17 - Selection & Evolution

17.1 VARIATION

A) CONTINUOUS & DISCONTINUOUS VARIATION

→ genetic variation among individuals in a population is caused by -

| | | |
|---|---|---|
| (1) | independent assortment | Reshuffle existing alleles, produces phenotypic variation |
| (2) | crossing over | |
| (3) | random mating between organisms | |
| (4) | random fertilisation | |
| (5) | mutation | |

MUTATIONS

| gene mutation | somatic cells |
|---|---|
| * can produce NEW alleles | * often no effects on the organism |
| * often recessive, therefore does not show up in population | * cannot be passed on to offspring by sexual reproduction |
| | * however mutations in gonads may be inherited e.g. if the cell containing the mutation divides to form gametes |

- genetic variation can be passed to offspring, giving differences in phenotype
- genetic variation provides the raw material on which natural selection can act
- variation in phenotype is also caused by the environment (but this is NOT passed to offspring)

→ DISCONTINUOUS VARIATION - qualitative differences

× no intermediates

× e.g. blood group, inheritence of haemophilia, sickle-

× genetic basis -

① different alleles at a single gene locus have large effects on the phenotype

② different genes have quite different effects on the phenotype

→ CONTINUOUS VARIATION - quantitative differences

× many intermediates

× e.g., height, weight

× genetic basis

① different alleles at a single locus have small effects on the phenotype

② different genes have the same / additive effect on the phenotype

③ POLYGENES :- a large no. of genes may have a combined effect on a particular phenotype

↳ Google :- a gene whose individual effect on a phenotype is too small to be observed, but which can act together with others to produce observable variation

→ FACTORS THAT TEND TO REDUCE PHENOTYPIC VARIATION

① dominance

② gene interaction

b) ENVIRONMENTAL EFFECTS ON PHENOTYPE

→ environmental effects may allow the full genetic potential height to be reached or stunted in some way

* e.g., an individual w/ less food / nutritious food

e.g.) ANIMALS - hair colour of himalayan rabbits, etc

→ development of dark extremeties

→ caused by an allele that allows formation of dark pigments only at low temp.

e.g.) PLANTS - cob length of BLACK MEXICAN & TOM THUMB maize plants

→ difference in light intensity & nutrients will lead to different growth of plants with the genetic combination

→ we t-test to compare variation of 2 different populations

c) t-TEST TO COMPARE VARIATION

→ used to determine if there's a significant difference between the means of 2 groups

* data collected should be continuous data

* data is from a population that is normally distributed

① STATE THE NULL HYPOTHESIS

* there is no significant difference between the 2 means we are comparing

② CALCULATE THE t-VALUE

$$t = \frac{|\bar{x}_A - \bar{x}_B|}{\sqrt{\left(\frac{\sigma_A^2}{n_A} - \frac{\sigma_B^2}{n_B}\right)}}$$

(given)

$\bar{x}$: mean; $\sigma$: sd; $n$: sample size

③ calculate degree of freedom
$= (n_A + n_B) - 2$

④ find critical value @ $P = 0.05$ (95% confident value)

⑤ COMPARE CALCULATED t & critical t VALUE

→ if calculated t > critical t, then p is less than 0.05. Null hypothesis is rejected

→ if calculated t < critical t, Null hypothesis is accepted

* The difference between means is insignificant, small diff. in them is due to chance (e.g., sampling error) & can be neglected

d) IMPORTANCE OF GENETIC VARIATION IN SELECTION

* genetic variation provides the raw material which natural selection can act

* variation within a population means that some individuals have features that give them an advantage over other members of that population

F.2 NATURAL & ARTIFICIAL SELECTION

a) WHY NATURAL SELECTION OCCURS

* all organisms have the reproductive potential to increase their populations

* however, over time their population oscillates about a mean level

① Natural selection occurs as populations have the capacity to produce many offsprings

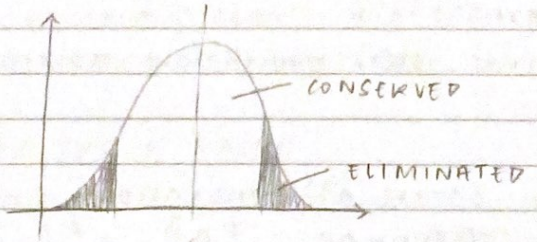
② Offsprings compete for resources

③ individuals best adapted to survive breed & pass on their alleles

- Environmental factors
  - BIOTIC - caused by other organisms
    - e.g. - predation, food competition, infection by pathogens
  - ABIOTIC - caused by non-living components of the environment
- Selection pressure - factors that contribute to selecting which variations will provide the individual with an increased chance of surviving over others
  - e.g animals w/ coat colour matching env. survive & pass on alleles
  - → selection pressures control the chances of alleles being passed onto the next generation
- natural selection - effects of selection pressures on the frequency of alleles in a population
  - → natural selection raises the frequency of alleles that are advantageous, & reduces the disadvantageous ones

