Genetics

Genetics : Its branch of biology that deals with study of 'Heredity' (mechanism of in inheritance) and 'Variation'

The term Genetics was coined by 'William Bateson' at Conference of Plant Breeding in 1906.

The word "Genetics" is derived from the Greek root 'Gen' meaning to become or grow into.

1. **Mendelian Genetics :** Study of heredity of clear cut and contrasting characters ‘ Mendelian Traits’ like eye colour, feather pattern.
2. **Quantitative Genetics :** Biometry is branch deals with quantitative characters. The study when extended to group of individuals or a population, it gets the name as “ Population Genetics” .
3. **Cytogenetics :** A close study of structure and functions of the cell, in particular related to Chromosomes, with reference to heredity is known as Cytogenetics.
4. **Molecular Genetics :** It deals with the study of chemical structure of hereditary material in relation to control of cell activity.

History of Genetics

People have known about inheritance for a long time.

- --children resemble their parents
- --domestication of animals and plants, selective breeding for good characteristics
- --Sumerian horse breeding records
- --Egyptian data palm breeding
- --Bible and hemophilia

Old Ideas

Despite knowing about inheritance in general, a number of incorrect ideas had to be generated and overcome before modern genetics could arise.

All life comes from other life. Living organisms are not spontaneously generated from non-living material. Big exception: origin of life.

Species concept: Offspring arise only when two members of the same species mate. Monstrous hybrids don't exist.

Pythagoras : proposed life comes from moist vapours which descends form brain, nerves and other parts of the body of male.

Aristotle : Female furnished the building material, while male furnished the life giving power dynamics.

Preformation Theory : Dutch Scientist, Jan Swamerdam developed the idea that in each sperm (or egg) is a tiny, fully-formed human that merely grows in size.

Regenier de Graaf : Rejected Preformation theory. Fusion of egg and sperm contribute to formation of Embryo. Organisms develop by expressing information carried in their hereditary material.

Robert Hooke (1635-1703), a mechanic, is believed to give '**cells**' their name when he examined a thin slice of cork under microscope, he thought cells looked like the small, rectangular rooms monks lived.

1735 CV Linnaeus (originally Linne) proposes the taxonomic system including the naming of Homo sapiens.

1761-7 JG Kolreuter finds in experiments on Nicotiana that each parent contributes equally to the characteristics of the offspring.

Theory of Lamarckism : Use and disuse of organs or body parts and inheritance of acquired characters.

1831 Robert Brown notes nuclei within cells;

1839 MJ Schleiden & T Schwann develop the cell theory

All animals and plants are made up of cells. Growth and reproduction are due to division of cells.

1859 C Darwin publishes *The Origin of Species / The theory of evolution of theory of pangenesis :*

The organisms steadily evolve over time (evolution theory)
Struggle for existence or survival of the fittest i.e natural selection theory.

Theory of pangenesis : Every cell of the organs produced minute particles known as ‘ Pangenes” which are carried through blood and reproductive cells also contain these pangenes. They conjoin to form the new cells and tissues resulting in new individual, due to blending qualities of both parents.

1865 Gregor Johann Mendel presents his principals of heredity [particulate inheritance] to the Brunn Society for Natural History and publishes in the Proceedings of the Brunn Society for Natural History in the following year [CPG p.1] (Brunn is now Brno in Czech Republic).

1875 F Galton demonstrates the usefulness of twin studies for elucidating the relative influence of nature (heredity) and nurture (environment) upon behavioural traits.

Germplasm Theory 1882 August Weismann : Notes the distinction between somatic and germ cells; Every organism is constituted of somatoplasm which makes body tissue and germplasm found in germinal tissue, restricted to goads. Germplasm is immortal and somatoplam is transient. A new individual is produced by intermingling of germplasm of both parents.

1887 A Weismann postulates the reduction of chromosome number in germ cells

Karl Pearson publishes his first contribution to the mathematical theory of evolution (he develops the Chi-squared test in 1900)

1900 The Dutch botanist Hugo de Vries and Von Tschermark of Austria and Correns of Germany Rediscover Mendel's principles.

1901 Hugo de Vries adopts the term mutation

1902 WS Sutton and T Boveri (studying sea urchins) independently propose the chromosome theory of heredity [full set of chromosomes are needed for normal development; individual chromosomes carry different hereditary determinants; independent assortment of gene pairs occurs during meiosis

1905 W Bateson gives the name genetics (means 'to generate' in Greek) to this branch of science, and introduces the words allele (allelomorph), heterozygous (impure line) and homozygous (pure line);

W Bateson & RC Punnett work out the principles of multigenic interaction (linkage) and heredity

1908 GH Hardy and W Weinberg independently formulate the Hardy-Weinberg principle of population genetics

W Johannsen uses the words phenotype, genotype and gene for the first time in his studies with beans.

1910 Thomas Hunt Morgan discovers the white-eye and its sex-linkage in Drosophila (the beginning of Drosophila genetics) [receives the Nobel prize in 1933];

1911 TH Morgan shows the first example of chromosomal linkage in the X chromosome of Drosophila [Nobel prize 1933];

1912 TH Morgan shows that genetic recombination does not take place in males in Drosophila and also discovers the first sex-linked lethal gene [Nobel prize 1933]

1925 CB Bridges proposes the balanced chromosome determination of sex theory [relationship between the autosomes and sex chromosomes]

1927 HJ Muller demonstrates that X-rays are mutagenic in Drosophila [CPG p.149] [receives the Nobel prize in 1946]

1941 George Wells Beadle & Edward Lawrie Tatum proposes the one gene - one enzyme (polypeptide) concept [Tatum receives the Nobel prize in 1958]

- 1953: James Watson and Francis Crick **determine the structure of the DNA molecule, which leads directly to knowledge of how it replicates.**

- 2001: Sequence of the entire human genome is announced

More Old Ideas

- 5. Male and female parents contribute equally to the offspring.
- --ancient Greek idea: male plants a “seed” in the female “garden”.
- --alleged New Guinea belief: sex is not related to reproduction.

