Limited gene pool compared to previous population

P/S: Conservation effort may increase population number BUT does not increase genetic diversity!

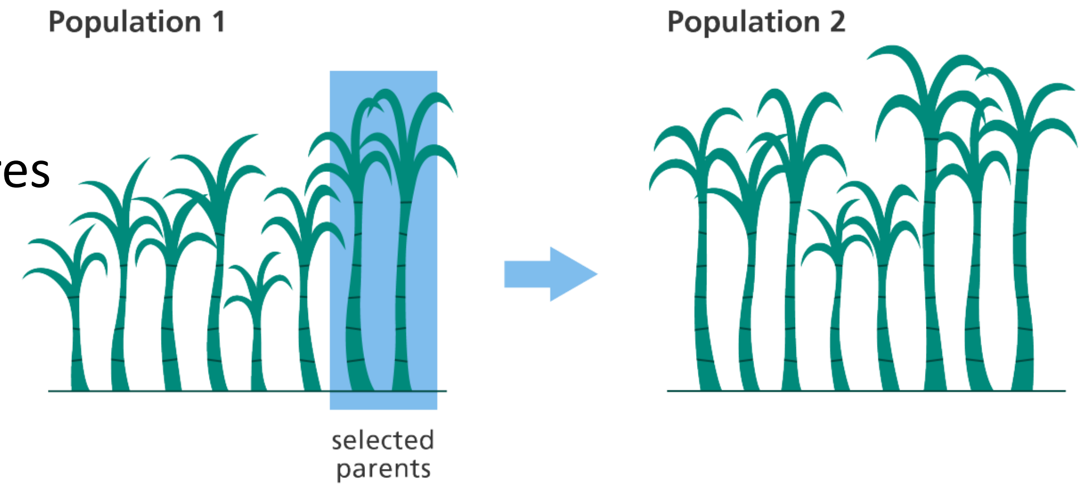
Low genetic diversity = susceptible to disease / environmental changes
(more on this next chap!)

Artificial Selection

- Aka selective breeding
- Individuals with desired features are selected to breed

→By humans

- **Selection pressure = humans**



1. **Humans choose** parents with **desirable features**
2. **Parents** with desired features are crossed
3. Select **offspring** with desirable features
4. **Repeat** for many generations

→ Increase in **allele frequency** for ideal characteristics

→ Decrease in frequency of undesired alleles

Artificial Selection

Disadvantages of artificial selection:

- Artificial selection can result in **inbreeding**!!!

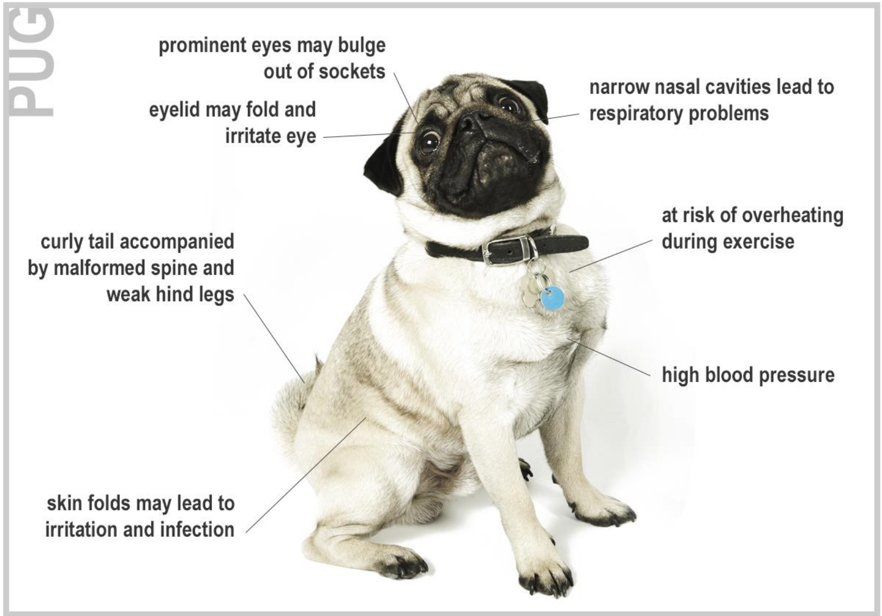
→ **Increase in homozygosity**

→ Harmful recessive alleles may be expressed

→ **Inbreeding depression** / loss of hybrid vigour

→ Limited gene pool / decrease in genetic variation

- Offspring may show desired traits, but **may not be well-adapted to its environment**



Artificial Selection vs Natural Selection

Artificial Selection	Natural Selection
Humans are the selection pressure	Environmental selection pressure
Selected feature for human benefit	Selected feature of organism's benefit
Not for survival/evolution	Promotes survival/evolution
Inbreeding common	Outbreeding common
Genetic diversity lowered	Genetic diversity remains high
Results in inbreeding depression	Increased hybrid vigour
Increased homozygosity / decreased heterozygosity	Increased heterozygosity / decreased homozygosity
No isolation mechanisms operating	Isolation mechanisms do operate
Usually faster	Usually slower

Examples of Artificial Selection

a) Improving the milk yield of dairy cattle
b) Disease resistance in varieties of wheat and rice
c) The incorporation of mutant alleles for gibberellin synthesis into dwarf varieties
d) Inbreeding and hybridisation of maize

a) Improving the milk yield of dairy cattle

Desired traits:

- Increased docility / calm temperament
- Fast growth rates (for meat production)
- High milk yield
- Fat-rich milk
- High fertility
- Disease resistance

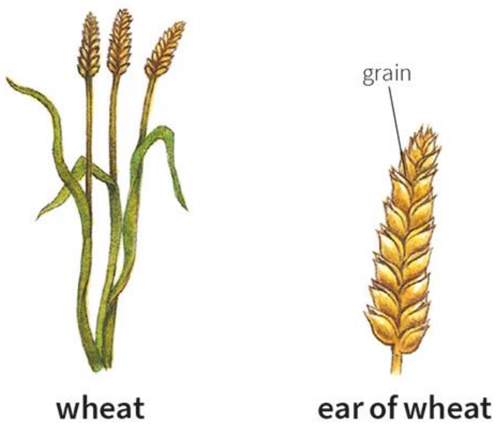
- Breed individuals by collecting sperm from bull

→ Can freeze and use later

→ Artificial inseminating defrosted semen into the cow during its fertile period

→ Can avoid inbreeding by referring to pedigree records

b) Disease resistance in varieties of wheat and rice



Wheat, *Triticum aestivum*

- Resistance to fungal diseases
- E.g. wheat rust

Rice, *Oryza sativa*

- Resistance to bacterial and fungal diseases
- E.g. bacteria blight, ‘spots’, ‘smuts’ and rice blast

Other desired traits in crop improvement:

- High yield… so bigger ears / more grains per ear / bigger grains
- Fast grow rates
- Tolerance to high temperature
- Pest-resistance
- Gluten-rich grain for bread flour

c) The incorporation of mutant alleles for gibberellin synthesis into dwarf varieties

Desired trait: **shorter stem, dwarf varieties in wheat**

→Greater proportion of energy put into grain instead of height = **higher yield**

→ Less susceptible to being knocked over by weather

→ Less straw produced

- Gibberellin (GA) stimulate stem elongation

→ Incorporate **mutant alleles for gibberellin synthesis into wheat** by crossing shorter plants

→ Mutant alleles are of the *Rht* (reduced height) gene

→ Mutant alleles code for faulty enzymes in GA synthesis pathway

→ **Inhibit gibberellin synthesis**

→ **DELLA protein not broken down** and continues to bind to transcription factor PIF

→ **Inhibit transcription of growth genes**

→ **Dwarf variety**

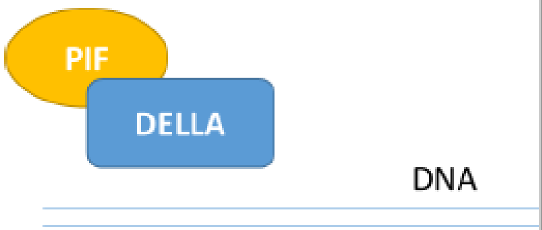
Role of Gibberellin in Stem Elongation

How it works

Chap 15 Recap

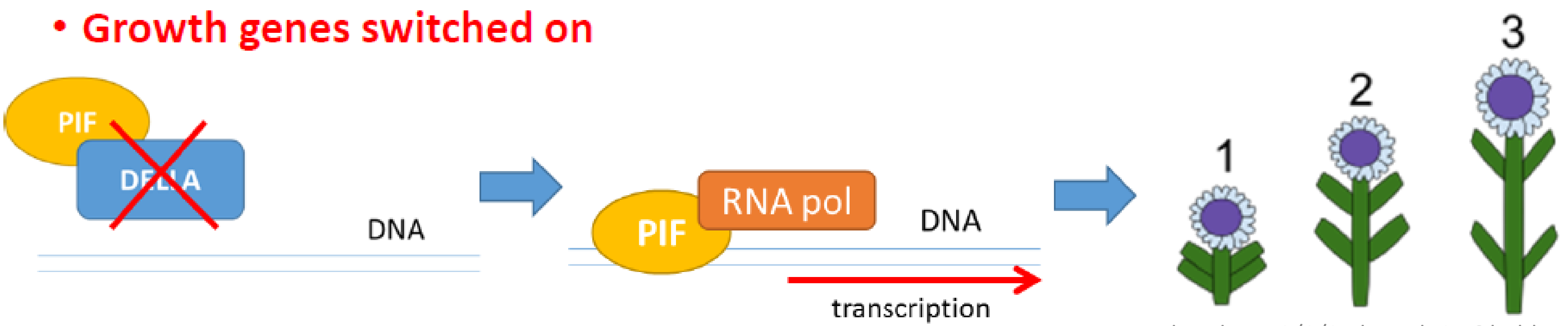
Without GA:

- **Transcription factor** (i.e. PIF) **attached to DELLA protein**
- PIF cannot bind to DNA



When GA binds to **receptor**:

- **causes DELLA protein destruction**
- inhibition of transcription removed
- PIF **binds to DNA**
- PIF recruits **RNA polymerase to bind to DNA**
- **Growth genes switched on**



d) Inbreeding and hybridisation of maize

Maize, *Zea mays*

- **Problem:** inbreeding leads to uniformity
- **Homozygous plants are less vigorous than heterozygous ones**
- Inbreeding caused plants of each gen to progressively become smaller and weaker (**inbreeding depression**)

- Outbreeding produces heterozygous plants that are healthier, grow taller and have high yields
- BUT problem! there will be no uniformity – hard to harvest and sell

Inbreeding depression

Updated on 12/8/21 by Beh SJ @behlogy

d) Inbreeding and hybridisation of maize

Solution: Inbreeding and hybridization!

