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Resources for Science Teaching & Learning for the Australian Curriculum

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KISS topic number → Topic 19.10B ← Year level designation in Nat.Curric.

Science Understanding Strand
B = Biological Sciences
C = Chemical Sciences
E = Earth & Space Sciences
P = Physical Sciences

Genetics & Evolution

Year 10 Biological Sciences

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Topic Outline

What is this topic about?

To keep it as simple as possible, (K.I.S.S. Principle) this topic covers:

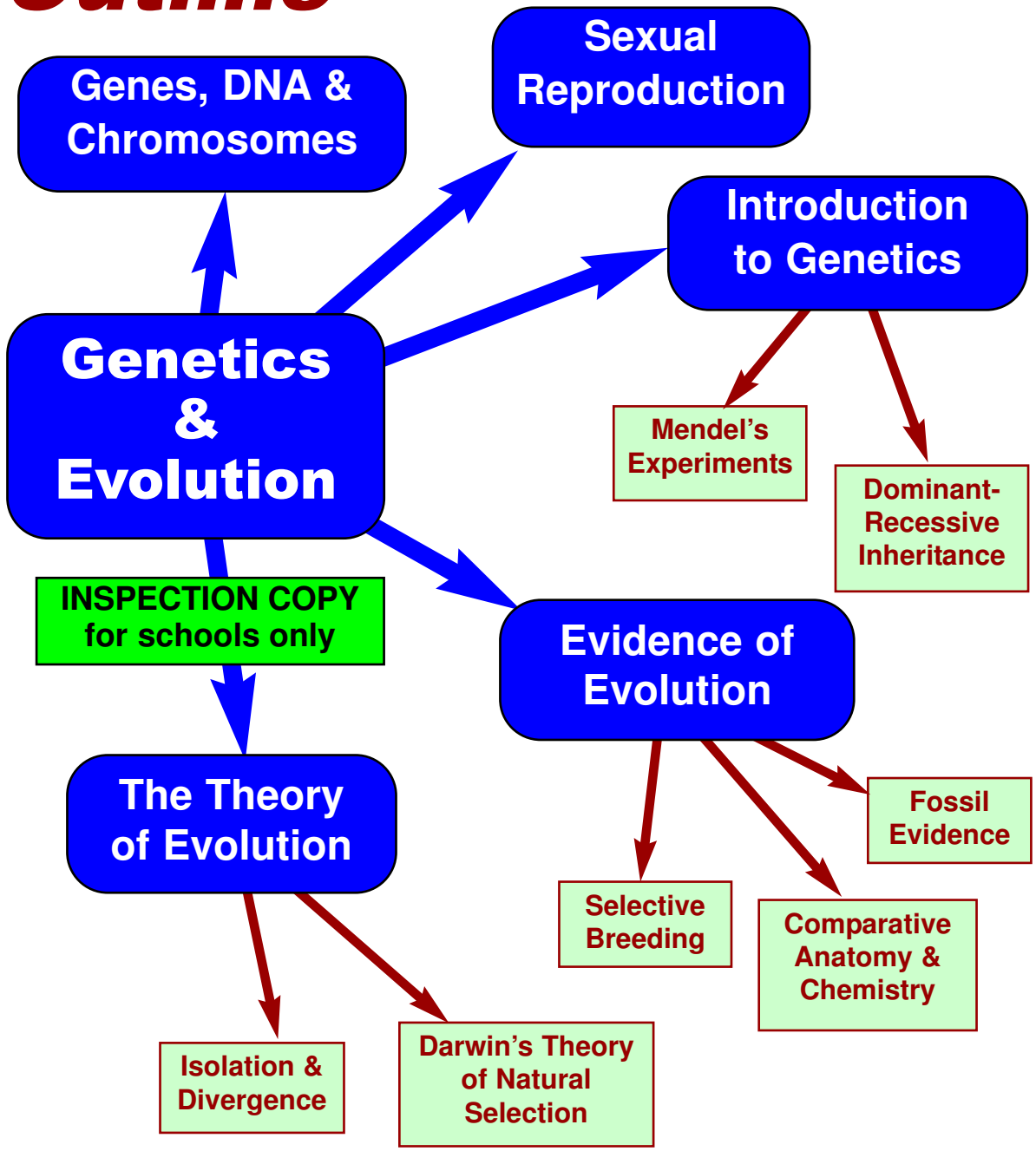
GENES & CELL DIVISION
Genes, Chromosomes & DNA. Cell differentiation. Mitosis.

SEXUAL REPRODUCTION
Asexual v. Sexual. Meiosis & chromosome numbers. Sex Chromosomes. Mutation.

INTRO. TO GENETICS
Mendel's experiments. Simple Dominant-Recessive inheritance. Punnett squares. Pedigrees. Genes v. Environment.

EVIDENCE FOR EVOLUTION
Fossil record. Transitional fossils. Selective breeding. Comparative Anatomy & Chemistry.

THEORY OF EVOLUTION
Darwin's Theory. Variation & Selection. Isolation & divergence.



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Genetic Information

("Genetic" = to do with genes, which control inheritance)

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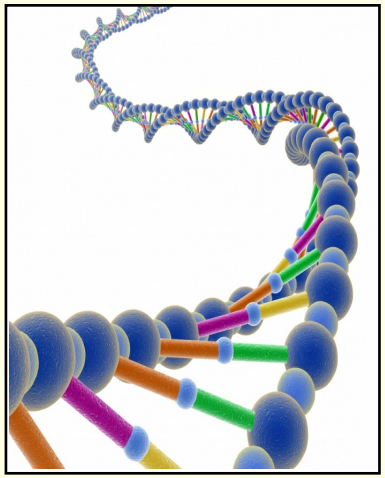
Every type of living thing must reproduce. Mice have baby mice, gum trees make seeds which grow into new gum trees, and bacteria make more bacteria.

Each living thing carries information on how to make offspring of its own type. Mice never make gum trees, and horses do not give birth to cats. The genetic information needed to accurately reproduce the same type of living thing is located in the nucleus of every living cell.

DNA

Genetic information is stored in a chemical known as DNA. DNA molecules are the largest known and carry a "code" within their helix-shape structure.



It is the DNA inside every cell nucleus which controls the cell and all its functions.

The key to reproduction is to make copies of the DNA and pass it on to the next generation.

How Does It Work?

For the full details, you will need to study Biology in years 11-12, but here is a basic outline:

DNA molecules are huge, but very simple in one sense... they are made of just 4 different "nucleotide" chemical units joined together in thousands. The exact sequence of nucleotides is a "genetic code" or chemical language.

A cell can "read" this code to make protein molecules to build functioning cells, tissues and organs. Every cell in your body contains all the DNA instructions to build a unique human organism... YOU! **A little more detail follows...**

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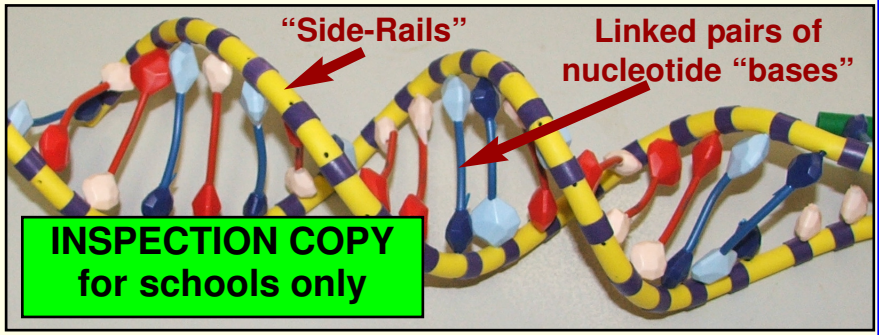
DNA Structure & Function

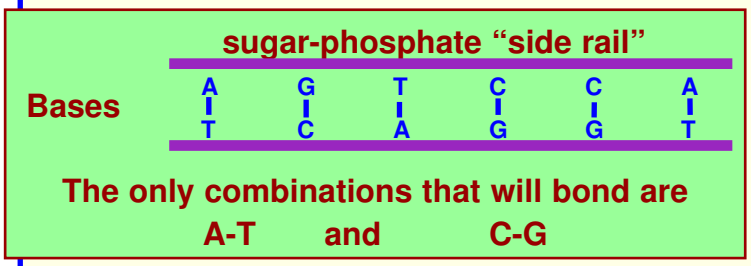
In the early 1950's James Watson & Francis Crick discovered the structure of DNA.

Immediately, they realised how this structure could lend itself to the role of the genetic chemical. To be a "gene", a molecule has to be able to do 2 vital things:



DNA & Protein Synthesis

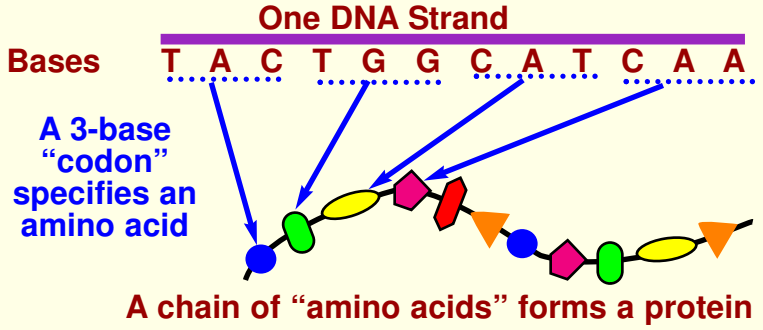
It must be able to make cell and body structures by causing particular proteins to be made within cells. Proteins are large molecules made from chains of "amino acids". The exact nature and function of a protein depends on the sequence of different amino acids. Some proteins build cell parts, muscle and bone, etc, while others are "enzymes" which control all the chemical reactions in a living thing. How can the DNA make the proteins?



The model above shows that DNA is a helix-shaped structure, like a spiral staircase. Firstly, let's simplify the structure with the diagram at left. Between the "side-rails" are pairs of "bases" which can only stick together in a particular way. The 4 bases (known simply as A, C, G & T) can only combine A-T and C-G.

The sequence of bases along one strand is a code. Each 3 bases are a "code word" (called a "codon") which specifies an amino acid to go into the polypeptide chain. If a protein containing 100 amino acids is needed, then a DNA molecule made up of 300 bases, will be the gene for that protein.

Further details of how this process occurs can be studied in senior Biology.



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DNA Replication

The second thing that a gene chemical must be able to do, is to replicate, or make copies of itself. Before every cell division, all the genes must be copied so that every new cell receives the genetic information it needs.

So how does the structure of the DNA molecule lend itself to replication?

The key is the way the complementary bases bond together in the double stranded structure.

This means that if you have ONE STRAND of a DNA molecule it is a "mirror-image" template for the other. If you split a DNA molecule into 2 separate strands, each strand can be used to build a new, complementary strand.

That's exactly what happens to all the DNA in each chromosome, before a cell division occurs.