## TYPES OF SELECTION

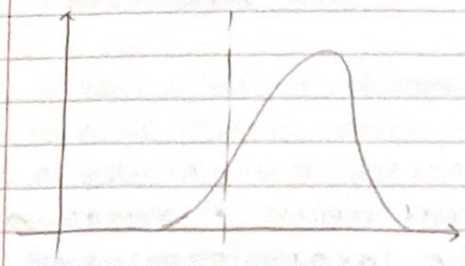
1. Stabilising selection
   - status quo is maintained as organisms are already well-adapted to their environment
   - acts against extremes
   - favours the environment




   - e.g., birth weight

② Directional selection

> the most common varieties of an organism are selected against → change in features of the population



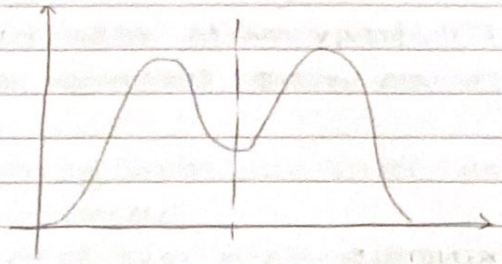
× favours variants of 1 extreme when new allele/env. factor appears

× e.g. peppered moths

③ Disruptive selection

> occurs when conditions favour both extremes of a population

× different phenotypes (polymorphism) is maintained in the population



× e.g. galapagos finches

! changes in environmental factors only affect the likelihood of an allele surviving in a population

↳ then do not affect the likelihood of an allele arising by mutation

c) FACTORS AFFECTING ALLELE FREQUENCY IN POP

① genetic drift
- change in allele frequency
- occurs by chance, as only some of the organisms of each generation reproduce
- most noticeable in small populations

↳ ② the founder effect
- e.g., of genetic drift that occurs when a small group of individuals breaks off from a larger population to establish a colony
- alleles in the founding population may be present at different frequencies or missing altogether
- evolution of this population may take a different direction from the larger, parent population

③ natural selection
- causes changes in allele frequencies with fitness-increasing alleles becoming more common in the population

d) THE HARDY-WEINBURG PRINCIPLE
- a formula used to calculate allele, genotype or phenotype frequencies in a population when a certain criteria are fulfilled -

① no mutation (no change to type of alleles in population)
② no natural selection (environmental factors do not favour an allele over the other)
③ population is infinitely large (as its not possible for allele frequencies to be maintained in a small population)
④ no non-random breeding (all members with different characteristics have equal chance to breed)
⑤ no significant selective pressure against one of the genotypes
⑥ no migration (no change in population size)

frequency of DOMINANT → $p$

frequency of RECESSIVE → $q$

$[p + q = 1]$ → TOTAL POPULATION

} allele frequencies

$[p^2 + 2pq + q^2 = 1]$ } genotype frequencies

* A calculation of the chance of a certain combination of genes occuring in a population
* A population's allele & genotype frequencies are constant, unless there is some sort of evolutionary force acting upon them

e) IMPROVING MILK YIELD BY ARTIFICIAL SELECTION

> ARTIFICIAL SELECTION - humans purposefully applying selection pressures to populations

① selective breeding :- individuals w/ desirable features are chosen to interbreed
② some of these desirable alleles are passed onto offspring
③ offspring with the most desirable features r chosen to interbreed
④ repeated over many generations

* over generations, alleles deemed 'desirable' increase in frequency while the 'disadvantageous' ones may completely disappear

- DIARY CATTLE -

o Desirable features - ① Docility, ② fast growth rate, ③ high milk yields

- PROBLEMS ASSOCIATED W/ SELECTIVE BREEDING :-

① Animals are large
② takes a long time to reach maturity
③ gestation period long
④ no. of offspring produced is small

- bulls cannot be assessed for milk production as it's a sex-limited trait
- ∴ PROGENY TESTING is used
- progeny testing - measure of the bull's value to a breeder, checking the performance of a bull's female offspring to see if it should be used in future crosses

- background alleles have to also be considered by the breeder
- BACKGROUND GENES - all the alleles of genes within each organism's genotype that adapt it to its particular environment

f) CROP IMPROVEMENT

- introduction of disease resistant varieties of wheat & rice
- to reduce loss of yield resulting from such infections

- the incorporation of mutant alleles for gibberellin synthesis into dwarf varieties so increasing yield by having a greater proportion of energy put into grain
- most dwarf varieties carry mutant alleles of 2 reduced height (RHT) genes
- the genes code for DELLA proteins which reduce effect of gibberellin on growth
- another mutant allele of a diff gene has its dwarfing effect as plant cells don't have receptors for gibberellins