1. Companies use **inbreeding** to produce **homozygous maize plants** of desired traits for many generations

→E.g. more kernels / big kernels / high yield etc.

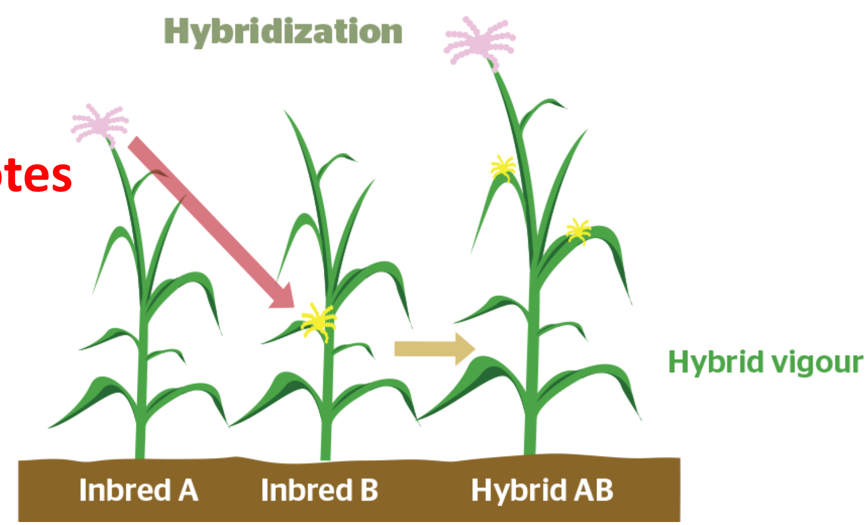
2. Cross-pollinate two inbred lines = **hybridisation**

→Produce **F1 seeds**

3. Farmers buy seeds and plant them

→ **F1 plants are all hybrids / heterozygotes**

- All have the same genotype
- Uniform!
- Has hybrid vigour



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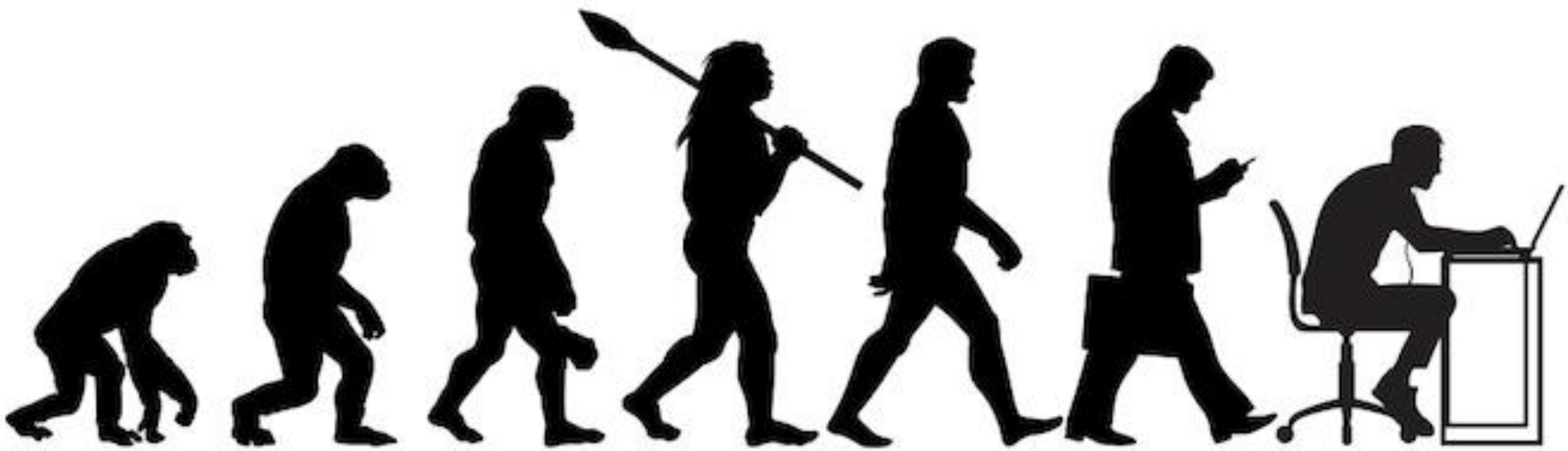
Chapter 17

Selection & Evolution

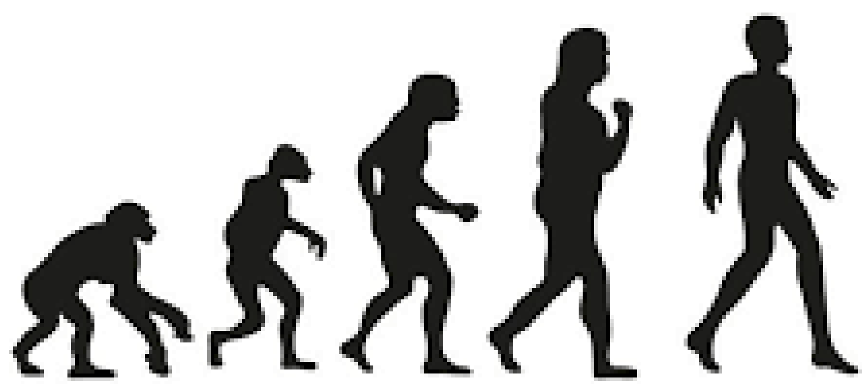
Part 3: Evolution



Chapter Outline

Part III: Evolution and Speciation

- Molecular evidence for evolution
- Allopatric vs sympatric speciation
- Extinction



Intro to Evolution

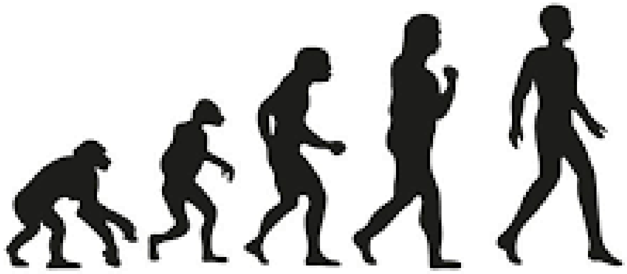
- Theory of **evolution** = idea that **organisms change over time**

Main ideas:

- Species have evolved over time **from pre-existing species**
- Organisms are descended from a **common ancestor**
- The more **closely related** the species is, the more recent the **common ancestor**
- Natural selection is a mechanism to explain how evolution can occur
- Genetic drift and artificial selection can change allele frequencies too!

- Molecular evidence for evolution is found in….

1. **Amino acid sequences of protein**
2. **Mitochondrial DNA (mtDNA)**



1) Amino acid sequences of protein

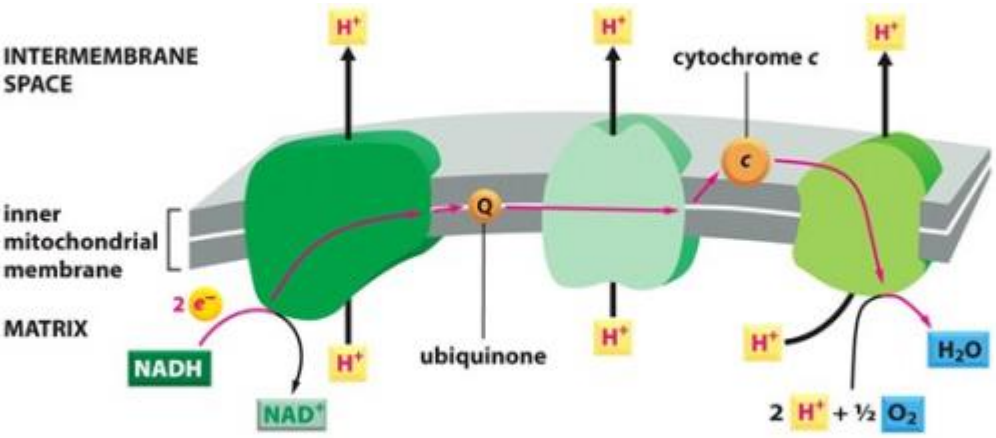
- **Compare amino acid seq** of 2 species
- **The more similar the amino acid seq, the more closely related the species**
- More similar amino acid sequence = less time has elapsed since the most recent common ancestor

Opticin protein	66 … 89
Human	NYGEVIDLS-NYEELTDYGDQLPEVKVTSLAP--ATSIS
Monkey	DNYGEVIDLSNYEELTDYGDQLPEVKVTSFAPATRISPA
Mouse	DYNEVIDLS-NYEELADYGDQIPEAKISNLTL--PTRIS
Rat	EDYSEVIDLSSYEELADYGDQIPEAKTSSPTLPTRTSPT
Cow	NYDEVIDPS-NYEELIDYGDQLPQVKGTSLAS--LTRTR
Dog	NYDEVIDLS-DYEGLMDYGDQLPEAKVTNLAP--PTGTS
Pig	SHDGVLDLS-NYEELMDYGDQLPKVKGASLAS--PTRAS
Duck	NYGDIMDLN-NYEELYDYGDLAPKIEVGTLAPRPKDRES
Frog_Xenopus	-YEESIDTG-KYVDLYDYYEHEPKTEVHTLTP--LNEKS
Zebrafish	DDPDSWDLHYNYDDEHEEVETVAPPTALTPPPAVVVPEN

1) Amino acid sequences of protein

E.g. Cytochrome c

- Electron carrier in the ETC
- Important proteins like these are highly conserved

