KEEP IT SIMPLE SCIENCE

Topic 19: Genetics & Evolution

Stage 5 Biological Sciences

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STUDY NOTES & WORKSHEETS

Attention Teachers

1.
KISS Study Notes & Worksheets are designed to consolidate students' knowledge & understanding and/or develop or practice a skill, such as graphing, calculating, reporting prac.work, etc. Some are suitable to issue as homework assignments. Some can be used as a "quick quiz".
The level of complexity & difficulty increases at each year level.

2.
In the KISS "Study Notes" section, an information box (example shown) indicates the worksheet(s) appropriate to be completed.

Please complete Worksheets 1 & 2 before going on.

3.
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Worksheets begin on p29.
Answer Section begins on p40.

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Topic Outline

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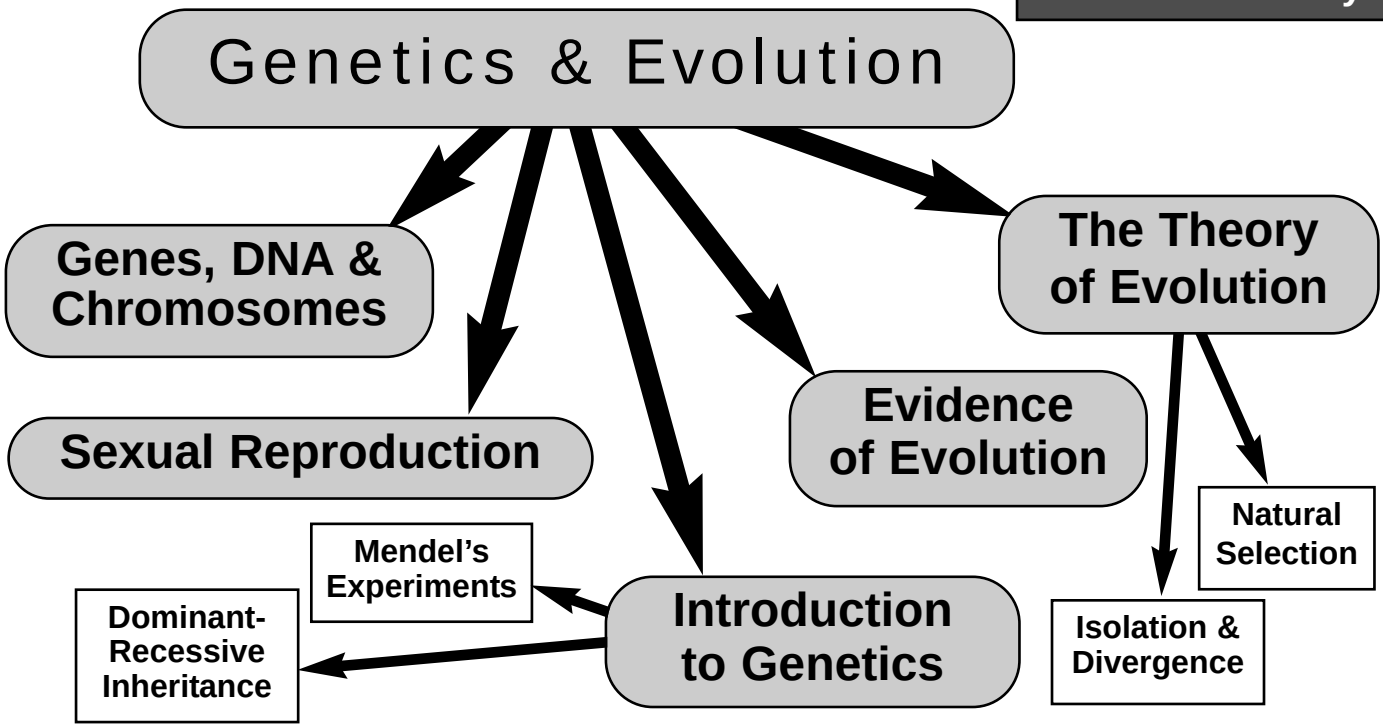

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Genetic Information

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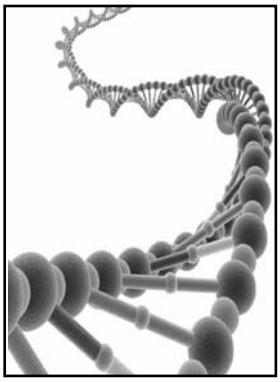
("Genetic" = to do with genes)

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?