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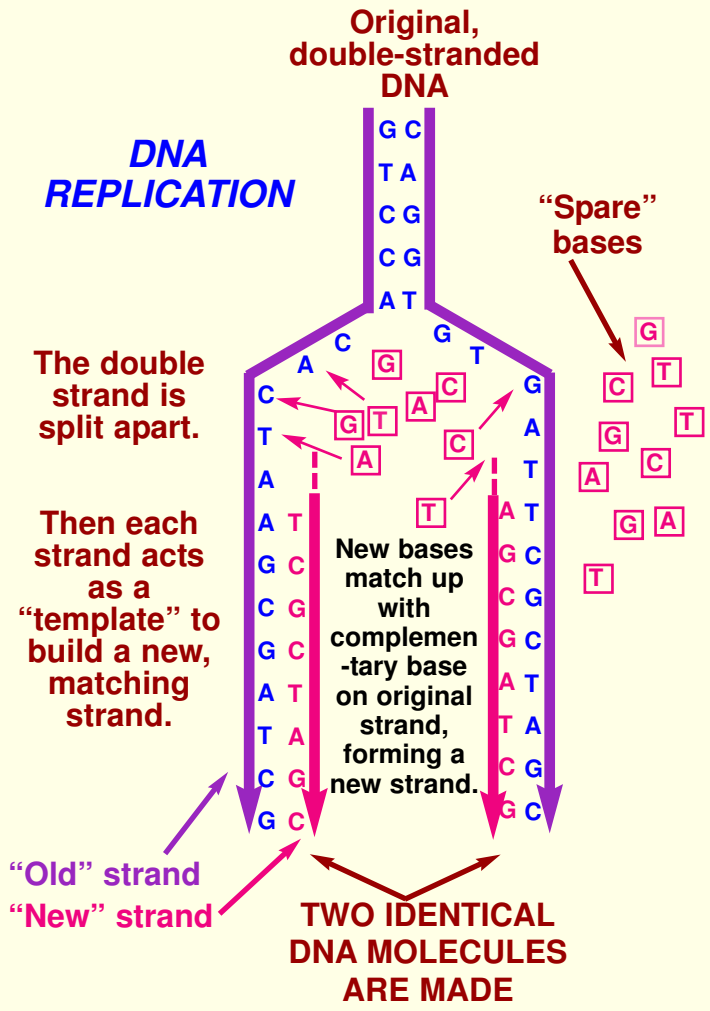
Each DNA molecule (a gene) must be replicated before any cell division.



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Cell Differentiation

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Every cell in the body has a complete set of all the DNA. However, each cell only uses a small part of the total genetic information.

During the early stages of pregnancy, the tiny **embryo** grows rapidly by cell division. (details next 2 slides)

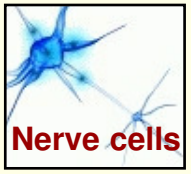
The cells divide, then divide again, doubling the number of cells each time. At this stage the cells are all the same. They do not have any particular function. The embryo does not have any limbs, muscles, a heart, etc.

If this continued, each animal (including you) would be just a big rubbery "blob" like a jellyfish.

Cells Become Specialised

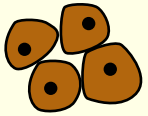
Within a week after fertilisation, **"cell differentiation"** begins. Cells begin to follow particular instructions in their DNA so that they become specialised. For example, some cells follow DNA instructions to become (say) muscle cells. Others ignore the "muscle instructions" and follow other parts of the DNA instructions to become nerve cells, or bone cells, etc.

Blood cells



Nerve cells

Skin cells



Body organs, limbs and blood vessels begin to grow, so that the "cell blob" develops into a perfect little human, or kitten or gum tree, according to the DNA instructions.

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Purposes of Cell Division

All living cells are able to reproduce themselves by dividing in two. The process is called "mitosis" and is detailed in the next slide.

The purpose of cell division depends on what kind of organism you consider.

Unicellular Living Things

Mitosis cell division is the way that unicellular organisms reproduce. Under ideal conditions, some bacteria can go through the whole cycle in an hour or even less.

If you started with 1 bacterial cell, and it divided in two every hour, how many would there be after 1 day?

Time (hours)	0	1	2	3	4	5
No. of Bacteria	1	2	4	8	16	32

If you continue this calculation to 24 hours, you will have over 16 million cells!

Multicellular Plants & Animals

In multicellular organisms, mitosis is how new cells are made for growth and repair. You started out as 1 single cell, but you now have billions. All multicellular organisms grow by adding new cells produced by mitosis.

Cells constantly need replacing as well. Blood cells have a short life span and must be replaced. Skin constantly flakes off, so new layers grow. The new cells are produced by mitosis.

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Cell Division: Mitosis

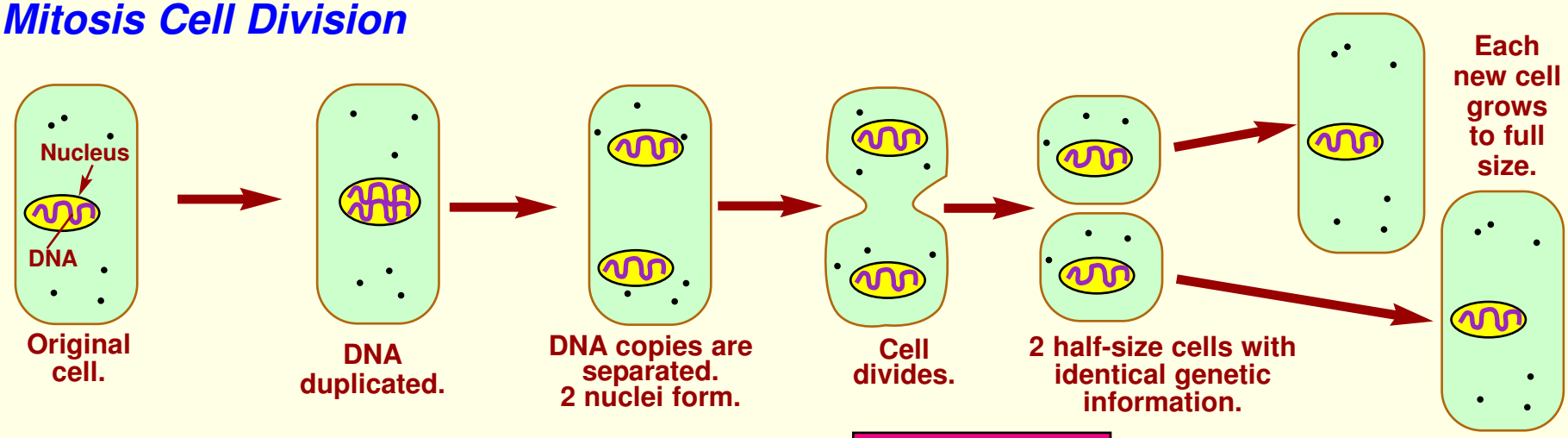
Each cell first makes a duplicate copy of the DNA in the cell nucleus. In most cells, the DNA is contained within structures called "chromosomes". The DNA contains the genetic information which controls the structure and functioning of the cell and the entire organism.

Next, the 2 sets of genetic information are separated.
At this point it is as if the cell has 2 nuclei (plural of nucleus).

Then the cell itself divides into 2 smaller cells. Each new cell is only half-size but has a complete nucleus with a full copy of the genetic information in its DNA.

Finally, each cell can then grow to full size before the whole process starts again.

Mitosis Cell Division



Please complete Worksheets 1 & 2 before going on.

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Discussion / Activity 1

The following activity might be for class discussion, or there may be paper copies for you to complete.

Cell Division

Student Name .....

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1.

a) Name the chemical which carries genetic information?

b) In which part of a cell is this information kept?

2.

a) What is "cell differentiation"?

b) If you analysed the genetic information in a muscle cell and compared it to the information in a nerve cell from the same person, how would they compare?

3. What is the purpose of mitosis cell division in:

a) a unicellular life-form?

b) a multicellular living thing?

4.

a) What is the first step in the process of mitosis?

b) How do the 2 "daughter cells" formed by mitosis compare to each other:

i) in size?

ii) genetically?

c) How do the "daughter cells" formed by mitosis compare to the "parent cell"?

i) in size?

ii) genetically?

Suggested Answers are located in a separate file

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How Current Research Might Affect People's Lives

One of the areas of current biological research which may have enormous impacts on people's lives is "stem cell research".

What are "Stem Cells"?

Stem cells are unspecialised human cells that have not differentiated. They can be grown in the laboratory. If correctly stimulated, stem cells can differentiate into any kind of specialist cells such as nerve cells.

Possible Benefits of Research

By studying the way stem cells differentiate into specialist cells, scientists may learn how cancer cells begin. This could enable doctors to be able to "turn-off" tumour cells and cure many types of deadly cancer.

By stimulating stem cells to differentiate into specialist cells, scientists might eventually be able to replace damaged tissue to cure conditions such as Parkinson's Disease in which brain cells degenerate.

Another possibility is to replace the destroyed cells in the panceas which is the cause of diabetes. Current research seems close to success.

Heart muscle damaged by a heart attack could be repaired. Ultimately, it may be possible (although probably far into the future) that stem cells could help to repair a kidney or liver which requires a transplant.

The promise of stem cell research is to be able to cure cancers, diabetes and many other diseases, plus repair organs which currently require transplants.

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Social Factors Influence the Acceptance of Science

**Stem cell research has the potential to benefit many people.
However, that does not automatically mean it will be accepted and used.
In fact, the research is currently restricted by law in Australia and many other countries because there are certain ethical, moral and religious issues involved.**

Sources of Stem Cells

The best source of stem cells for research is from human embryos which are "left-overs" from IVF programs.

(IVF = in-vitro fertilisation or "test-tube baby" programs. This is where eggs are fertilised in the laboratory and the embryo is artificially implanted in the womb later. This helps some couples who are unable to have children normally.)

Although these embryos do not have a nervous system or any organs, many people consider them to be a human person. This raises the ethical issue of killing a person for research purposes.

The law in Australia currently allows excess IVF embryos to be used, but under strictly controlled licencing conditions. In some countries the research is banned completely.

Adult Stem Cells?

A type of stem cell can be extracted from adults. These stem cells are not as good for research because they will not undergo such a wide range of possible differentiations as embryo cells will.

A lot of research is going on to try to "re-program" adult stem cells to act like embryonic cells. This would remove most ethical, moral or religious objections to stem cell research.

Australian scientists are among the world's leading researchers in this field.

Despite the huge potential to benefit human health, stem cell research is limited by social factors, such as people's religious and ethical beliefs.

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Genes, Chromosomes & DNA

You may be a little confused by these words and how they relate to each other. This section aims to make this clear.

What is a "Gene"?

A gene is a unit of inheritance. What colour eyes you have is determined by which "eye-colour genes" you inherited from your parents. Whether your hair is naturally straight, wavy or curly depends on the genes you inherited.

In some plants, the colour of the flowers depends on the genes inherited from its parents. In flies there is a gene which causes "hairy body" and another gene for "hairless". Other genes control wing shape and eye colour, etc.

In some cases the situation is much more complicated. Human height is determined by dozens of genes as well as by childhood health and nutrition.

However, to keep it simple (K.I.S.S.) the principle

one gene → one characteristic

is often true.

Genes & DNA

DNA is a chemical. Its molecules are the largest known; 1 molecule of DNA may contain millions of atoms bonded in a precise, helix-shaped arrangement.

The sequence of "nucleotides"along the DNA molecule is a chemical code.

The nucleotide sequence is a coded gene.

This tells the cell how to build particular proteins and structures, or how to develop in a particular way. Each gene is specified by the code in a different DNA molecule.

DNA molecule = a gene

Whether your hair is straight or curly is due to just a slight difference in the "code" sequence of a DNA molecule in the nucleus of your cells.

Chromosomes, next slide

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Chromosomes

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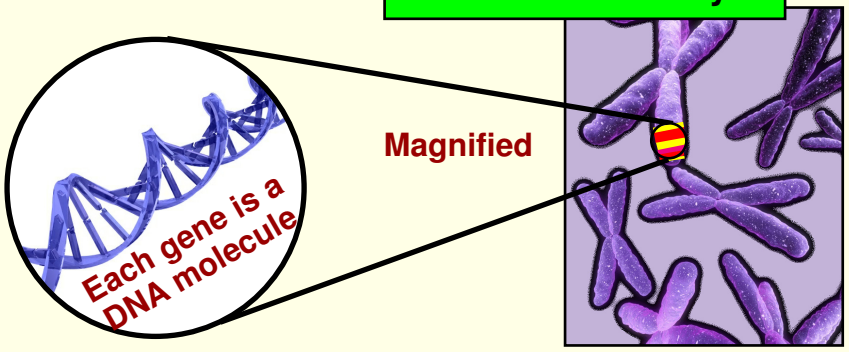
The DNA molecules which are your genes are not just rattling around loose in the cell nucleus.

Thousands of genes are wrapped up together with protective proteins to form a thread-like structure called a chromosome. Many are roughly "X-shaped" as in the diagram.