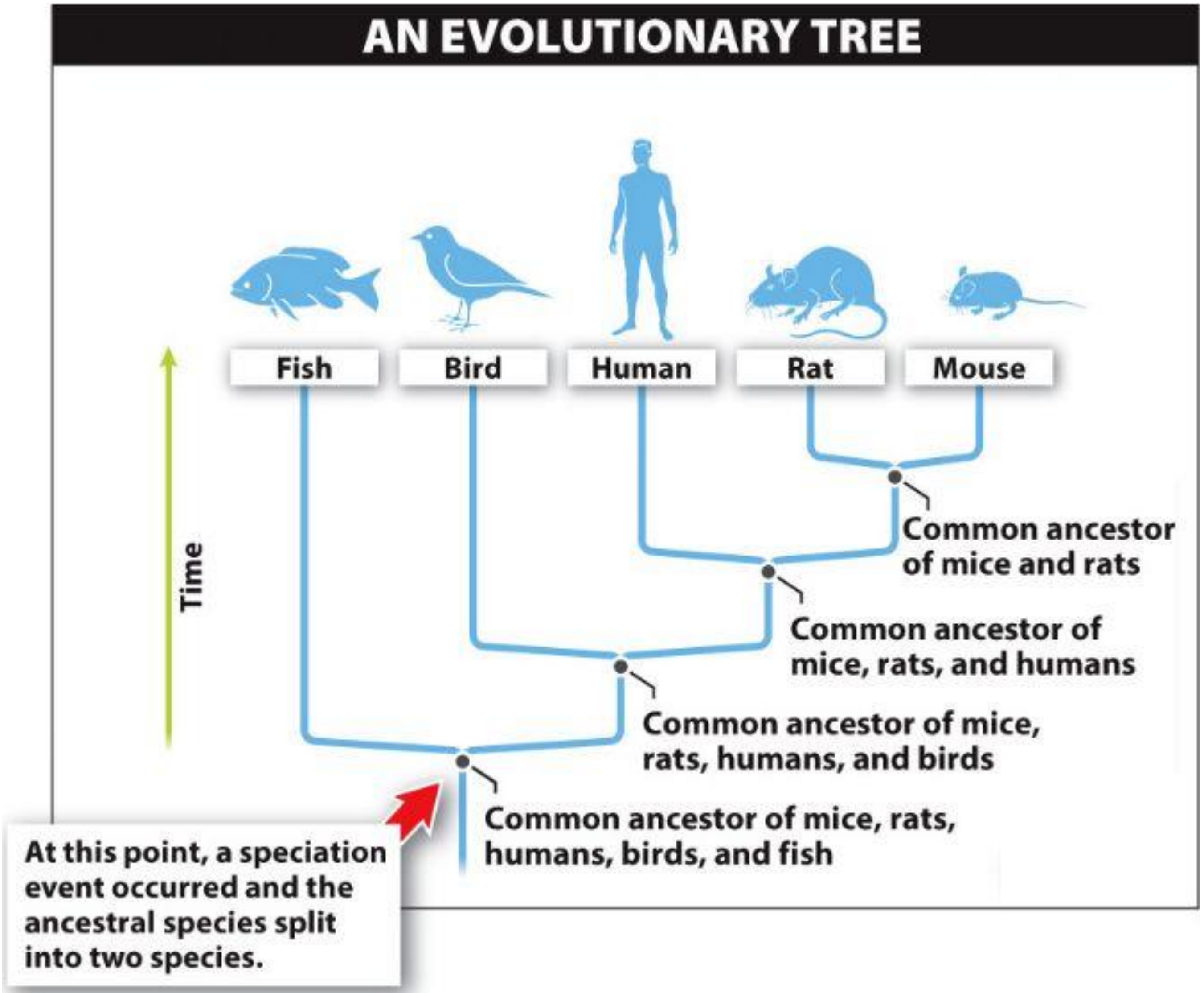


- Length and amino acid sequence for the protein are identical in rat and in mouse
- But human cytochrome c has 9 amino acids that are diff

→ Mouse and rat share a more **recent common ancestor**

→ Human is more **distantly related**

1) Amino acid sequences of protein



2) Mitochondrial DNA (mtDNA)

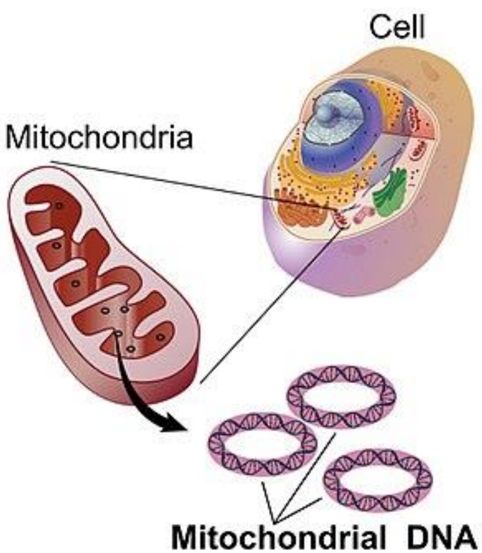
- Compare **nucleotide sequence in mtDNA** of 2 species
- **The less difference in nucleotide seq, the more closely related the species**
- Fewer mutations = less time has elapsed since the most recent common ancestor

Characteristics of mtDNA:

1. mtDNA is circular, **does not undergo crossing over**

2. Mutations occur at a **constant rate**

→Can act as a "molecular clock"



2) Mitochondrial DNA (mtDNA)

3. mtDNA **mutates faster** than nuclear DNA

→Changes only arise by **mutation**, and are **not repaired**

→ Not associated with histones

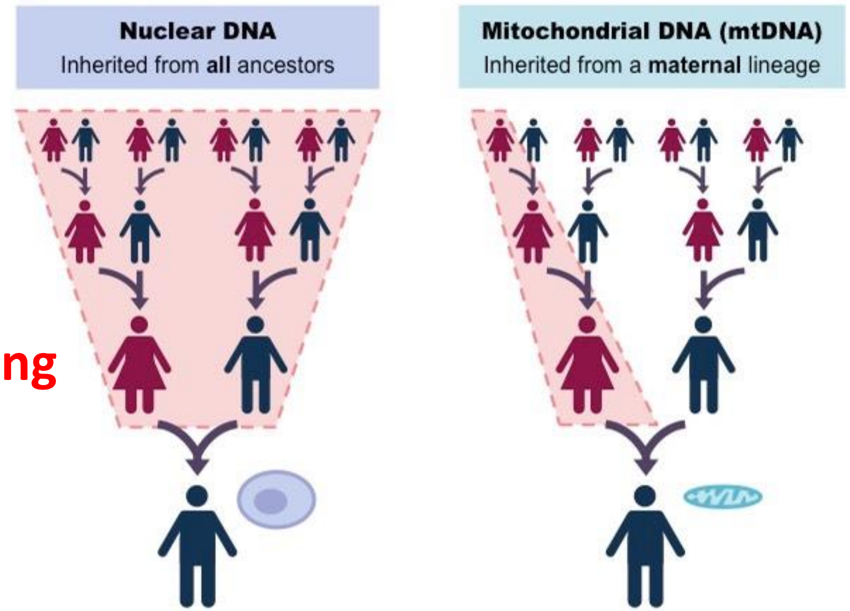
→ Oxidative phosphorylation can produce reactive oxygen species that can act as mutagens

4. **Smaller, has few genes**

→mtDNA analysis is quicker

5. mtDNA is passed from **mother to offspring**

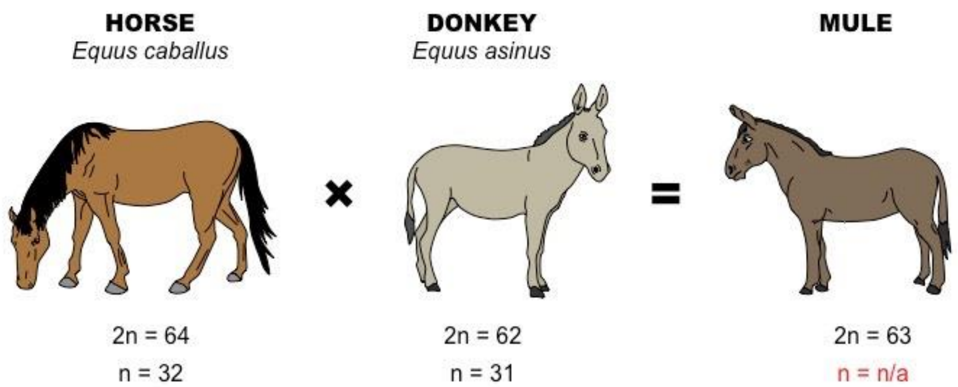
→ All descendants of one female have identical mtDNA



Species

Species: Group of similar organisms with the **same**

- morphological,
- physiological,
- behavioural,
- biochemical features,



- which can **interbreed** to produce **fertile offspring**
- i.e. **NOT reproductively isolated** from each other

- Members of one species are **reproductively isolated** from another species

Speciation

- Formation of a new species
- Speciation involves a reproductive barrier between populations

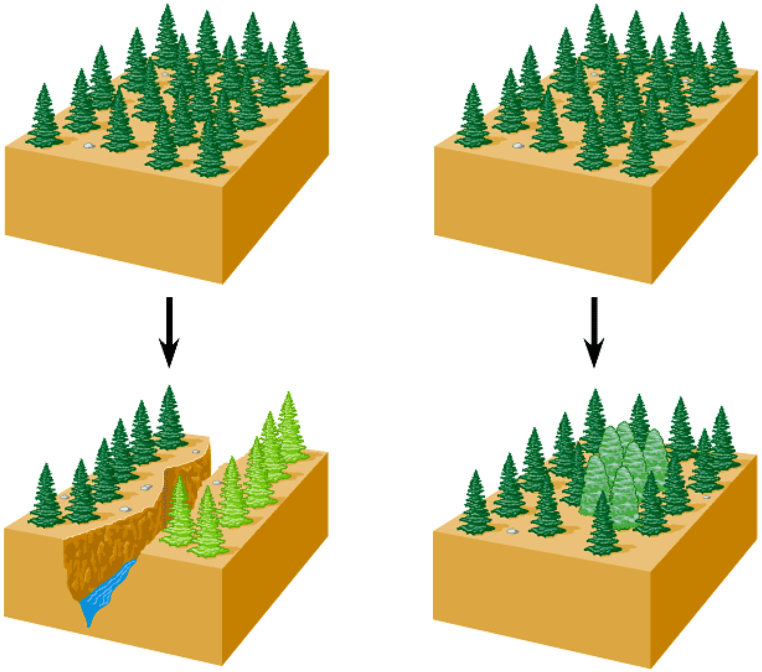
Two types of speciation:

1. Allopatric speciation

- Caused by geographical isolation

2. Sympatric speciation

- Same location



(a) Allopatric speciation (b) Sympatric speciation

Allopatric Speciation

- Speciation that occurs as result of geographical barrier of same species

1. Geographical barrier

- E.g. river, mountain, sea
- 2 populations of same species physically separated
- No breeding between populations = **no gene flow**
- Barrier prevents interbreeding between populations = populations **reproductively isolated**

Allopatric Speciation

2. Different selection pressures act on separated populations

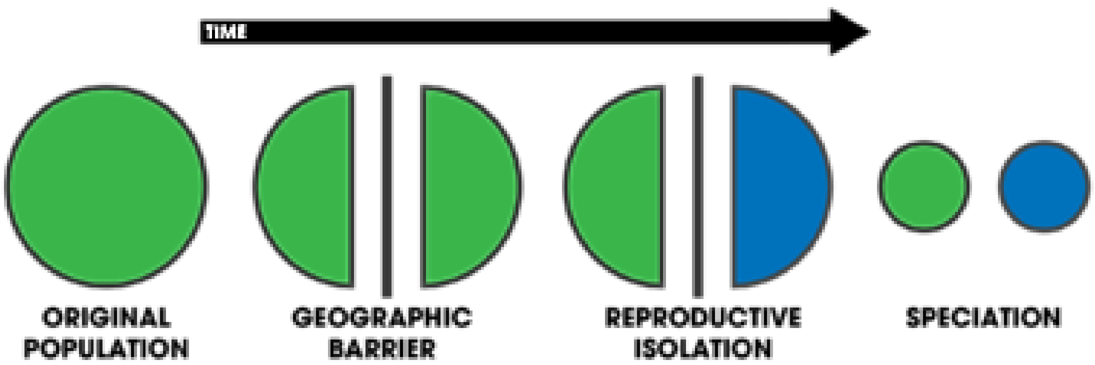
- Isolated population subjected to **different environmental conditions**
- Individuals with beneficial alleles are **selected for**

→ More likely to **survive and reproduce more**

→ **Pass on beneficial alleles** to offspring

→ **Change in allele frequency** / gene pool

- **Different mutations** occur giving rise to new alleles
- **Genetic drift occurs randomly** in separate populations

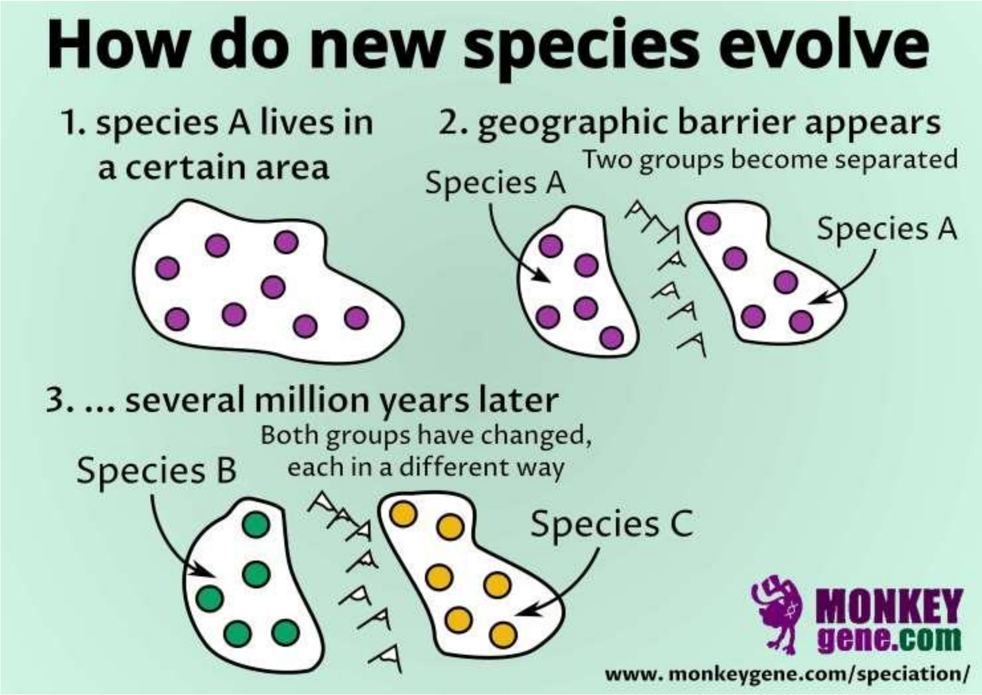


Allopatric Speciation

3. Over a long time / many generations…

- Populations have sufficient differences
- Populations are **unable to interbreed to produce fertile offspring = reproductively isolated**

→ **New species**



Allopatric Speciation

E.g. cormorants on the Galapagos island

- The islands' cormorants are flightless
- Originated from a flying cormorant species from the mainland

1. Geographical isolation

- Ancestral flying species reached the islands from the South American mainland
- No gene flow between 2 populations

Allopatric Speciation

2. Different selection pressures act on separated populations

On island…

- No predators / reduced predation
- Less selection pressure for efficient flight
- Still selection pressure for efficient movement underwater
- Birds that were better adapted for swimming selected for

3. Over time…

- Wings of cormorants reduced in size
- Allopatric speciation occurred

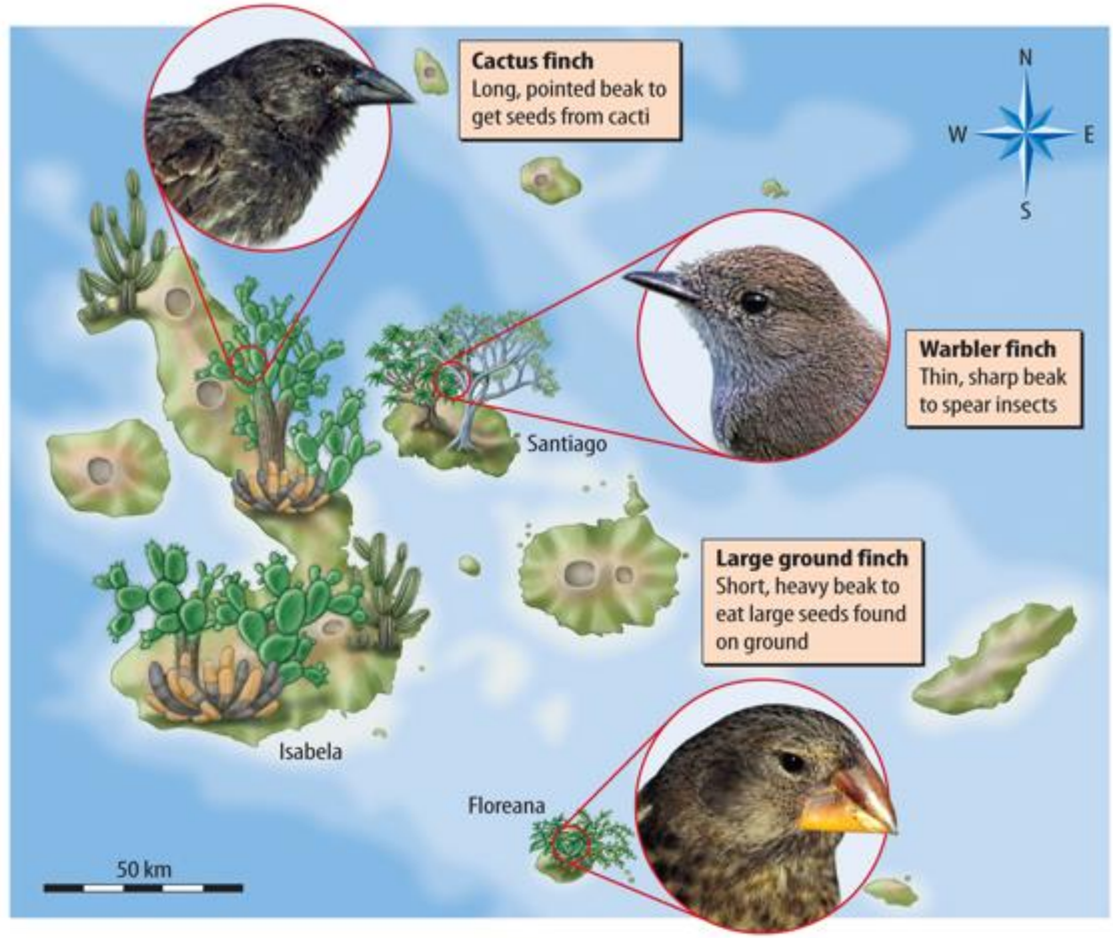
BUT…

- Recently, feral cats and dogs arrived on the island
- Selection pressure changed again
- Massive reduction in population – endangered species

Allopatric Speciation

E.g. Darwin's finches on the Galapagos islands

- About 18 different finches have the same common ancestor from mainland
- Each have different beak shape and size to adapt to their environment
- All reproductively isolated
- Geographical isolation happened several times!