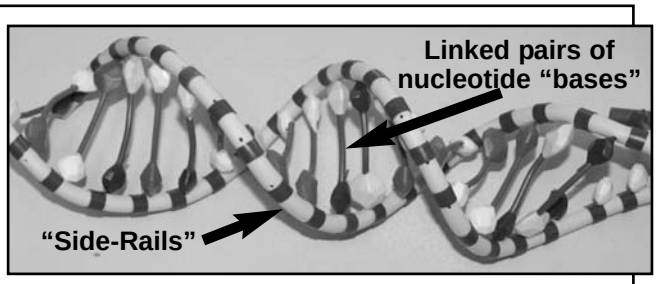
For the full details, you will need to study Biology in years 11-12, but here is a basic outline:

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!

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:



1. Protein Synthesis

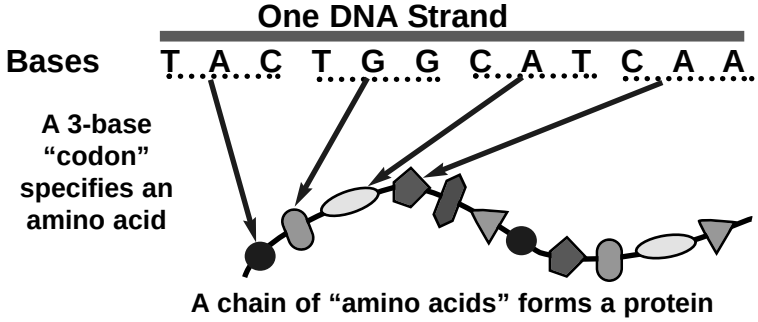
It must be able to make cell and body structures by causing particular proteins to be made within cells. Proteins are large molecules made from chains of "amino acids". The exact nature and function of a protein depends on the sequence of different amino acids. Some proteins build cell parts, muscle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

sugar-phosphate "side rail"

Nucleotide Bases	A	G	T	C	C	A
	I	I	I	I	I	I
	T	C	A	G	G	T

The only combinations that will bond are 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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2. 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.

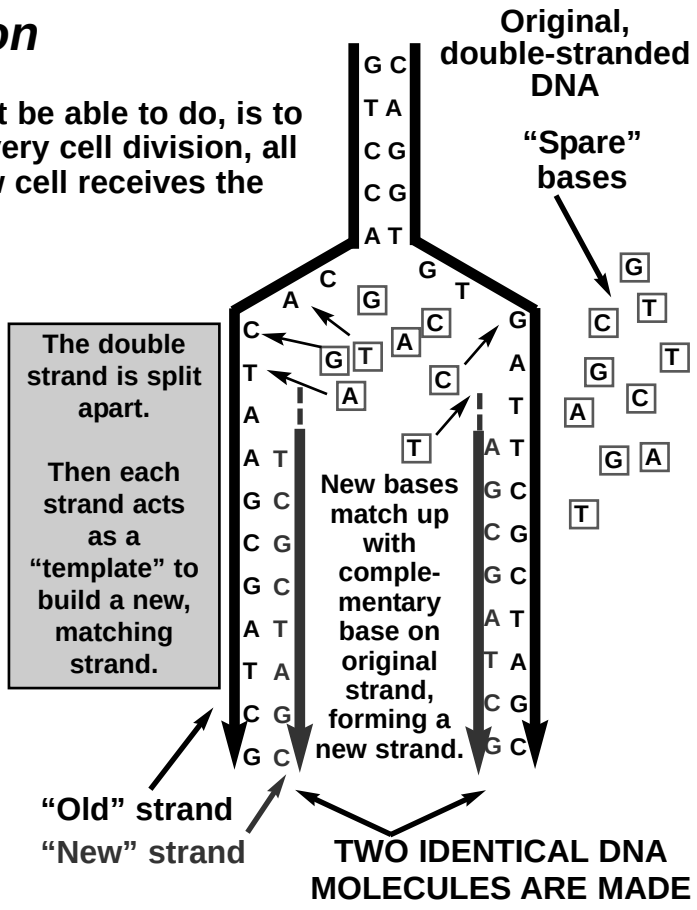
So how does the structure of the DNA molecule lend itself to replication?

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.

Each DNA molecule must be replicated before a cell division.



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Cell Differentiation

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.

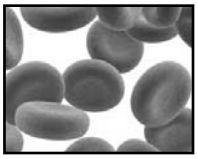
During the early stages of pregnancy, the tiny embryo grows rapidly by cell division. (details next page)

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.