Each chromosome may have 1000's of genes.

Chromosomes are only visible (by microscope) during cell division.

In a human body cell there are 46 chromosomes. A sperm or egg cell has only half that number.

Chromosomes come in matching pairs. The first 22 pairs are the same size and shape in every human.

The 23rd pair are different in each half of the population. This pair of chromosomes are the "sex chromosomes" and determine if you are male or female.

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Sexual & Asexual Reproduction

("Sexual" = having male & female sexes. "Asexual"= no sexes.)

All living things reproduce themselves. We are used to the idea that reproduction involves male and female parents who combine their genetic information to produce offspring.
However, many organisms do not need male and female parents to reproduce.

Asexual Reproduction

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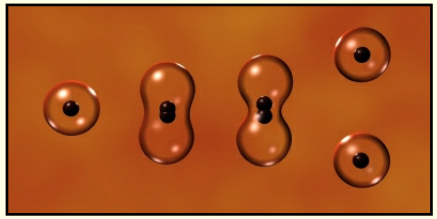
Unicellular Reproduction

Single-celled organisms such as bacteria reproduce by simply dividing in two by **mitosis.**



There is no need for "males" and "females". Each cell can be a parent.

The offspring cells are genetically identical to each other, and to their single "parent cell".

Regardless of details, asexual reproduction always:

- requires only one parent.
- involves mitosis cell division.
- produces offspring which are genetically identical to the parent and to each other.

Asexual Reproduction in Multicellular Life

Many multi-cellular organisms reproduce asexually.

Fungi, such as mushrooms, reproduce by releasing "spores". Each spore is a single cell which can grow into a new fungus. The spore cells are produced by mitosis, and released from a single "parent".

Many **Plants** can reproduce asexually by sending out "runners".

These same plants can also reproduce sexually with their flowers.

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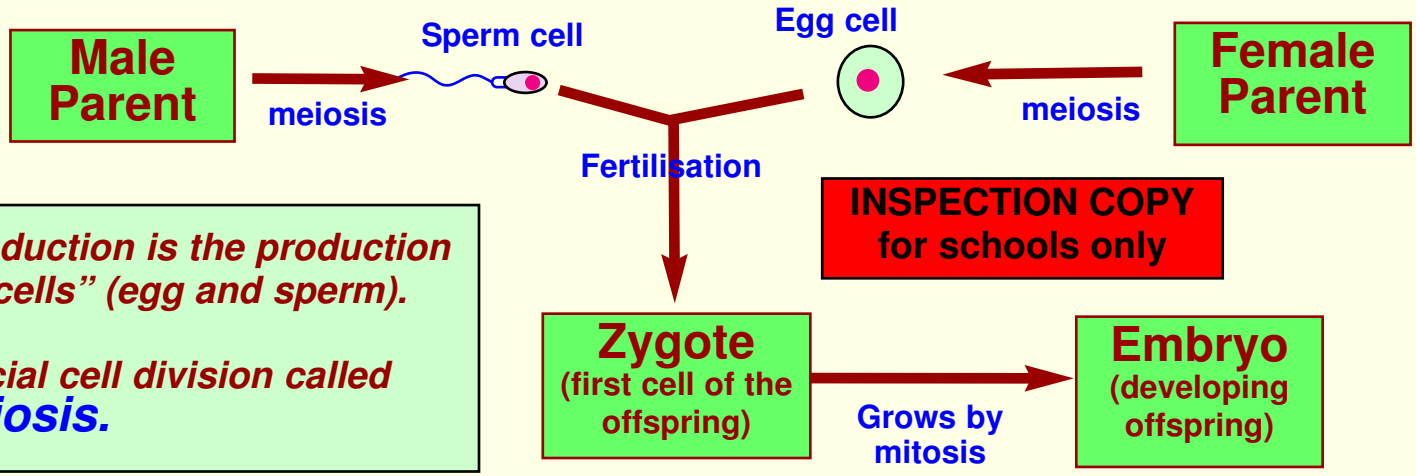
Sexual Reproduction

Sexual reproduction always involves 2 parents who combine part of their genetic information to produce offspring which are different to both parents.



The key to sexual reproduction is the production of the "reproductive cells" (egg and sperm).

This involves a special cell division called ***meiosis.***

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Meiosis & Sexual Reproduction

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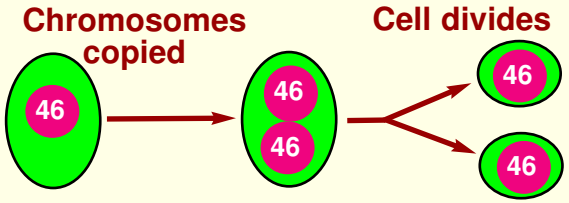
Chromosomes

You already know that the genetic information (DNA) in each cell is located in thread-like structures called chromosomes. These can be seen within the cell nucleus during cell division.

The number of chromosomes varies from species to species. In humans, every body cell has 46 chromosomes in the nucleus.

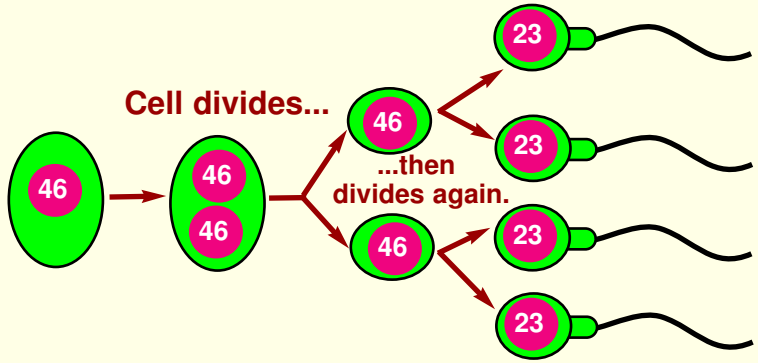
During mitosis, the chromosomes (and the DNA they contain) are first copied, then divided between the "daughter cells".



The result is that each new cell has a full set of chromosomes and complete copy of all the genetic information.

Meiosis Halves the Chromosomes

To produce the reproductive cells or "gametes" a different cell division occurs. In meiosis, (pronounced "my-osis") the chromosomes are copied, but then the cell divides twice to form 4 cells with only half the number of chromosomes.



In males, each of these 4 new cells becomes a sperm cell. In human females, only 1 of the 4 new cells develops into an egg. The other 3 never develop.

The main point is that both sperm and egg have only half the normal number of chromosomes.

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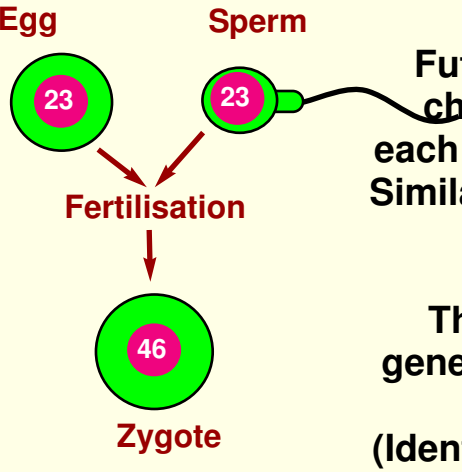
Fertilisation Restores Chromosome Numbers

When a sperm cell fertilises an egg, their nuclei combine and the chromosomes of each are added together.

This restores the chromosome number so the offspring has the correct number for that species.

Meiosis is essential for sexual reproduction so that 2 parents can contribute chromosomes to the offspring, while maintaining the correct total number for the species.



Since the offspring receives DNA from both parents, it is different to both.

Futhermore, because of the way the chromosomes separate in meiosis, each sperm a man produces is different. Similarly, each egg a woman produces is different.

The result is that each offspring is genetically different, even siblings from exactly the same parents. (Identical twins are an exception to this.)

Please complete Worksheets 3 & 4 before going on.

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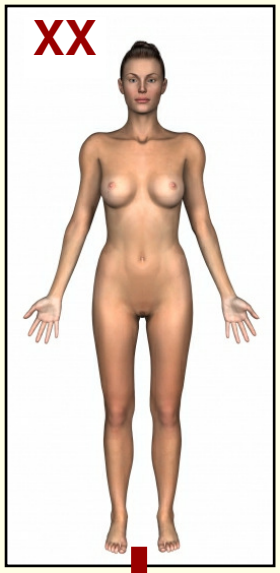
Male or Female? Sex Chromosomes

Human body cells have 46 chromosomes which are arranged in 23 pairs. The first 22 pairs are the same for everyone, although of course each person has their own particular set of genes. The 23rd pair of chromosomes are special... they determine your sex.

Female

A woman's 23rd pair are a matching pair of large, X-shaped chromosomes. This is referred to as "XX".

When she produces eggs by meiosis, each egg gets one of each pair, so every egg carries a single "X" chromosome.



Male

A man's 23rd pair do not match. He has one large "X" chromosome, but its partner is a small, stubby chromosome called "y". He is "Xy".

When he makes sperm cells by meiosis, half of them will carry an X, the other half will have a y-chromosome.

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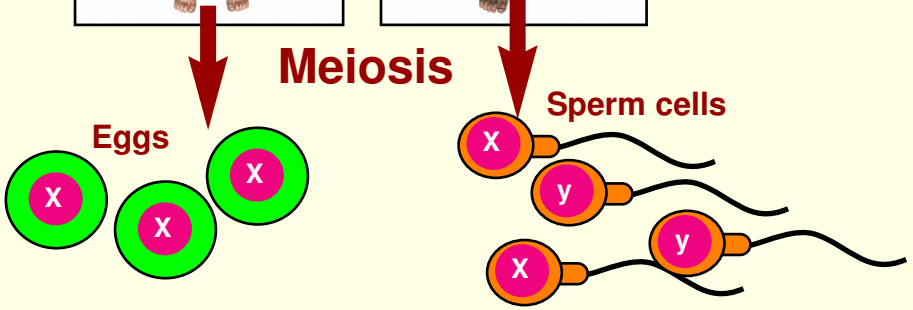

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Dad Determines the Sex of the Baby

Millions of sperm cells race to fertilise the egg.
Which one wins the race is pretty much random chance.

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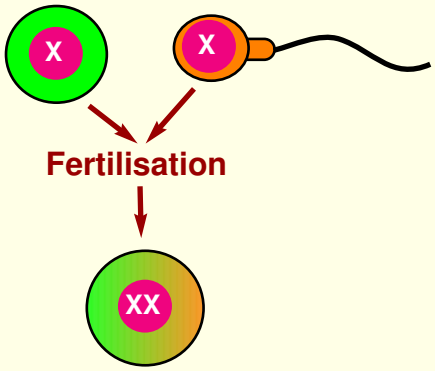
If the egg is fertilised by a sperm cell carrying an X-chromosome:



This zygote will develop into a baby girl.

At puberty her hormones will re-shape her body and bring eggs to maturity in a regular cycle.

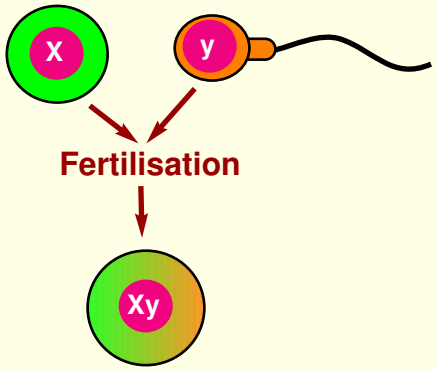
Punnett Squares

A Punnett Square is a way to work out the probabilities of inheritance.
All the possible genes or chromosomes from each parent are shown on the outside, and then all the possible combinations are shown inside the table.

Father's sperm	Mother's eggs: X	Mother's eggs: X
X	XX	XX
y	Xy	Xy

Offspring Probabilities: Boys = 50% chance, Girls = 50% chance

If the egg is fertilised by a sperm cell carrying a y-chromosome:



This zygote will develop into a baby boy.

The y-chromosome contains just a few critical genes which cause the development of male organs. At puberty, his hormones do the rest.