- inbreeding & hybridisation to produce vigorous, uniform varieties of maize
- when maize plants are inbred, the plants in each generation become progressively smaller & weaker
- this INBREEDING DEPRESSION occurs because homozygous plants are less vigorous than heterozygous plants
- challenge when growing maize :- heterozygosity & uniformity

x SOLUTION - HYBRIDISATION
↳ using maize seeds that produce homozygous plants
↳ these homozygous varieties are crossed, producing F1 that all have the same genotype

- IDEAL MAIZE CHARACTERISTICS -
① high yields
② resistance to more pests & diseases
③ good growth in nutrient-poor soils / short water supply

17.3 - EVOLUTION
A) GENERAL THEORY OF EVOLUTION
↳ organisms have changed over time

① organisms produce more offspring than are needed to replace the parents
② natural populations tend to remain stable in size over long periods
③ there is competition for survival / struggle for existence
④ There is variation among the individuals of a given species
⑤ The best adapted variants will be selected for by natural conditions operating at the time / natural selection occurs / survival of the fittest

b) MOLECULAR COMPARISONS BETWEEN SPECIES
• molecular evidence from comparisons of the amino acid sequences of proteins & nucleotide sequences of mitochondrial DNA can be used to reveal similarities between related species

① COMPARING AMINO ACID SEQUENCES OF PROTEINS
> when the amino acid sequence of a particular protein is compared in different species, the number of differences gives a measure of how closely related the species are

② COMPARING NUCLEOTIDE SEQUENCES OF MITOCHONDRIAL DNA

> differences in the nucleotide sequences of mtDNA can be used to study the origin & spead of our own species

→ HUMAN mtDNA:-

① inherited through female line (why? they don't really know)

② a zygote contains mitochondria of ovum & not sperm

③ mtDNA is circular so can't undergo any form of crossing over ∴ changes in nucleotide sequence can only occur by mutation

→ Different human populations show differences in mitochondrial DNA sequences

→ these provide evidence for the origin of different populations

→ 'MOLECULAR CLOCK' HYPOTHESIS

> a technique that uses the mutation rate of biomolecules to deduce the time in prehistory when 2 or more life forms diverged

* assumes a constant rate of mutation over time

* the greater the number of differences in the sequence of nucleotides, the longer ago those individuals shared a common ancestor

* 'clock' can be estimated from fossil evidence

c) SPECIATION

> how new species can be produced

> SPECIES - a group of organisms with similar morphological, physiological, biochemical & behavioural features, which can interbreed to produce fertile offspring & are reproductively isolated from other species

① ALLOPATRIC SPECIATION (geographical separation)

> speciation that occurs when 2 populations are separated from each other geographically

① population of species splits & move to different areas

② each new population experiences different selective pressures causing morphological, physiological & behavioral features to change

③ when the different populations are re-introduced, they can no longer interbreed

② SUMPATRIC SPECIATION (ecological & behavioural separation)

→ usually occurs through POLYPLOIDY

> POLYPLOIDY ORGANISM - has more than 2 complete sets of chromosomes in its cell

→ this occurs e.g., when meiosis goes wrong

> TETRAPLOID - when 2 diploid gametes fuse (2+2 = 4) & zygote gets 4 complete sets of chromosomes

→ often sterile as its difficult for 4 pairs of chromosomes to pair during meiosis I

→ however the tetraploid cell may grow & reproduce asexually

→ occurs often in plants but rarely in animals

> TRIPLOID - when a tetraploid's gametes (diploid) fuses with a normal, haploid gamete (2+1 = 3)

→ it may be able to grow normally but ALWAYS sterile as it can't form gametes (cannot share 3 sets of chromosomes equally between daughter cells)

→ KINDS OF POLYPLOIDIES

① AUTOPOLYPLOID - all sets of chromosomes from the same species

② ALLOPOLYPLOIDS - different sets of chromosomes from a different but related species

- meiosis happens more easily in an allotetraploid than in an autotetraploid as the chromosomes are not quite identical
- allotetraploid can be fertile & produce gametes

d) PRE & POST-ZYGOTIC ISOLATING MECHANISMS

> REPRODUCTIVE ISOLATION - the inability of 2 organisms of the same species to interbreed due to geographical separation or behavioural differences

Reproductive isolation can take place -

① PRE-ZYGOTIC ISOLATION

→ individuals not recognising one another as potential mates or not responding to mating behaviour
→ animals being physically unable to mate
→ incompatibility of pollen & stigma
→ inability of male & female gametes to fuse

② POST-ZYGOTIC ISOLATION

→ failure of cell division in zygote
→ non-viable offspring
→ viable, but sterile offspring

* post-zygotic isolation is more wasteful of energy

e) EXTINCTION

① climate change
② competition (from better adapted species)
③ Habitat loss
④ killing by humans } human causes