Mid 1800's Discoveries

- Three major events in the mid-1800's led directly to the development of modern genetics.
- 1859: Charles Darwin publishes *The Origin of Species*, which describes the theory of evolution by natural selection. This theory requires heredity to work.
- 1866: Gregor Mendel publishes Experiments in Plant Hybridization, which lays out the basic theory of genetics. It is widely ignored until 1900.
- 1871: Friedrich Miescher isolates "nucleic acid" from pus cells.

More 20th Century Events

- 1926: Hermann J. Muller shows that X-rays induce mutations.
- 1944: Oswald Avery, Colin MacLeod and Maclyn McCarty show that DNA can transform bacteria, demonstrating that DNA is the hereditary material.
- 1966: Marshall Nirenberg solves the genetic code, showing that 3 DNA bases code for one amino acid.
- 1972: Stanley Cohen and Herbert Boyer combine DNA from two different species *in vitro*, then transform it into bacterial cells: first DNA cloning.
- 2001: Sequence of the entire human genome is announced.

Major Events in the 20th Century

- 1900: rediscovery of Mendel's work by Robert Correns, Hugo de Vries, and Erich von Tschermak .
- 1902: Archibald Garrod discovers that alkaptonuria, a human disease, has a genetic basis.
- 1904: Gregory Bateson discovers linkage between genes. Also coins the word "genetics".
- 1910: Thomas Hunt Morgan proves that genes are located on the chromosomes (using Drosophila).
- 1918: R. A. Fisher begins the study of quantitative genetics by partitioning phenotypic variance into a genetic and an environmental component.

Molecular Reality (current view)

- (almost) all inheritance is based on DNA: the sequence of ACGT nucleotides encodes all instructions needed to build and maintain an organism.
- A chromosome is a single DNA molecule together with other molecules (proteins and RNA) needed to support and read the DNA.
- A gene is a specific region of a chromosome that codes for a single polypeptide (linear chain of amino acids).
- Proteins are composed of one or more polypeptides, plus in some cases other small helper molecules (co-factors). Proteins do most of the work of the cell.

Gene Expression

- Genes are expressed in a 2 step process:
  - First, an RNA copy of a single gene is made (transcription).
  - Then, the nucleotide sequence of the RNA copy (messenger RNA) is translated into the amino acid sequence of the polypeptide.
  - the genetic code is a list of which 3 base DNA or RNA sequence (codon) encodes which amino acid. The same genetic code is used in (almost) all organisms.
- All cells in the body have the same DNA, but different genes are expressed in different cells and under different conditions.

Gene Differences

- Genes often have several alleles: the same gene in the same chromosomal location, but with minor nucleotide changes that yield slightly different proteins.
- For a given gene, many different alleles can exist in a population (members of the same species), but an individual diploid organism can have 2 alleles at most: one from each parent. Diploid = having 2 copies of each gene and each chromosome.

Other Chromosome Components

- Chromosomal DNA contains other things besides genes:
  - centromere (where the mitotic spindle attaches)
  - telomeres (special structures on the ends of chromosomes)
  - origins of replication (where copying of DNA starts)

  - pseudogenes (non-functional, mutated copies of genes)
  - transposable elements a.k.a. transposons (intranuclear parasites)
  - genes that make small RNAs and not proteins
  - “junk” (?)

Prokaryotes vs. Eukaryotes

- Prokaryotes:
  - Eubacteria and Archaea. Usually unicellular.
  - No internal membrane-bound compartments: DNA floats free in the cytoplasm.
  - 1 circular chromosome (plus optional plasmids, which are also circular)
  - reproduction usually asexual
  - sexual processes (mixing DNA from 2 individuals) occur, but with unequal contributions from the 2 partners
  - transcription and translation simultaneous
- Eukaryotes:
  - Plants, animals, fungi, protists. Often multicellular.
  - DNA contained within a membrane-bound nucleus.
  - linear chromosomes (usually more than 1)
  - careful division of chromosomes in cell division: mitosis and meiosis
  - transcription separated from translation
  - sexual reproduction: 2 partners contribute equally to offspring
  - life cycle: alternation of haploid and diploid phases (i.e. 1 vs. 2 copies of each gene and chromosome)

Mutation

- Mutations, which are any change in the DNA base sequence), occur constantly in all cells and organisms. Offspring rarely get a perfect copy of the DNA from its parents.
  - but mutations are rare: about 1 DNA base change per 10^9 bases each cell generation. (Humans have about 3 x 10^9 bases and E. coli bacteria have about 4 x 10^6 bases).
- Some mutational changes are much larger: chromosome rearrangements that include genes torn in half and moved to new locations, sometimes combined with other genes.

Evolution

- Fitness: the ability to survive and reproduce. An individual's fitness is affected by its genes.
- Natural selection: more fit individuals tend to increase their numbers each generation, at the expense of less fit individuals. Alleles that confer higher fitness tend to take over in the population, causing a loss of less fit genes.
- Large scale changes, new species, are thought to usually occur in small isolated populations, where they don't get swamped out or out-competed by the "normal" individuals.