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Discussion / Activity 2

The following activity might be for class discussion, or there may be paper copies for you to complete.

Sexual & Asexual Reproduction

Name .....

1. In asexual reproduction:
a) how many parents are required?
b) what is the cell division process involved?
c) how do the offspring compare to each other (and the parent) genetically?

2. In sexual reproduction:
a) how many parents are required?
b) what is the cell division process involved?
c) how do the offspring compare to each other (and the parent) genetically?

3. Explain the importance of meiosis in sexual reproduction.

4.
a) What is a chromosome?

b) What is a gene?

c) What are genes made from?

5.
a) Outline how a person's sex is determined by the "sex chromosomes".

b) Explain how the sex of a baby is determined by its father.

Suggested Answers are located in a separate file

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DNA Replication... accurate, but not perfect!

One of the critically important steps in cell division is when duplicate copies of the genetic information, the DNA, is made. This copying is called "replication". Most of the time the copying is perfect, but occasionally mistakes occur.

Importance of Accurate Replication

Every cell depends on its DNA instructions to operate properly and efficiently.

If an error occurs in DNA replication during mitosis cell division, the "daughter cells" may receive DNA in which the genetic code has been changed. Sometimes a small change might not make any difference, but some changes could be fatal to the cell, or the entire organism.

For example, if a mistake in DNA replication changed a gene needed for cellular respiration, the cell would not be able to get energy from food. The cell would die.

If this happened frequently to many cells, then an entire body organ might shut down and the whole organism could die. Luckily, it's not that common.

Mutation

Accidental changes to DNA, or to an entire chromosome, do happen. These changes are called "mutations".

Certain chemicals or radiations can cause mutations, but sometimes they just happen by accident during DNA replication.

***In a Body Cell,* a mutation may cause the death of that cell, but this may have no effect on the whole organism. In some cases, a mutated body cell may develop as a cancer cell. This may become life-threatening.**

***In a Gamete,* a mutation may kill the egg or sperm cell, or kill the embryo. Some disorders, such as Cystic Fibrosis, can be caused by a mutation which has carried through an egg or sperm to affect the whole person.**
Generally, mutations are not good news!

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Benefits of Mutations

Most mutations are detrimental to the cell, or the organism, in which they occur.
However, a very small percentage of mutations do no harm. These are vital to life on Earth!
A mutation may simply produce a new characteristic which is not harmful, but simply different.
It might be a new eye colour. It could cause hair or fur to be thicker. It might cause a shorter tail, bigger kidneys or longer ear lobes... anything at all. Over generations, these new characteristic can spread through a population by inheritance from parents to offspring.
Eventually, the new features may become vital to the future survival of the entire species.

Evolution of Life

We know that life on Earth has changed dramatically over many millions of years. Soon you will learn more about the facts of these changes.

You will also study the scientific explanation for how these changes have occurred.

This is the Theory of Evolution, which underpins modern Biology.

Importance of Variations

When you study Evolution, you will find out how important it is for any species to have variations from one individual to another. Ultimately, these variations all begin as mutations.

Mutations are usually bad for individuals, but are good for the survival and evolution of the whole species. Look out for this idea again in this topic!

Please complete Worksheet 6 before going on.

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Introduction to Genetics

Genetics is the study of how the inheritance of characteristics works.

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A Little History

A good way to learn the basics of genetics is to learn about how it was discovered. About 150 years ago, in a monastery in central Europe, a monk with an interest in Science did some breeding experiments in the vegetable garden. His name was Gregor Mendel (1822-84).

Mendel's Pea Plants

Mendel noticed that some of the garden pea plants always grew tall, but others were dwarf, no matter how well they were cared for. He decided that the difference must be inherited, and that parent plants must be passing on genes for height; either "tallness" or "dwarfness".

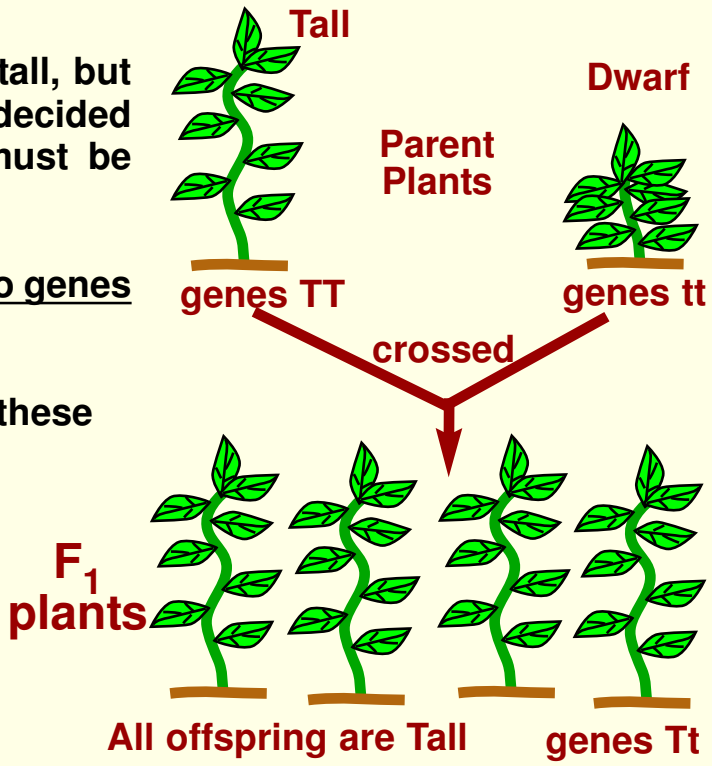
He figured out (from the later results) that each plant must have two genes for either tall stem (symbol "T") or for dwarf stem (symbol "t").

When these parent plants made gametes by meiosis, only one of these genes was passed into each gamete.

The fertilised eggs became seeds which Mendel planted and grew. Every one grew tall.

He explained this as follows:

- Each parent has passed on one of its 2 height genes.
- All the offspring plants (F_1) received genes T and t.
- Gene "T" is dominant to gene "t", so all seedlings grow tall.



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Mendel's Pea Plants cont.

Next Mendel bred a second generation (F_2) by self-pollinating the F_1 plants.

They produced seeds which he grew in hundreds.

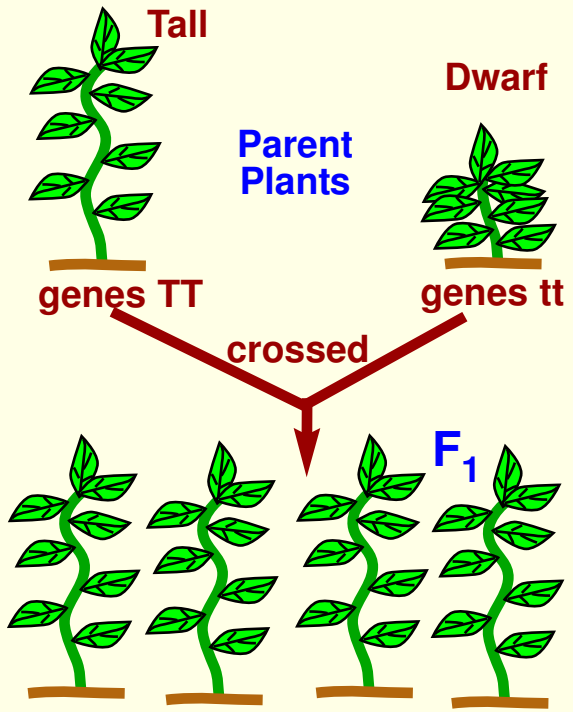
75% of these grew tall and 25% were dwarf.

The Punnett Squares explain why:

Plant gametes are called "ovules" (eggs) and "pollen" (sperm). They are produced in the flowers.

Mendel controlled the breeding by placing pollen from his selected "father plants" onto the flowers of "mother plants".

Pea plants can also be "self-pollinated", or crossed with themselves.



First Generation F_1

Genes of Parents: TT x tt

gametes: T T x t t

	t	t
T	Tt	Tt
T	Tt	Tt

Offspring Probabilities F_1
100% have genes Tt.
All grow TALL because gene T is dominant to gene t.

2nd Generation F_2

Genes of F_1: Tt x Tt (self-pollinated)

	T	t
T	TT	Tt
t	Tt	tt

Offspring Probabilities F_2
75% have genes TT or Tt = TALL
25% have genes tt = dwarf

Second Generation
$^3/_4$ Tall (75%)
$^1/_4$ Dwarf (25%)

Ratio
3 : 1
Tall : Dwarf

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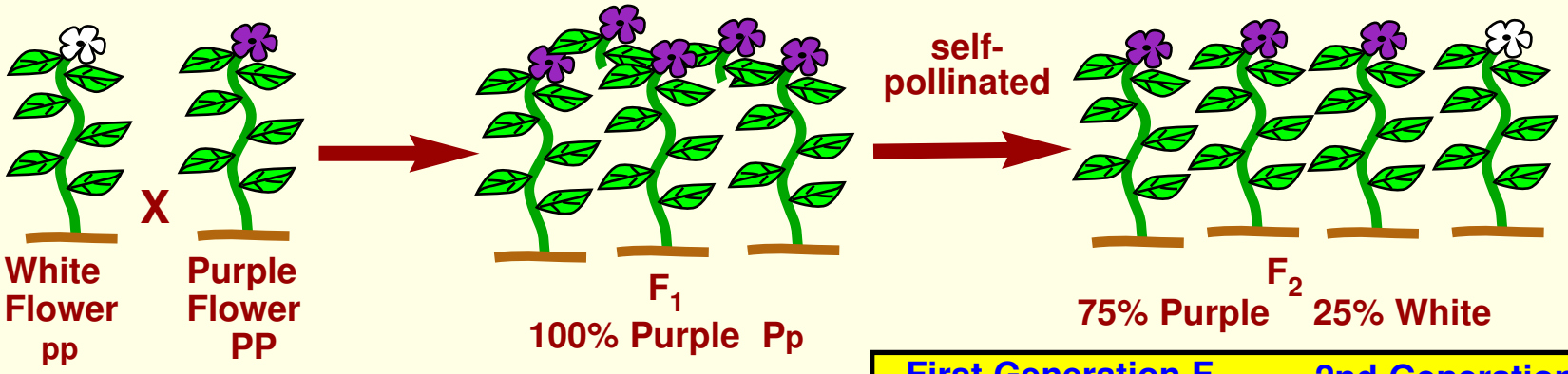
More about Mendel

Gregor Mendel didn't stop with plant heights.
He also experimented with flower colours, seed shape, pod shapes, etc.



Everytime Mendel carried out the experiment he got the same results:

First generation (F_1) plants were 100% like one parent only, because one gene is dominant to the other.
(The other gene is said to be "recessive")

Second generation (F_2) plants always showed a ratio approximately 3:1 (75% : 25%) of the dominant type to the recessive type.

First Generation F_1

Genes of Parents: PP x pp

gametes: P, P / p, p

Pp	Pp
Pp	Pp

Offspring Probabilities F_1
100% have genes Pp.
All have Purple flowers because gene P is dominant to gene p.

2nd Generation F_2

Genes of F_1: Pp x Pp (self-pollinated)

	P	p
P	PP	Pp
p	Pp	pp

Offspring Probabilities F_2
75% have genes PP or Pp = PURPLE
25% have genes pp = white

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Significance of Mendel's Experiments

Gregor Mendel had discovered the basic way that inheritance works and genes are passed on from parents to offspring.

We now know that many genes operate this way. Many characteristics have 2 alternative forms (e.g. tall-dwarf, purple-white, etc) controlled by 2 genes, one of which is dominant, the other recessive.

For each characteristic, an organism carries 2 genes in its DNA. The 2 genes could be the same (e.g. TT or tt) or may be different (Tt). When gametes (sex cells) are formed by meiosis, only one of the genes is passed on. The offspring receives one gene from each parent. Dominance-recessiveness then determines which characteristic the offspring will have.