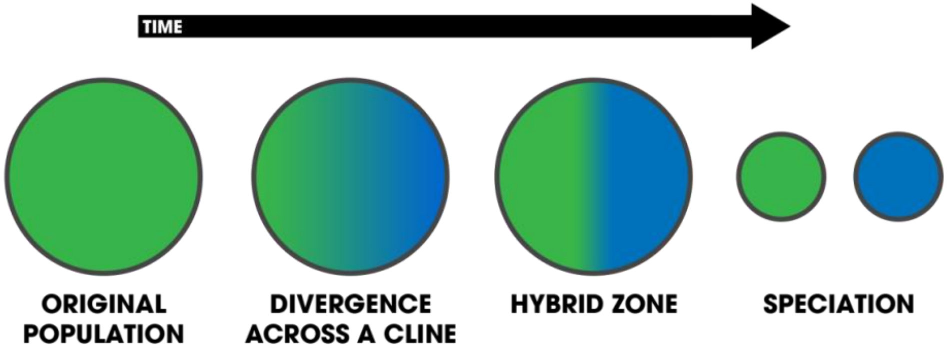
Sympatric Speciation

- **Same location**, no physical isolation

1. Different features / behaviour (or other isolating mechanisms) within a population

→ Cause populations to **not interbreed**

→ This is a **barrier to gene flow**



2. Over time…

- Change in allele frequency due to **genetic drift**

→ Cause populations to become **reproductively isolated**

→ Cannot breed as they are now different species

Sympatric Speciation

E.g. Polyploidy in plants

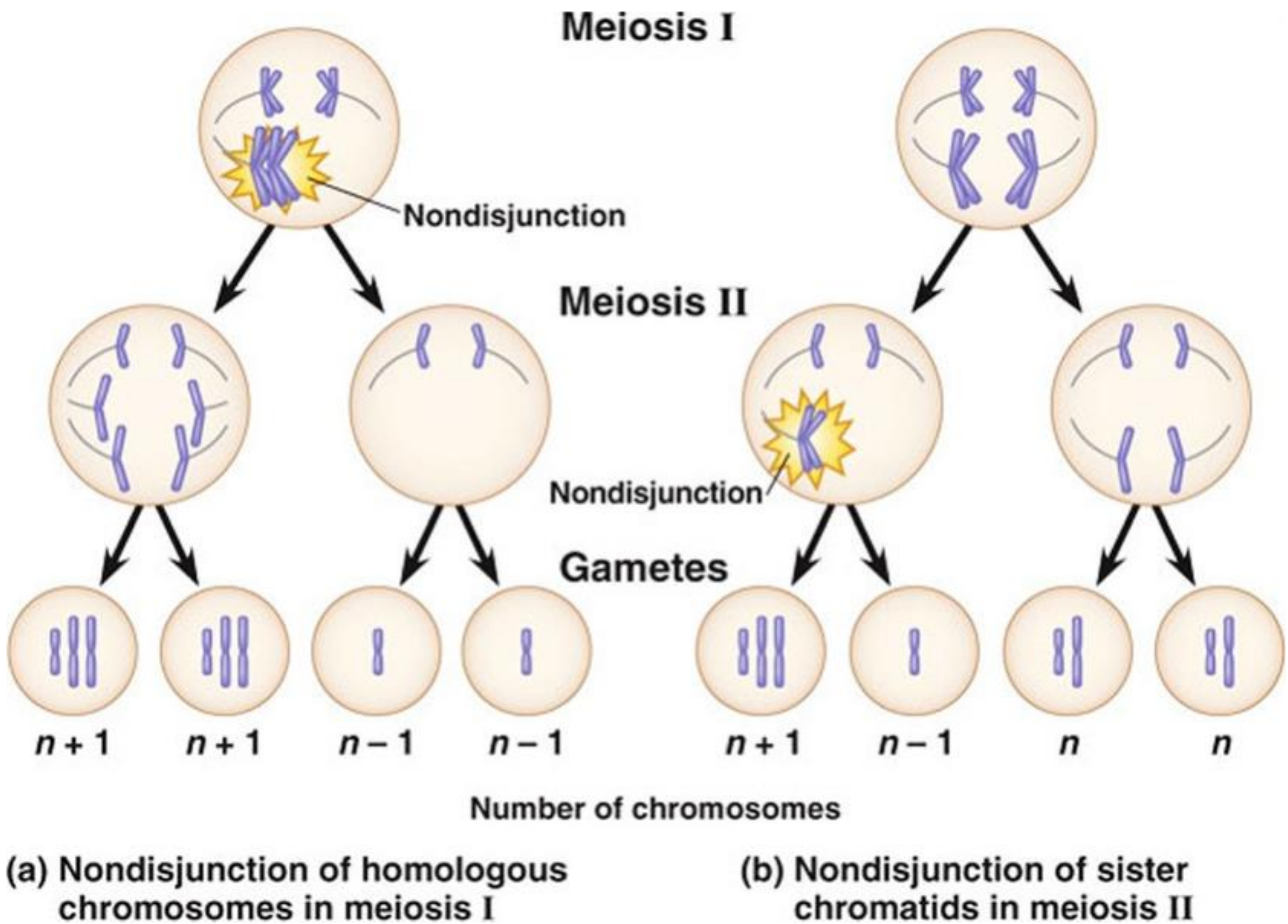
- Polyploid plants = **has more than two sets of chromosomes**

→ Result of **complete non-disjunction in meiosis**

→ **Chromosomes fail to segregate to opposite poles**

→ Result in gametes with extra/missing chromosome

Non-disjunction

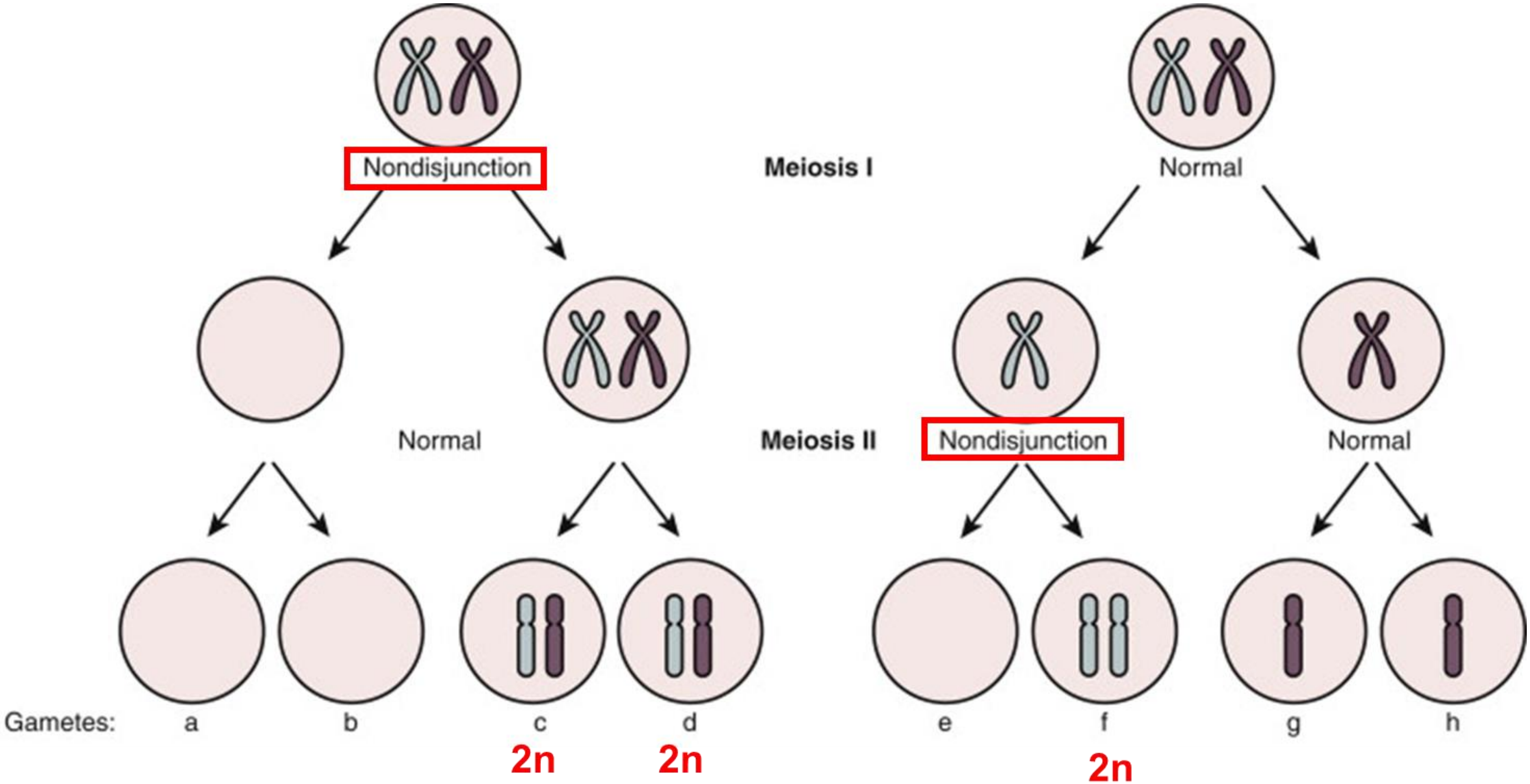


- **Non-disjunction** = chromosomes fail to segregate to opposite poles

→ Can cause an individual to have **extra/missing chromosomes**

→ Cause diseases like Down Syndrome, Triple XXX syndrome etc.