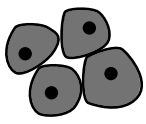
Cells Become Specialised

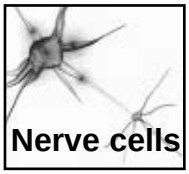
Within a week after fertilisation, "cell differentiation" begins. Cells begin to follow particular instructions in their DNA so that they become specialised. For example, some cells follow DNA instructions to become (say) muscle cells. Others ignore the "muscle instructions" and follow other parts of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



Blood cells

Skin cells





Nerve 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 below.
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.

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.

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!

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.

Cell Division: Mitosis

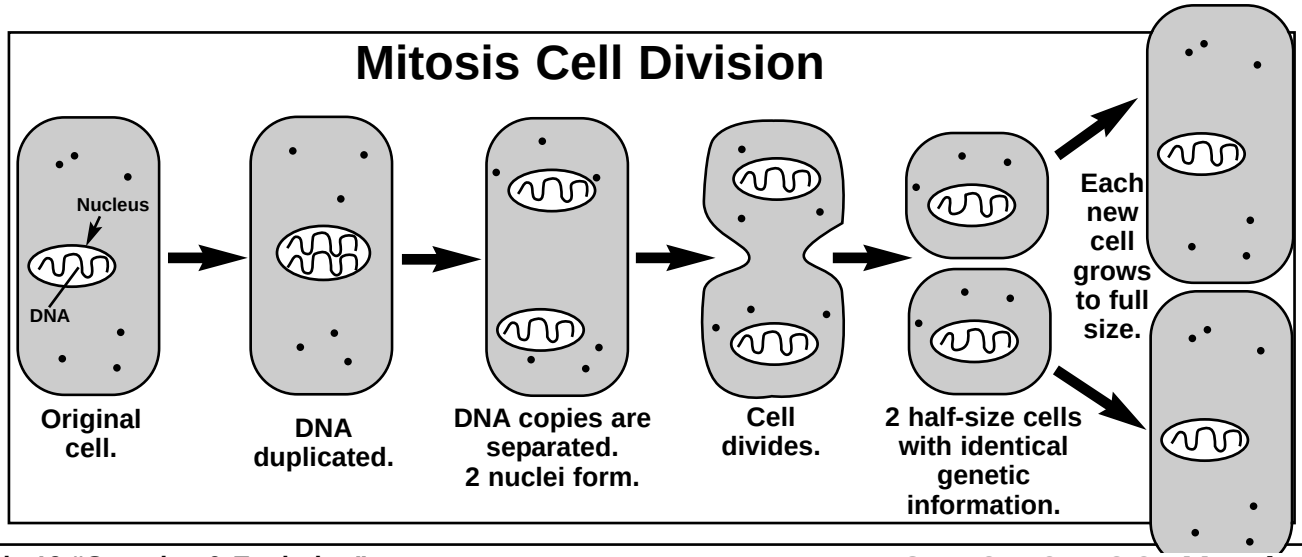
Each cell first makes a duplicate copy of the DNA in the cell nucleus. In most cells, the DNA is contained within structures called "chromosomes". The DNA contains the genetic information which controls the structure and functioning of the cell and the entire organism.

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

After this page, please complete Worksheets 1 & 2

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.



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How Research Can 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.

Social Factors & 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 page 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.

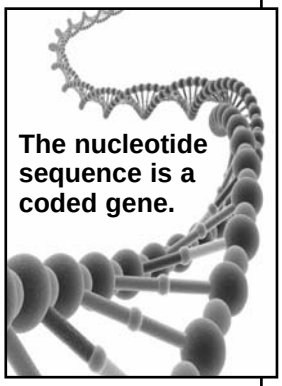
In some cases the situation is much more complicated. Human height is determined by dozens of genes as well as by childhood health and nutrition.

However, to keep it simple (K.I.S.S.) the following principle is often true.

one gene ⟶ one characteristic

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.

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.

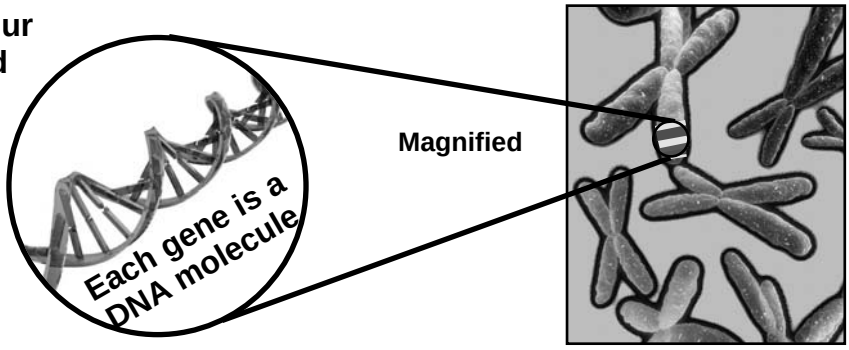
DNA molecule = a gene

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

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. More on this later...