Be aware also, that many genes DO NOT operate in this "Mendelian" way... but that's another story.

Some Genetics Words to Learn

Alleles = the alternative genes for a characteristic. e.g. "T" and "t" are the alleles for stem height in Mendel's peas.

Genotype = the genes an individual has for a characteristic. e.g. a dwarf pea has the genotype "tt". Genotype "Tt" would grow TALL.

Notice how dominant genes are symbolised by CAPITAL letters and recessive genes by the same letter in lower case.

Phenotype = the appearance of the organism caused by its genes. e.g. genotype "tt" results in the phenotype "dwarf". Phenotype "TALL" could have genes TT or Tt.

Homozygous = having 2 genes the same. (e.g. "TT" or "tt")

Heterozygous = having 2 different genes. (e.g. "Tt")

Please complete Worksheets 7 & 8 before going on.

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Discussion / Activity 3

The following activity might be for class discussion, or there may be paper copies for you to complete.

Genetics

Student Name .....

Suggested Answers are located in a separate file

1.

a) What is Genetics?

b) Name the person who discovered the basics of genetics.

c) What living things did he use in his experiments?

d) Outline what he did to carry out one of his experiments.

e) What did he always find in the "F_1" of the experiment?

f) What did he always find in the "F_2" of the experiment?

2. What is meant by:

a) a dominant gene compared to a recessive gene.

b) being homozygous for a trait compared to being heterozygous.

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Pedigrees (Family Trees)

A pedigree diagram is a way to show the inheritance of a genetic characteristic or "trait" through a family over a number of generations. Pedigree diagrams were once used to study human inheritance, but modern DNA testing methods have largely replaced this.

Symbols Used in Pedigree Diagrams

Male with trait being studied ■ □ Male without the trait

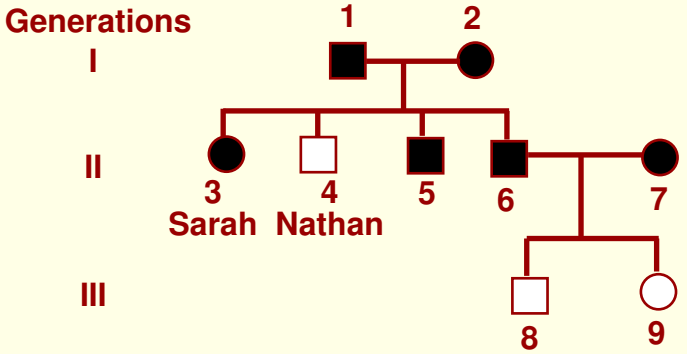
Female with trait ● ○ Female without the trait

Horizontal connections are "marriage lines".
Vertical lines lead to children of that couple.
Each generation is numbered by Roman Numerals.
Individuals may be numbered for identification.

Example

In humans, some people can "roll their tongue" while others cannot. This is passed on by simple Mendelian Inheritance.

Here is a pedigree diagram of Sarah & Nathan's family, showing how the tongue-rolling trait has been inherited over 3 generations.



Can you tell which gene is dominant?

Can you work out which people carry what genes?

How to Interpret the Diagram

Sarah & Nathan's parents (labelled 1&2) can both roll their tongue, yet Nathan cannot. The only way this is possible is if "Tongue Rolling" is caused by a dominant gene.

To be a "Non-roller", Nathan must have inherited 2 recessive genes. Since he received one from each parent, then Mum & Dad must be both heterozygous.

Using symbols "R" for Tongue Roller and "r" for Non-roller, Nathan must have "rr" while his parents are both "Rr". What else can you work out?

Please complete Worksheet 9 before going on.

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Mendel's Genes, Cell Division & Chromosomes

Gregor Mendel knew nothing about chromosomes or the details of cell division because these things had not been discovered when he was breeding pea plants. You may have already noticed how Mendel's genes follow "rules" which match what happens to chromosomes during meiosis cell division.

Comparison:

Mendel's Genes	Chromosomes
Each plant has 2 genes for each characteristic.	Chromosomes in body cells are always in pairs.
Only 1 of the 2 genes is passed into a gamete.	Meiosis halves the chromosome number.
The offspring receive 1 gene from each parent at fertilisation.	The offspring get chromosomes from each parent and get back to having pairs.

When chromosomes were first discovered and scientists studied what happened to the chromosomes during mitosis and meiosis, this comparison became obvious.

Therefore, the genes must be located on the chromosomes.

About 100 years after Mendel's experiments, the structure of the DNA molecule was discovered and understood.

Genes are made of DNA.
The 2 genes for any characteristic are located one on each of the chromosomes in a pair.

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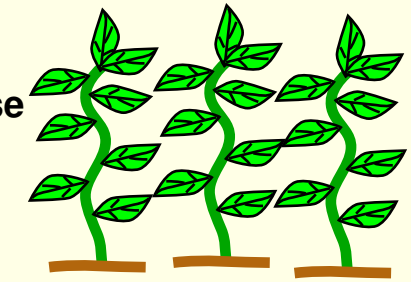
Genetics versus Environment

Is every characteristic of every living thing determined entirely by its genes?
No, definitely not! The genes give each organism a "potential" to which it may develop, but the environment determines if that potential is reached.

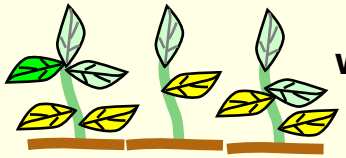
Tall Plants in Poor Soil

Imagine growing some of Mendel's pea plants. You have plants which have genotype "TT".

These genes will cause them to grow tall... or will they?



If these plants are grown from seed in very poor soil and choked with weeds they cannot grow tall, and may be "stunted" and have fewer leaves.



Although genetically tall, their environment has not allowed them to reach their genetic potential for height.

Nature v. Nurture (nurture = how you are brought up)

Statistics show that, on average, Australians have been getting taller every generation for about 100 years. Why are humans getting taller?

(Be aware that the genetics of height in humans is much more complicated than in pea plants.)

Scientific studies have shown that it's not the genes that have changed, but improvements to health and nutrition available in society. 100 years ago, fewer people reached their genetic potential, so average height was less.

Similarly, the high rate of obesity in our society is not due to genetics, but to changes in eating habits and lifestyles.

Overall, scientists believe that many characteristcs are about 50% due to genes, and about 50% due to environment.

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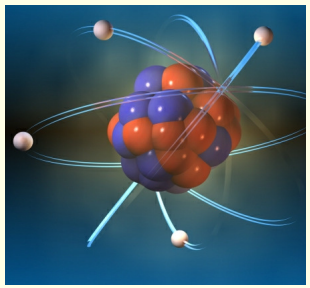
The Theory of Evolution

There can be no doubt that life on Earth has changed over millions of years. The changes are not random. There is a distinct pattern; from simple life-forms towards more complex; from those unlike modern types, to creatures more and more like those alive today. The word for a series of changes which follow a pattern is *"Evolution".*

What is a "Theory"?

Some people choose to reject the Theory of Evolution. They point out that it is "only a theory... it's not proven". They do not understand the status of a scientific theory.

In Science, a theory is an explanation for a set of observed facts. To become accepted, it must have a huge body of supporting evidence from observations and/or experiment. It is NOT just an unfounded idea.



The idea that all substances are composed of tiny particles of matter is "Atomic Theory". There is a huge body of observations and experimental results which convince scientists that Atomic Theory is fundamentally correct. There may be more to learn, but the basic idea seems accurate.

Similarly, there is "Cell Theory", Einstein's "Theory of Relativity" and the "Theory of Plate Tectonics". Each is supported by a mass of consistent, coherent, mutually-supporting facts. The Theory of Evolution fits right in with these.

The Principle of "Falsification"

A basic principle of Science is that all scientific theories are subject to being proven false. There could be thousands of facts to support a proposed explanation of things, but just one confirmed fact against it can prove it false.

It would only take one confirmed fossil of the wrong age and the whole Theory of Evolution could fall over. For example, a mammal tooth in rock from when fish first appeared, or a human fossil among dinosaur bones. (Fred Flintstone perhaps?)

The fact is that millions of fossils have been studied, correlated and dated. Not one has ever been proven to be "out of place".

If that happened, scientists would be forced to question the current theory and find a new explanation. Scientists always keep this "falsification" in mind. They might believe a theory to be a correct explanation, but are also prepared to reject it IF THE EVIDENCE PROVES IT FALSE. So, what is the supporting evidence for Evolution?

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1. The Fossil Record

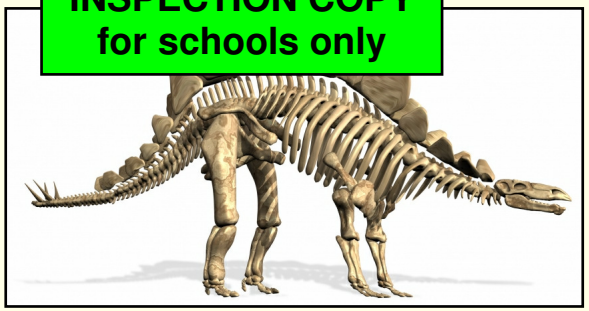
Evidence for Evolution

This is undoubtably the most important set of facts which convince scientists that life on Earth has gone through a sequence of changes.

Simple to Complex

The earliest fossils are all single-celled organisms and the stromatolites they built. Much later simple algae, worms and jellfish appear.

Later still come fossils of shelled animals and crustaceans. Then fish, the first land plants, then insects, amphibians, reptiles, mammals, dinosaurs, flowering plants and birds... the pattern is clearly from simple towards more complex organisms.



More & More Like Modern Life

Extinct life forms from 10 million years ago are recognisably similar to modern types. Go back 100 million years and the fossils are less similar to modern life.

Keep going back and the living things are less recognisable. It seems that the pattern of changes leads directly to the modern types of life on Earth.

(Don't be fooled by that... previous stages always look "old-fashioned". In 100 million years time, human fossils will seem very primitive!)

This area of evidence is so important that we need to go into more detail.

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Fossils

**A fossil is the remains, or traces, of a living thing from ages past.
It could be a bone, tooth or shell. It could be an imprint or a footprint or a burrow.
There is even a specialist study of fossilised dinosaur droppings!**

The study of fossils is called *Palaeontology.* (say: pay-lee-on-tology)

Fossil Formation

Usually, when a living thing dies its remains are eaten by scavengers or they rot away as the decomposers (bacteria & fungi) do their thing.

Very, very rarely the remains are preserved as fossils.

Perhaps the remains sink to the bottom of the sea or a lake and are rapidly buried in mud following a flood. Perhaps a volcanic eruption buries and "mummifies" the remains in volcanic ash.

Either way, some traces may be preserved in rock layers.

If the sediments containing the remains are buried and compressed, they may become sedimentary rock such as shale or limestone. This is where fossils are most commonly found.

**This fossilised shell is about 200 million years old. It has been cut open to show how mineral crystals have grown in the hollow cavities.
It is completely mineralised, so nothing remains of the original shell except its shape.**

During millions of years of burial the remains may be reduced to just a carbon imprint, or be replaced by minerals from the surrounding rock.

Much later, earth movements and erosion may expose these rocks at the surface. In many cases the fossil is then destroyed by erosion.

However, we have managed to find and study millions of fossils.