Complete Non-disjunction



Complete non-disjunction = **all** identical chromosomes fail to segregate to opposite poles

→ result in **diploid gametes**

→ if fertilised (2n + n), can result in trisomy (3n)

Sympatric Speciation

- In general, fusion of two mutated gametes result in:

→ New individuals with **different chromosome number** as parents

→ **Cannot interbreed** with original parent species

→ New species

Polyploid = has more than 2 sets of chromosomes

2 types:

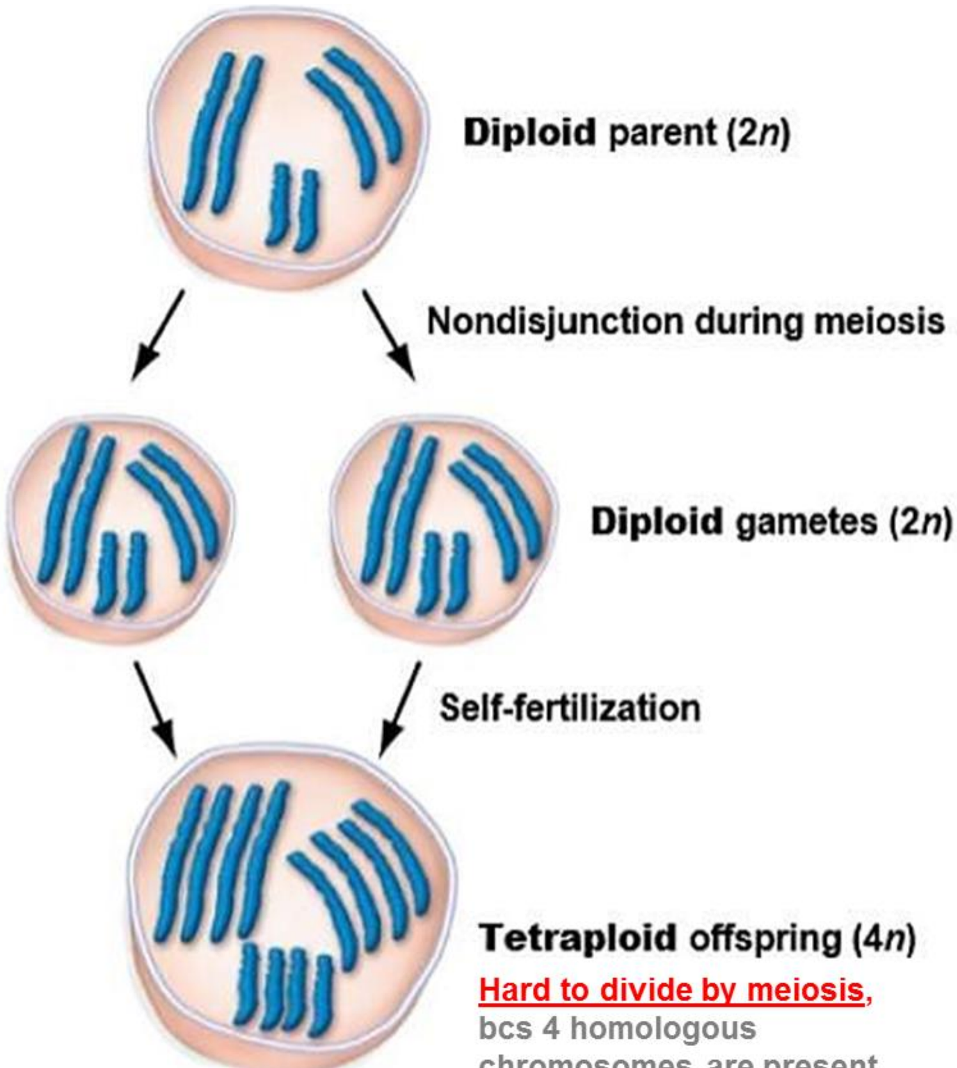
1) Autopolyploids

- Combination of chromosomes from the **same species**

2) Allopolyploids

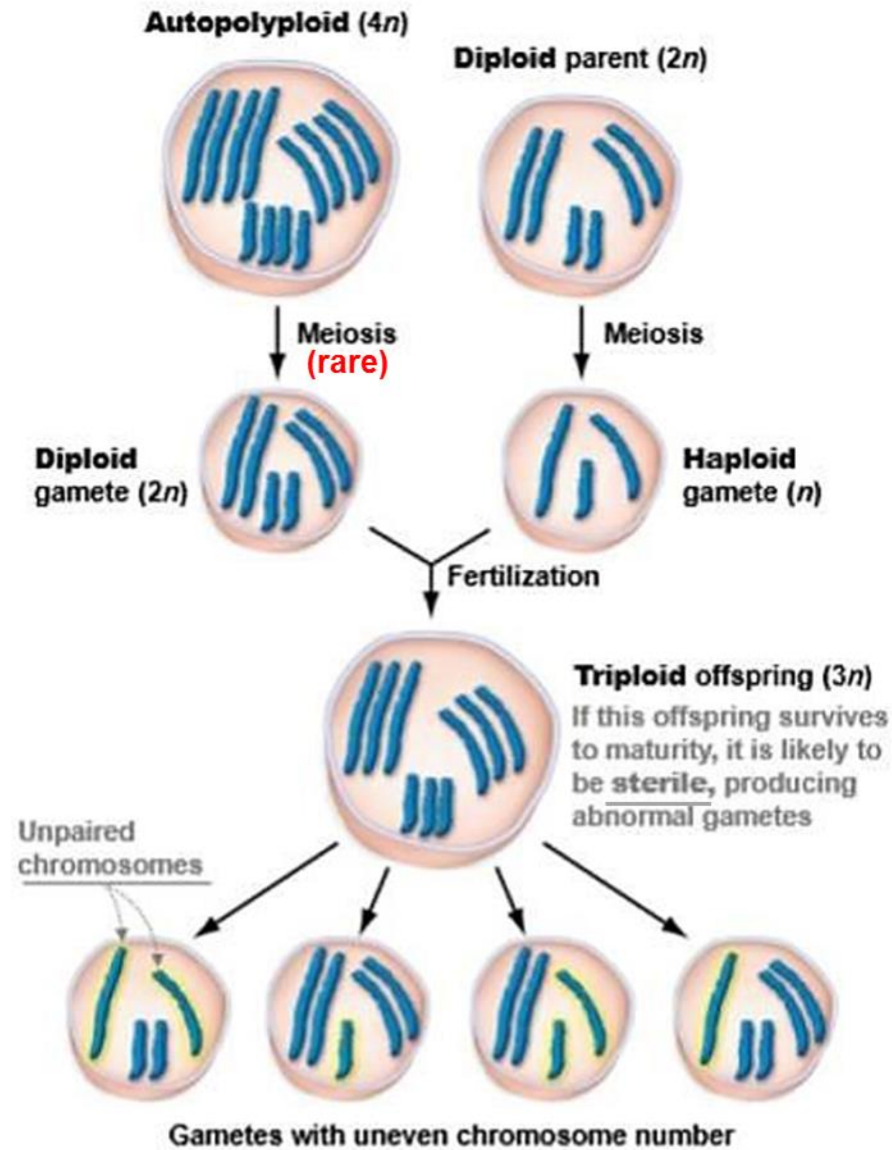
- Combination of chromosomes from two **different but closely related species**

Autopolyploid



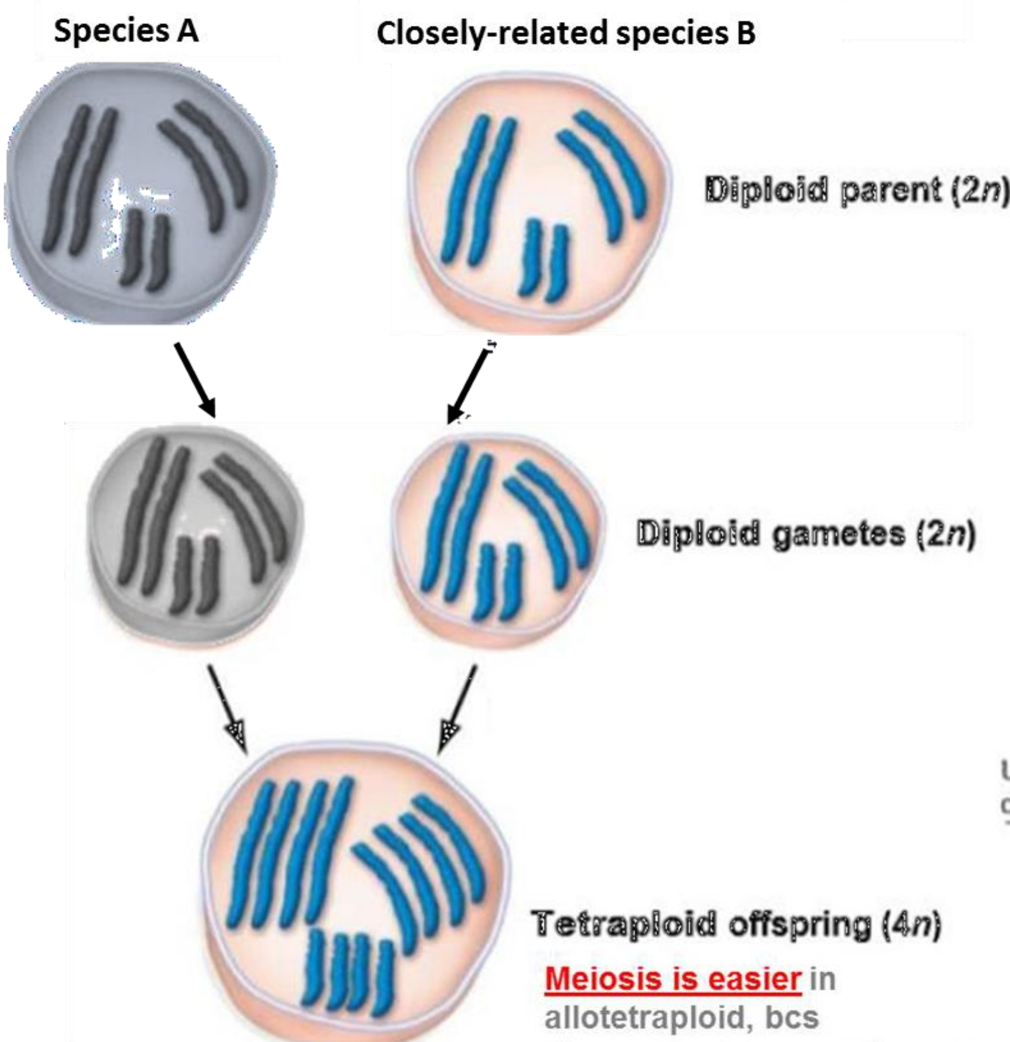
Hard to divide by meiosis, bcs 4 homologous chromosomes are present