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Putting Fossils in Time Order

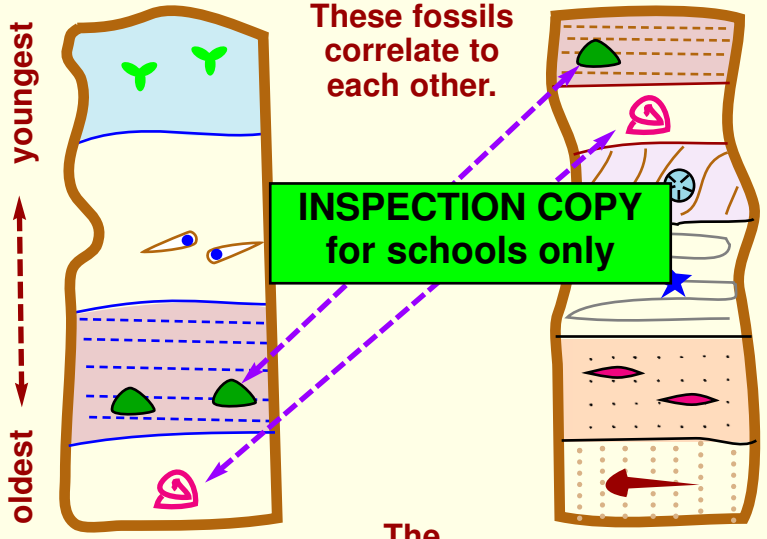
Most fossils are buried in sediments. Fresh sediment always settles on top of older sediments. Therefore, it is a basic principle that the younger fossils are above the older ones in the sedimentary layers.

Relative Dating

By applying the principle that older fossils are lower down, the fossils in any profile of sedimentary rocks can be arranged in age order.

This idea can be extended further by correlating fossils from one area to another.

From thousands of studies like this, scientists have built up a picture of the history of life on Earth.



Actual Age of Fossils

Correlating fossils can only give relative ages.

Actual ages can be determined by measuring the amount of radio-activity remaining in certain rocks.

From this, scientists can be quite sure about the age of many fossils.

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Life on Earth Has Changed

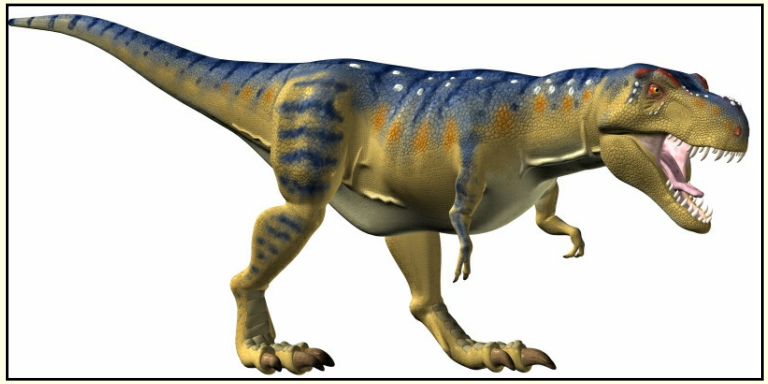
Even the earliest amateur fossil-collectors of 200 years ago noticed that the fossils they found were not the same as modern life-forms. Obviously, the living things of long ago were different to those of today.

Patterns of Change

When enough fossils had been studied and placed into relative time order, a pattern became obvious.

The younger fossils were more like modern plants and animals. Older fossils were quite unlike modern types. Really ancient fossils were all small, simple creatures only.

Rocks older than about 600 million years contain only the fossils of "mats"of microscopic cell growths and chemicals which indicate the activity of living things. (Early investigators could find nothing at all in these rocks.)



Geological Time

In the 19th century, palaeontologists began to give names to periods of Earth history according to the different fossils in rocks from each time.

To begin with, they only had the relative order of things, but in mid-20th century they were able to put actual dates on the changes by using "radio-active dating" of rocks.

They noticed that at certain times in the past there seems to have been sudden mass-extinctions of living things, always followed by the appearance of many new types of life.
These and other discoveries, have led to a detailed knowledge of the history of life on Earth.

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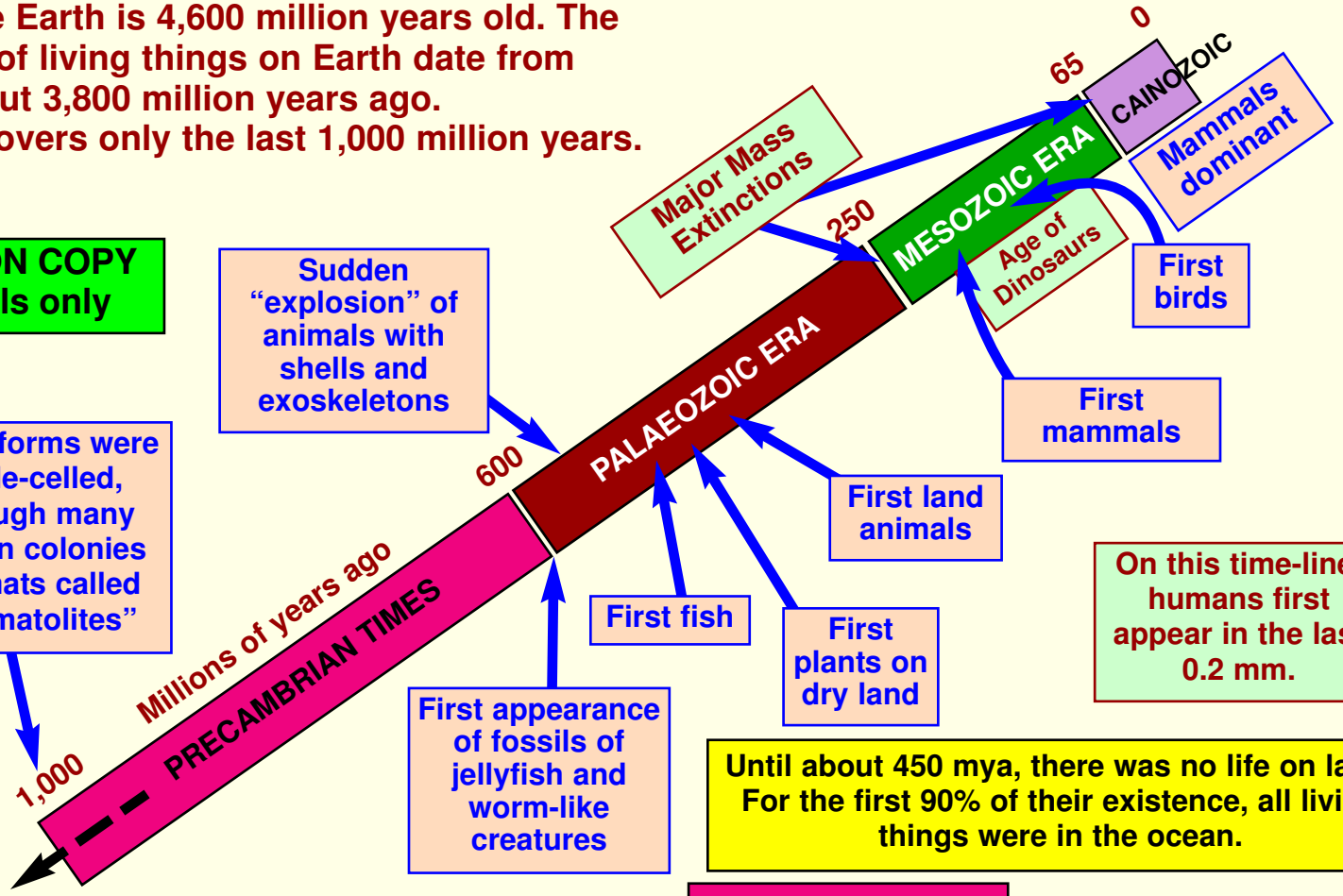
Time-Line of Earth History

This time-line summarises some of the main changes to life on Earth that have been learned from Palaeontology.

We believe the Earth is 4,600 million years old. The first traces of living things on Earth date from about 3,800 million years ago. This time-line covers only the last 1,000 million years.



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On this time-line, humans first appear in the last 0.2 mm.

Until about 450 mya, there was no life on land. For the first 90% of their existence, all living things were in the ocean.

Please complete Worksheets 10 & 11 before going on.

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Discussion / Activity 4

The following activity might be for class discussion, or there may be paper copies for you to complete.

Fossils & Earth History

Student Name .....

1. What is a fossil? In what type of rocks are they commonly found?

2.
a) Outline the principle involved in "relative dating" of fossils.

b) What technology can be used to measure the absolute age of rocks?

3. Describe the general patterns that become apparent when a large number of fossils are studied in time order.

Suggested Answers are located in a separate file

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2. Transitional Fossils

Evidence for Evolution

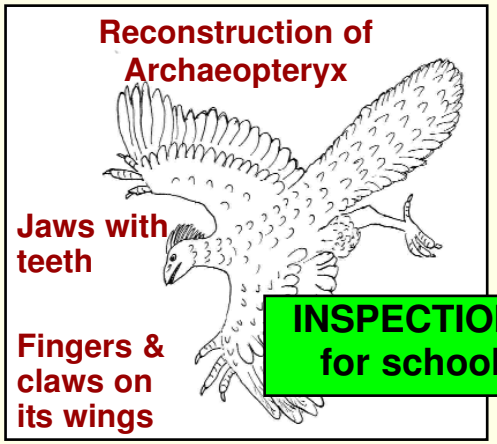
Not only does the fossil record show the overall pattern of change, but occasionally it reveals the remains of "intermediate stages" of life. These are fossils of organisms that are "in-between" in the evolution of a new type from a previously existing type of life.

Archaeopteryx (say: are-key-op-terix)

("Archae" = ancient, "pteryx" = wing)

Archaeopteryx is the most famous transitional fossil. It dates from 150 mya. Its bones are those of a small dinosaur, but it is covered with feathers.

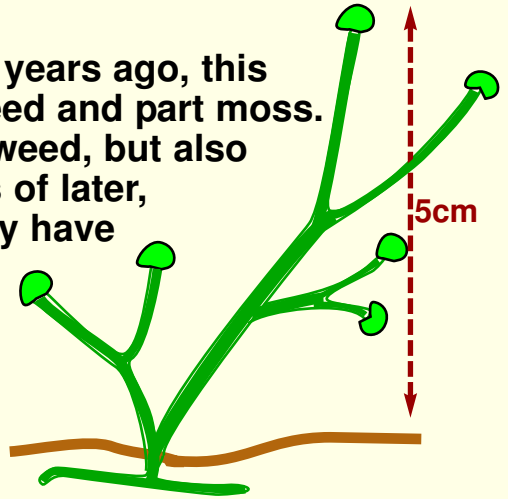
It probably could not fly well, but may have climbed trees and then glided down.



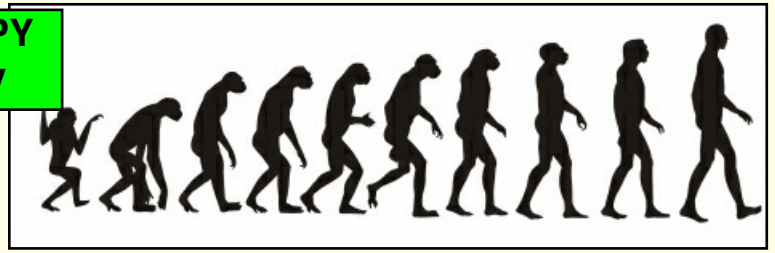
This was a dinosaur-bird.

Cooksonia

From about 420 million years ago, this plant seems part seaweed and part moss. It has features of a seaweed, but also some primitive features of later, land-living plants. It may have been one of the first plants to live on land.



Other transitional fossils include reptiles with fur (becoming mammals?), ferns with seed cones (becoming conifers?), fish with lungs and legs (becoming amphibians?) and many more... including our own ancestors.



Transitional Fossils give us a glimpse of the changes from one type to another as evolution progressed.

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Evidence for Evolution

3. Selective Breeding

People wonder how one organism can just "turn-into" another.
Well, that never happens! No individual animal changes during its life-time. The changes occur from one generation to another, as certain features are "selected" in favour of others.
Humans have been doing it to plants & animals for centuries.

Domesticated Plants & Animals

Human farmers have always chosen which seeds to keep for next year's crop, or which bull to breed with the cows.

This has drastically changed all these plants and animals. Modern wheat is nothing like the wild grass we believe it was bred from. Cabbages and cauliflowers used to be the same thing, but have been changed by selective breeding.

All breeds of dogs are descended from the wolf. Who would guess that a Dalmation and a Maltese Terrier are both wolves?!