It can grow and reproduce asexually by mitosis



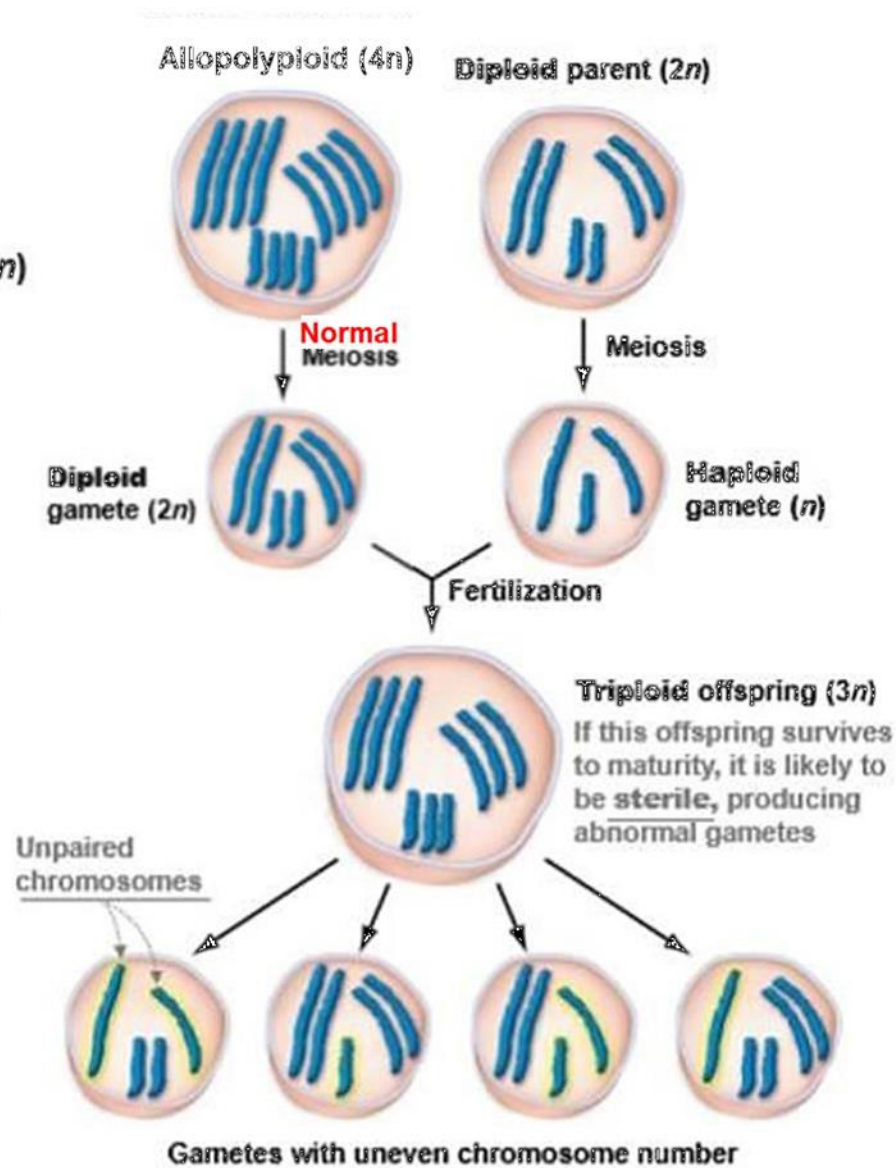
Diploid plant and autotetraploid plant cannot interbreed successfully → new species

Allopolyploid



Meiosis is easier in allotetraploid, bcs chromosomes are not identical

Allopolyploid is fertile



Diploid plant and allotetraploid plant cannot interbreed successfully → new species

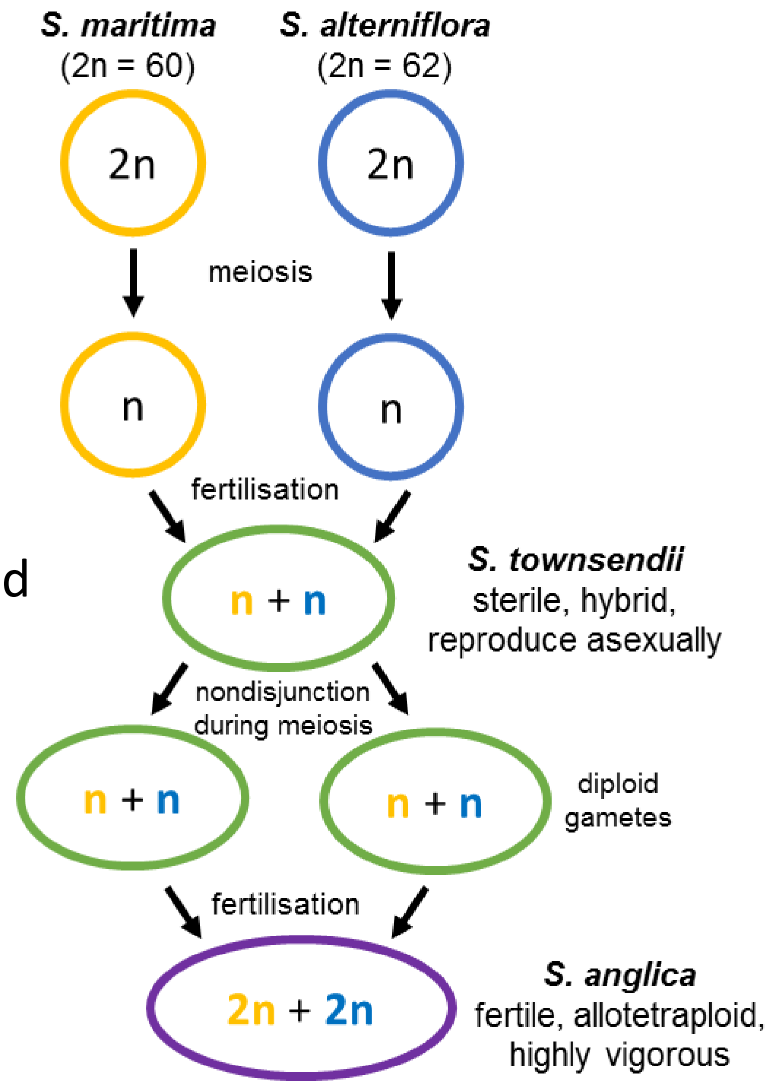
Updated on 12/8/21 by Beh SJ @behlogy

Sympatric Speciation

E.g. Allopolyploid plants – *Spartina* species

- *S. maritima* (from UK) and *S. alterniflora* (from US) is closely related
- *S. townsendii* (hybrid) formed from *S. maritima* and *S. alterniflora*
- *S. anglica* formed by speciation through alloploidy

- All 4 species of cordgrass cannot interbreed to produce fertile offspring



Extinction

- In past, mass extinction events were all natural
- E.g. due to severe changes to climate and physical conditions

- There were 5 previous mass extinction events

http://www.hhmi.org/biointeractive/mass-extinctions-interactive

- **Humans** may cause a 6th mass extinction event!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Science & Environment

Nature crisis: Humans 'threaten 1m species with extinction'

By Matt McGrath
Environment correspondent, Paris

6 May 2019

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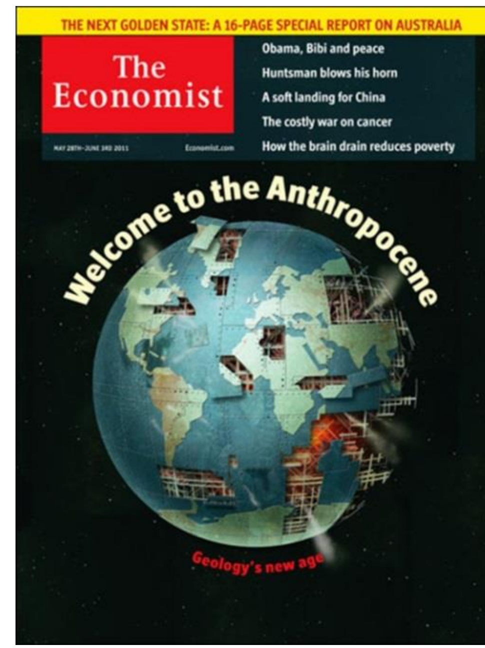
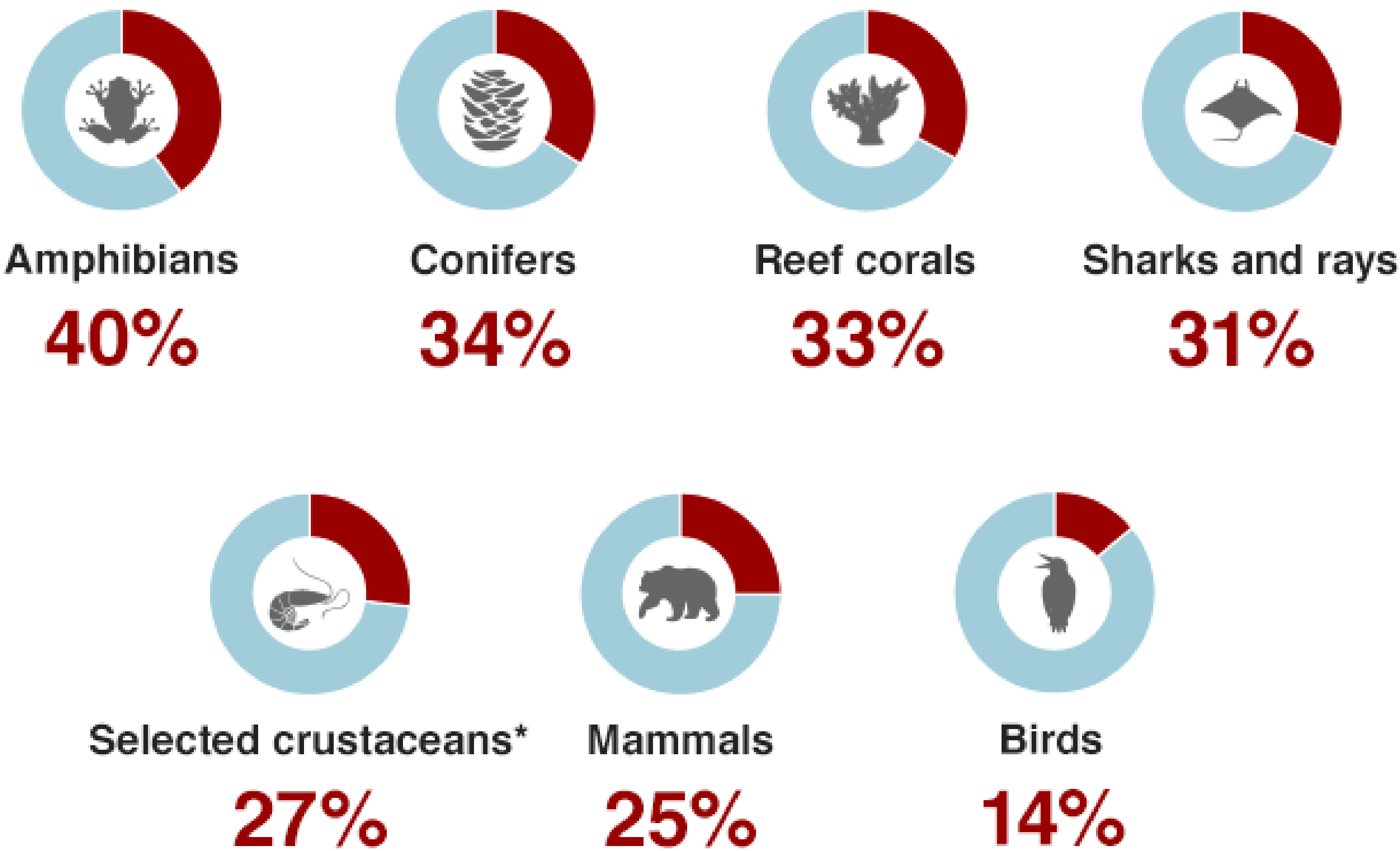
https://www.bbc.com/news/science-environment-48169783