Selective Breeding proves that a species can be changed. Humans can do it artificially, but in the wild it happens naturally.

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4. Comparative Anatomy

Evidence for Evolution

Many living organisms have basic structures which show that they have evolved from a common ancestor.

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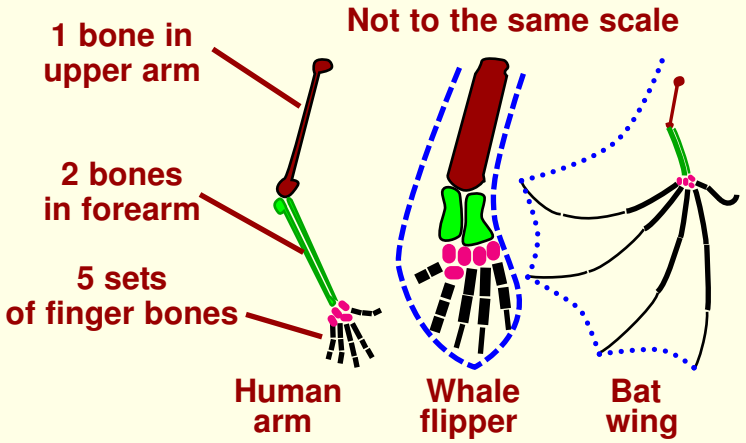
The Pentadactyl Limb ("Penta = 5, "dactyl"=finger)

Some fish, all the amphibians, reptiles, mammals and birds have the same basic bone structure in their limbs.

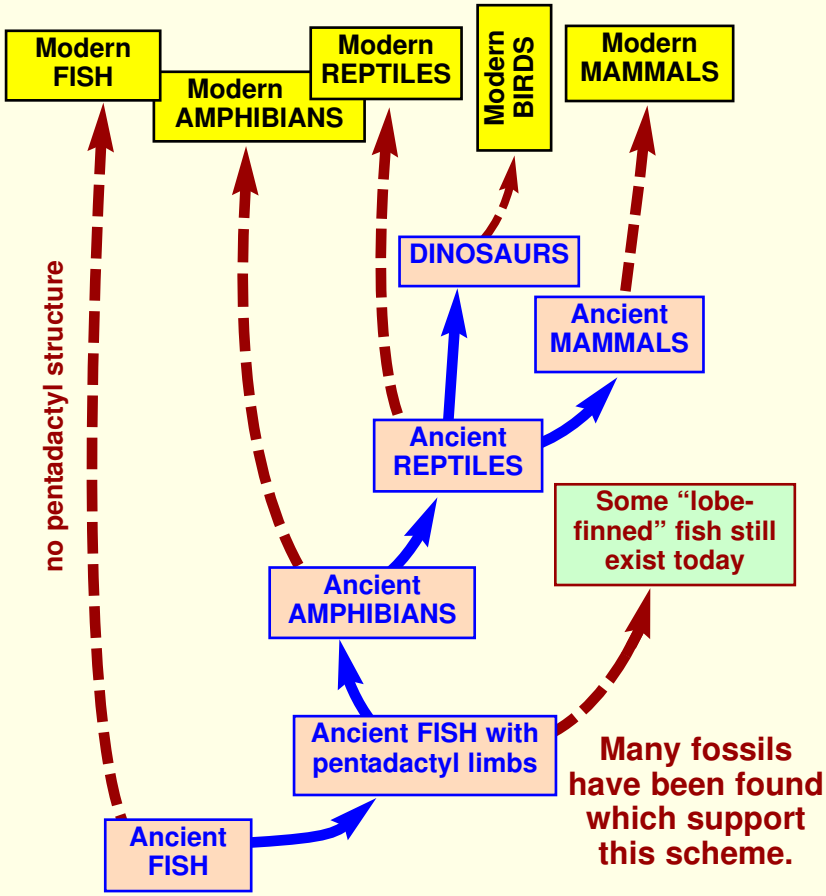


Their limbs are used in totally different ways... flying, swimming, running, grasping, digging, etc.

Why have the same bone structure?

We think it's because they have all evolved from an original ancestor which had that structure.

Evolution of Vertebrates



Many features of modern organisms point to evolution from a common ancestor.

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5. Cell Chemistry

Evidence for Evolution

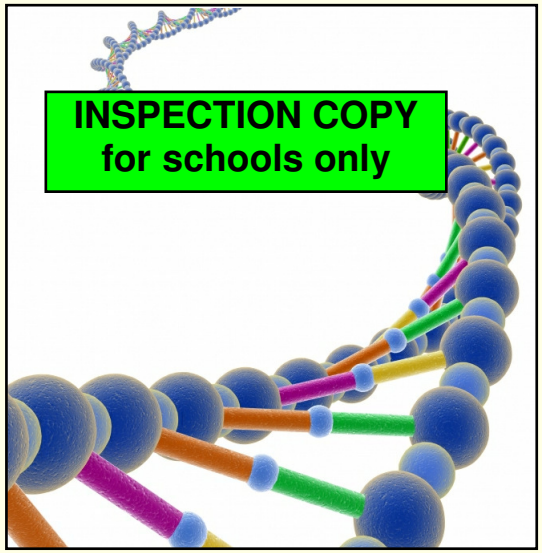
The structure of DNA, cell proteins & chemical pathways all point to a common ancestry.

The Genetic Code

Human DNA is 99% identical to that of a chimpanzee, but much less like that of a horse, less again for lizards, fish, insects, and so on.

Yet all these organisms use exactly the same "genetic code" in the DNA itself.

This is totally consistent with the idea of evolution from common ancestors.



Cell Chemicals & Pathways

The chemicals in living cells which control cell chemistry show the same patterns as DNA. The chemicals in a human cell and a fish, or even an insect cell are surprisingly similar.

When compared to plants, the differences become greater, and compared to certain types of bacteria the differences become huge.

Yet even there, there are some fundamental similarities. We think all life evolved from one ultimate ancestor!

The chemistry of modern organisms points to evolution from a common ancestor.

Please complete Worksheets 12 & 13 before going on.

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Discussion / Activity 5

The following activity might be for class discussion, or there may be paper copies for you to complete.

Evidence for Evolution

Student Name .....

1. Human art evolves. The design of motor cars evolves. Life on Earth has evolved. What does it mean when something "evolves".

2. Outline how the general trend in fossils shows us that life has evolved.

3. What are "transitional fossils" and what evidence of evolution do they give?

4. What does "selective breeding" of plants & animals by humans show?

5.

a) What is meant by the "pentadactyl limb" of vertebrate animals?

b) How does this (and other examples of comparative anatomy) give evidence of evolution?

c) What other comparison between living things shows similar evidence.

Suggested Answers are located in a separate file

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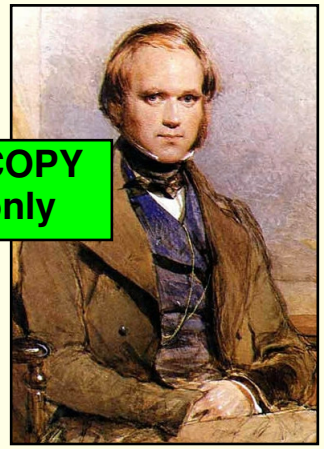
The previous section outlined the evidence that life on Earth has changed, or evolved over time. But HOW can that happen?

Evolution by Natural Selection

The Theory of Evolution is an idea which explains the FACTS of nature such as fossil sequences, cell chemistry, comparative anatomy, and so on.
The theory also contains an explanation for HOW THE CHANGES OCCUR.

Charles Darwin (English 1809-82)

In the 1830's this young naturalist travelled around the world for 5 years on a navy survey ship, HMS Beagle.



He studied thousands of plants and animals as well as rocks and fossils, especially in South America.

He became convinced that living things had changed and can change over time. He devoted the rest of his life to studying living things and developing a theory to explain how the changes could occur.

His theory was first published in 1859. It has survived the "falsification" tests of Science for 150 years, and now is backed by thousands of individual facts of evidence.

How Evolution Works

The steps of logic in Darwin's theory:

1. **All organisms produce more offspring than can possibly survive.**

2. **In every species there is variation. Each individual is slightly different.**

3. **Nature selects which individuals survive. Factors such as predators, diseases & climate determine which individuals survive to breed.**

4. **The survivors breed and pass on to offspring the characteristics which helped them survive.**

5. **This may mean that each succeeding generation is slightly different to the generation before. Gradually, over generations, changes accumulate as "natural selection" keeps choosing survivors. Gradually the population evolves into a new type, and eventually a new species.**

More detail follows...

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1. Too Many Offspring

An oyster releases 2 million eggs at a time. Only 1 or 2 ever make it to maturity. Many (in fact most) plants produce thousands of seeds. Hardly any survive.

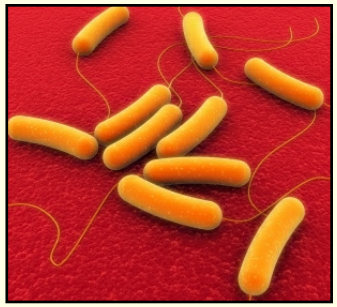
It can be shown mathematically that if every baby elephant survived to maturity and then produced 1 baby every 5 years, then the Earth's surface would be completely covered with elephants within a few thousand years. Obviously, this hasn't happened. That's because they don't all survive.

Darwin's first point is well proven by many studies of survival rates in thousands of living things. In all living things, the majority of all the offspring born, hatched or germinated DO NOT SURVIVE to reach maturity.

2. Variations

Zebras might all look the same to us, but every one has a different stripe pattern, a bit like our fingerprints. Some have a better sense of smell, others can run faster, another has better resistance to a disease, or can chew tougher grass.

In fact, in every species that reproduces sexually, we know that each individual is unique. Sexual reproduction keeps mixing genes from different parents together in different combinations.



Even among bacteria, differences arise due to mutations.

Variation is the raw material of evolution.

So, most cannot survive
AND each individual is different.
Sometimes survival might be just a matter of luck,
but all those little differences give some individuals a slightly better chance to find food, or survive disease, or avoid a predator...

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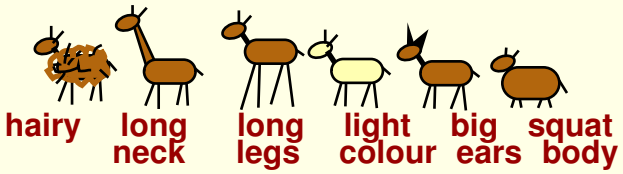
3. Natural Selection

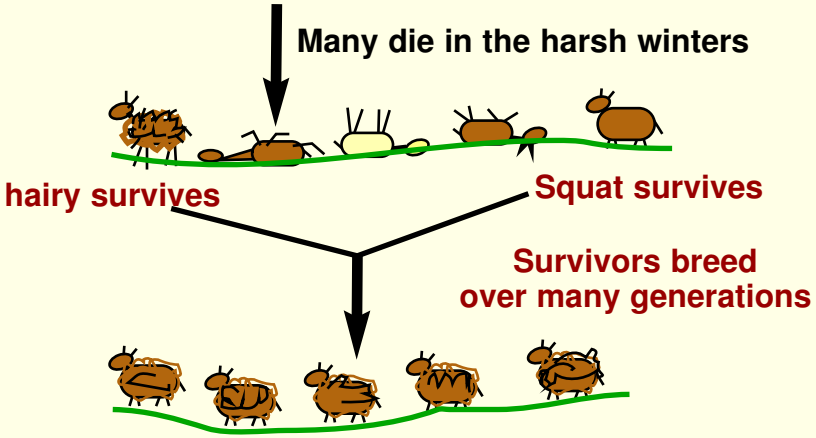
This is the key to understanding the Theory of Evolution.