Anthropocene = period during which human activity has been the dominant influence on climate and the environment.

One in four species are at risk of extinction

Species assessed by the IUCN Red List



*Assessed species include lobsters, freshwater crabs, freshwater crayfishes and freshwater shrimps

Source: IUCN Red List of Threatened Species

BBC

Updated on 12/8/21 by Ben SJ @behlogy

Extinction

- The **International Union for Conservation of Nature (IUCN)** is the world's largest global environmental organisation
- The IUCN Red List of Threatened Species™ evaluates the conservation status of plant and animal species
- Some endangered species are high profile, others less photogenic so not enough publicity

https://www.iucn.org/resources/conservation-tools/iucn-red-list-threatened-species

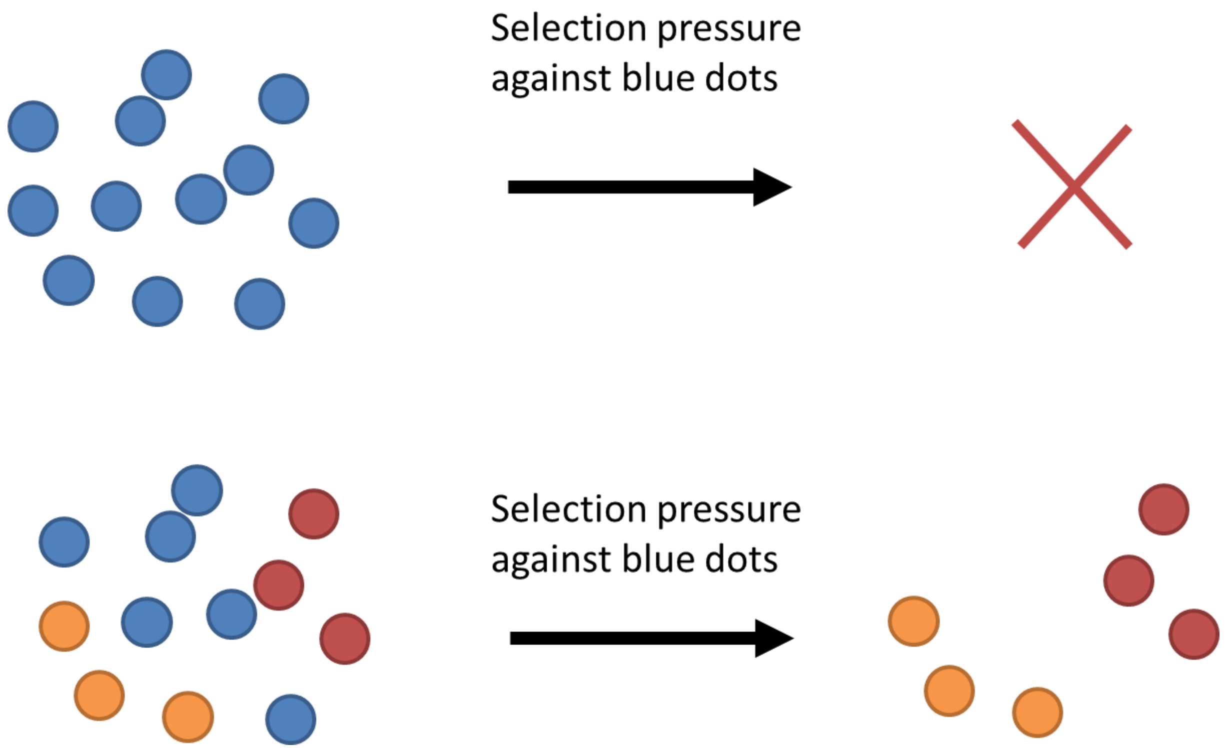
Extinction is largely due to:

- **Increased competition** from a better-adapted species (interspecies)
- **Habitat loss**
  - Draining wetlands
  - Cutting down rainforests
  - Pollution of air, water, and soil
- **Hunting/killing/poaching** for sport or food or medicine
- **Climate change**

Extinction

Which species are more likely to be affected?

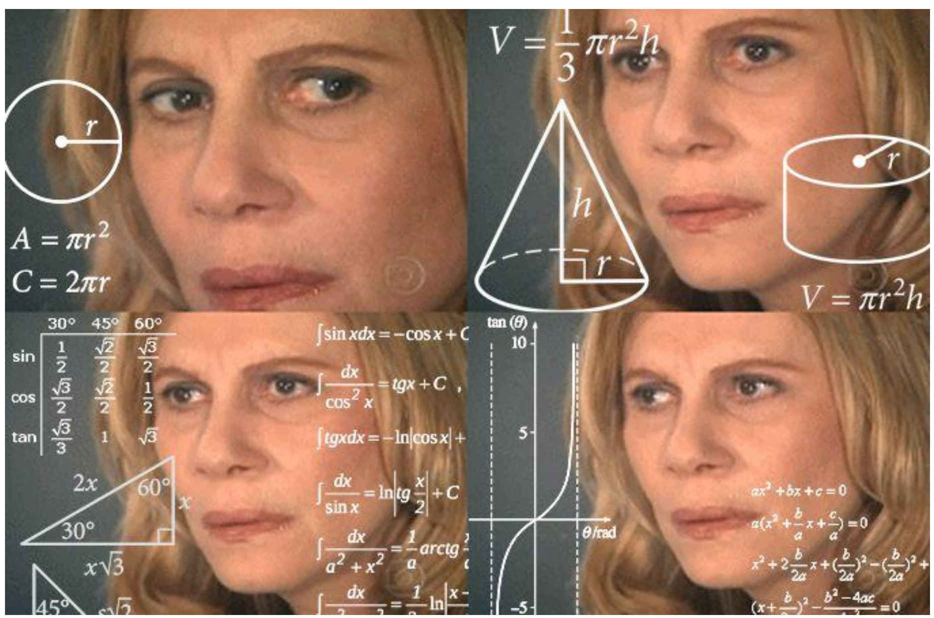
- **Smaller populations** are less resilient than larger populations
- **Populations with reduced genetic diversity face increased risk of extinction**



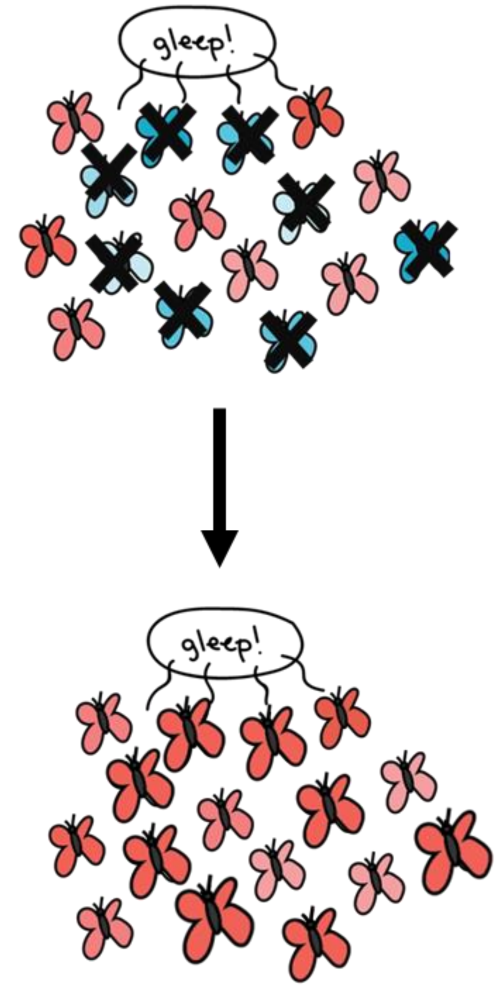
Chapter Outline

Part I: Variation

- Phenotype results from interaction of genotype and environment
- Continuous vs Discontinuous Variation
- Examples on how the environment influences phenotype
- **P5:** std dev, std error and error bars, t-test



Chapter Outline



Part II: Natural Selection

- Importance of genetic variation in selection
- Stabilising, disruptive and directional selection
- Examples for evolution by natural selection
    - Antibiotic resistance in bacteria
    - Industrial melanism in peppered moth
    - Sickle cell anaemia
- The Hardy-Weinberg principle
- Genetic drift and founder effect
- Selective breeding / Artificial selection
    - Milk yield of dairy cattle
    - Disease resistance in varieties of wheat and rice
    - Incorporation of mutant alleles for gibberellin synthesis into dwarf varieties
    - Inbreeding and hybridisation of maize

Chapter Outline

<u>Part III: Evolution and Speciation</u>

- Molecular evidence for evolution
- Allopatric vs sympatric speciation
- Extinction