HOW NATURAL SELECTION WORKS

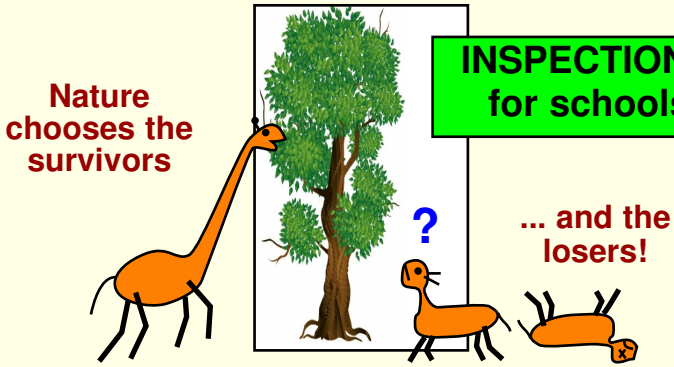
A population of a species with a lot of "variations"



Then, the climate changes... winters get colder



The survivors pass on their characteristics. Generations later, most of the population are squat and hairy. No single animal changed, but the population has changed because of which animals survived and reproduced.



What Helps Survival?

Any characteristic might be a help to survive under different conditions...

- **a better immune system helps fight diseases.**
- **more inquisitive behaviour might find more food.**
- **more timid behaviour might avoid dangers.**
- **larger body size might deter predators.**
- **smaller body size might help hide from predators.**

It is difficult to predict exactly which characteristic, or combination of characteristics, might help survival... it depends on what happens in the environment.

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4. Survive to Breed

Survival isn't just about individuals having a long life. It's really about reproduction.

The real survivors are ones who get to reproduce lots of offspring.

If you're dead, you cannot breed.

The survivors are the ones with slightly "better" characteristics to cope with the environment and all its challenges.

When survivors breed they pass on genetically those adaptations which helped them survive, so their many offspring have a better chance.

"Survival of the Fittest" really means reproduction by the best.

5. Population Evolves

It often seems as if evolution deliberately causes changes towards a certain goal. For example, in the ficticious example (previous slide) the climate became colder and it may seem as if the species deliberately evolved to become "squat & hairy" in order to survive better in the cold.

However, the characteristics "squat" and "hairy" were already present in the population among many other "variations". They simply became more common in later generations because of natural selection.

In later generations the whole population looks different because one "type" has become predominant.
Eventually it may become a new species.

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The Importance of Variations

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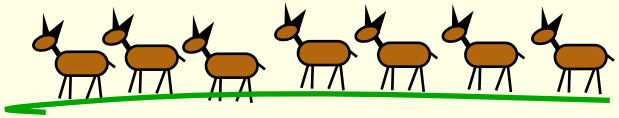
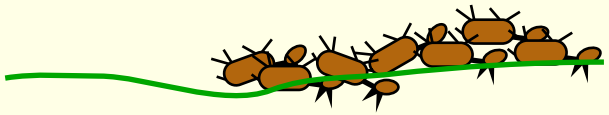
Variation Helps a Species Survive

What if all the individuals in a population were the same?



They might be "well adapted" to their environment and quite good survivors, but what if the environment changes?

What if the climate changes and winters become cold and harsh? With no "squat" or "hairy" variations, it's possible the whole population could be wiped out.



A species without variation is in danger of extinction. A larger number of variations gives a greater chance that at least some will survive and breed when the environment changes.

Where Does Variation Come From?

Sexual Reproduction always brings together genes from 2 different parents. It mixes genes together in new combinations... this creates variation.

Meiosis, the cell division which makes sperm and egg cells, also creates variations. It halves the chromosome number, but can do so in millions of different combinations of chromosomes. Every sperm or egg is different... variation.

Mutation

Ultimately, the source of all new characteristics is the accidental changes that can occur to the DNA and create a different gene.

Most mutations are detrimental, but some simply create a new variation, neither good nor bad... until the environment changes.

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Discussion / Activity 6

The following activity might be for class discussion, or there may be paper copies for you to complete.

Evolutionary Theory

Student Name .....

Make a summary statement of Darwin's Theory of Evolution, in 5 clear points.

1.

2.

3.

4.

5.

Suggested Answers are located in a separate file

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Extinction

There are millions of species alive on Earth today. This is probably less than 1% of all the species which have ever lived. Therefore, extinction is the normal (and inevitable) fate of every species, sooner or later.

The Causes of Extinction

Any change to the environment might cause extinction of a species. It could be:

- **a new deadly predator.**
- **a new competitor for food or nest sites.**
- **a disease epidemic.**
- **a loss of habitat. (Humans cause this a lot)**
- **a climate change, either natural or not.**

If a species has many variations, it has a better chance that at least some will survive and breed, possibly changing the features of the population and leading (eventually) to a new species.

Mass Extinctions

Palaeontologists have identified about 6 major, mass extinction episodes that have occurred within the past 500 million years.

The most recent world-wide mass extinction occurred 65 million years ago. There is evidence that a 10km meteorite from space hit the Earth.

It caused such a sudden and drastic climate change that more than half of all species were wiped out, including all the dinosaurs.

It is possible that a new mass extinction is currently underway due to human-caused Global Warming and environmental destruction.

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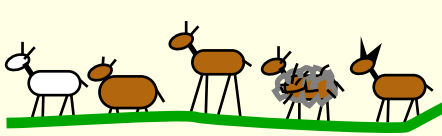
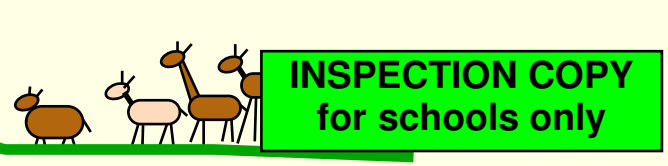
How One Species Evolves into Many

After every mass extinction in Earth history there has always been a recovery, with many new species "suddenly" appearing in the fossil record. How can multiple new species evolve?

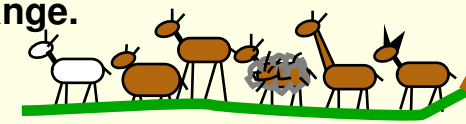
This species of animals has spread out widely across a continent.



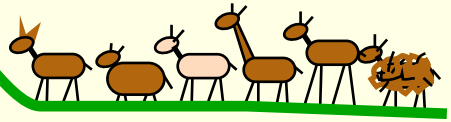
They are all one species, but have many variations among the individuals.



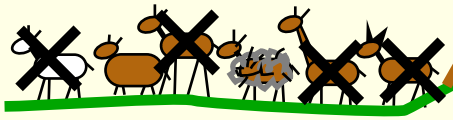
Over thousands of years, volcanic eruptions and earth movements enlarge the mountain range.



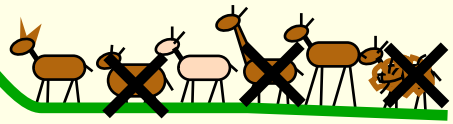
The species becomes divided into 2 groups which are <u>isolated</u> from each other and rarely meet or inter-breed.



In this region the winters have become cold. "Squat" and "hairy" have a survival advantage. Natural Selection weeds out those "less fit".

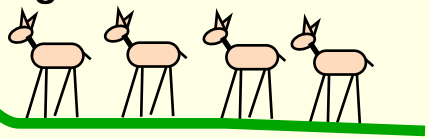


In this region a new predator has migrated in. Big ears hear it coming; long legs run away faster; lighter colour is better camouflage. A different set of variations are "fittest" here.



As always, the survivors breed.

The "survival traits" become predominant in each region over a number of generations.



Over generations, the animals in the 2 regions evolve to be quite different. Eventually they become unable to interbreed, even if they get the chance. They are now 2 different species.

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The Importance of Isolation

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In the ficticious example, (previous slide) one original species has evolved into two different species.

The key to this was the isolation of one group from the other. Isolation allows Natural Selection to work on each group differently, according to the environment and which characteristics might help survival in each place.

Organisms can become isolated by mountain ranges, by rivers, on different islands, etc.

On his 1830's voyage, Charles Darwin was deeply impressed by the many different (but obviously related) species of birds on the different islands of the Galapagos Islands.

He also noted the slightly different "sub-species" of the giant land tortoises on the islands.

Modern biologists have studied many changes to isolated groups living under different "selection pressures".

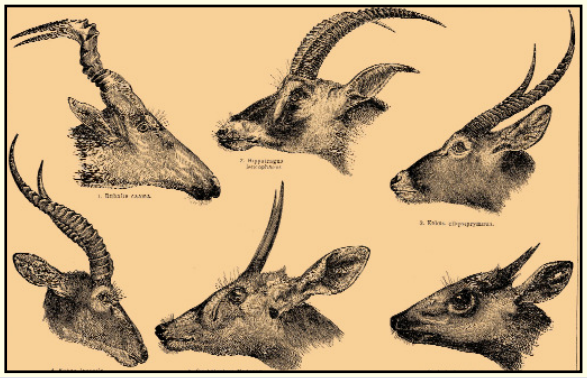
Please complete Worksheets 14 & 15 before going on.

Biodiversity & Evolution

"Biodiversity" refers to the variety of living things. It can refer to the many small variations within a species or refer to how many species there are in a particular ecosystem, or on the entire planet.

Either way, you need to realise that biodiversity is connected to evolution. For example, there are over 90 species of antelope alive today (and many more extinct types known from fossils).

Why so many types? Why not just one species of antelope?



Evolution theory explains:
there was once an "ancestor species" of antelope which spread across many parts of the world. In each different ecosystem the population evolved by natural selection according to what little variations helped survival in that place.

Over generations, each population changed in its own way until each group became a different species.

We think all biodiversity originated this way. Ultimately, all life on Earth is related. All life on Earth today evolved from a common ancestor.

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Observing Evolution

Can we ever watch evolution happening? Although we have not seen one species evolve into a different species, there are many examples of small evolutionary changes being observed.

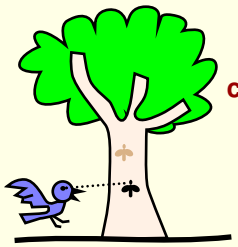
The Pepper Moth

A classic example of "micro-evolution" is the change in the population of the English Pepper Moth which has been studied and documented over the past hundred years.

This moth always rests during the day on tree trunks, which in natural forests, are mostly covered in light-patterned lichens. Under these conditions the light "peppery" moths are the most common form, although occasional black moths occur.

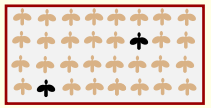
During the coal-burning phase of the Industrial Revolution many forests were damaged by pollution. The lichens were killed and tree trunks blackened with soot. It was observed that the Pepper Moth population changed in the proportion of peppery to black types.

Now that industrial pollution has been stopped, the moths have evolved back to being mostly of the lighter-coloured type.



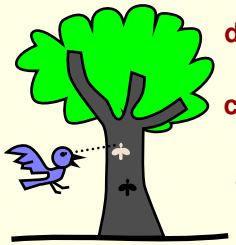
In unpolluted forests, the lighter-coloured moths are camouflaged.. . They are "fittest" for survival and breeding.

Lighter-coloured moths survive and breed in greater numbers



Population ratio. The black form is rare.

Predators spot the black moths more easily



In polluted forests, the dark-coloured moths are better camouflaged.. They are "fittest" for survival and breeding.

Black moths survive and breed in greater numbers

Population ratio. The lighter form is rare.

Predators spot the lighter moths more easily

Evolution of Resistance

Another example of "micro-evolution" was observed when DDT insecticide began to be used against a variety of insects, such as disease-carrying mosquitoes or crop-eating pests.

Initially, the chemical was a huge success, destroying the insect populations. But then Natural Selection did its thing...

Among the millions of insects in each population there was variation. A few individuals had a natural resistance to the DDT and they survived and reproduced and passed on their resistance to their offspring.

Over many generations the non-resistant types were killed, and resistant types kept surviving and breeding until almost the entire population was resistant. DDT was no longer useful for killing insects. (Just as well, because DDT caused ecological damage by Biological Magnification.)

The DDT acted as a "Chemical Selecting Agent" resulting in the evolution of the insects by natural selection and survival of the fittest.

Similar examples have been observed with bacteria becoming resistant to Penicillin and other antibiotics.