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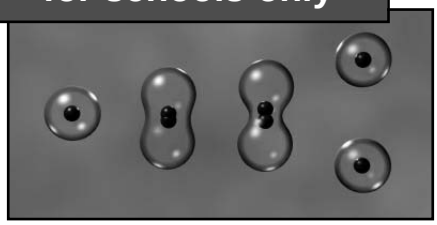
Sexual & Asexual Reproduction

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

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



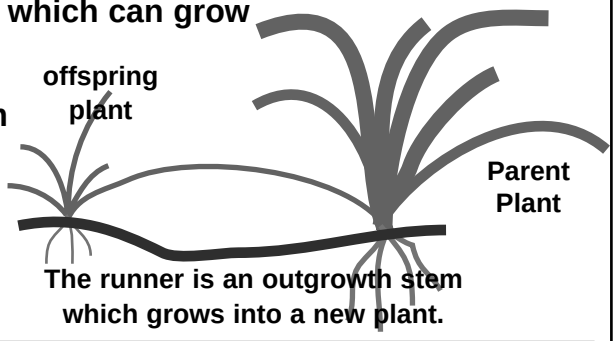
Unicellular Reproduction

Single-celled organisms such as bacteria reproduce by simply dividing in two by <u>mitosis</u>.
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".

Asexual Reproduction in Multicellular Life

Many multi-cellular organisms reproduce asexually.

<u>Fungi</u>, 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 & released from a single "parent".

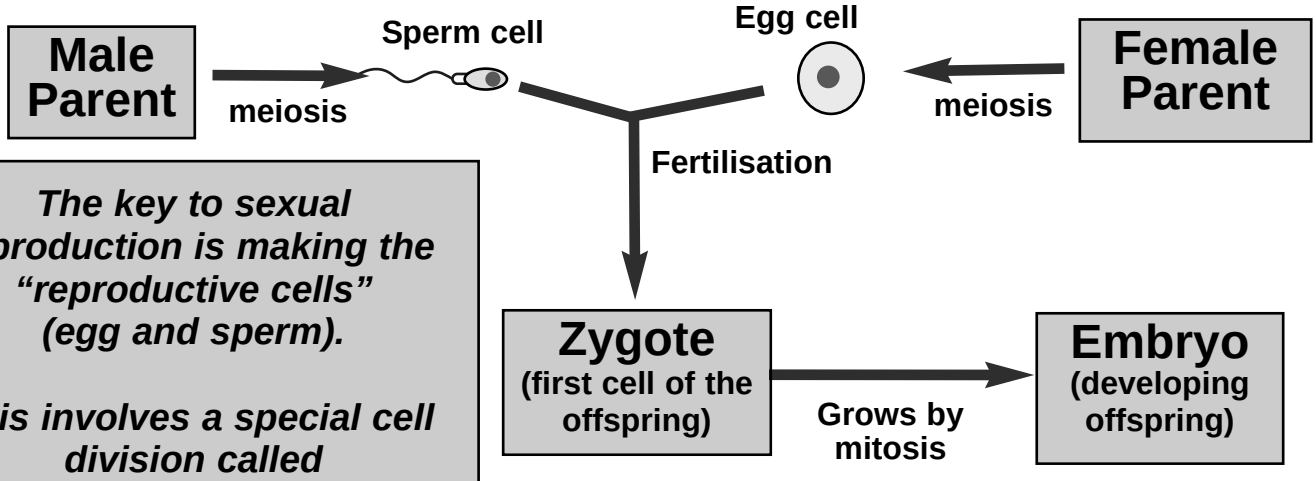


Many <u>Plants</u> can reproduce asexually by sending out "runners". These same plants can also reproduce sexually with their flowers.

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.

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 making the "reproductive cells" (egg and sperm).

This involves a special cell division called meiosis.

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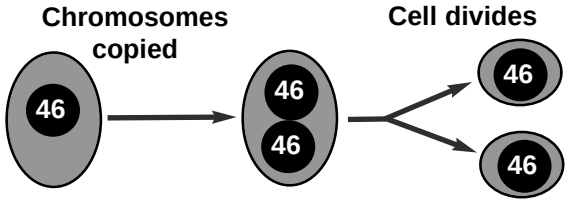
Meiosis & Sexual Reproduction

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.

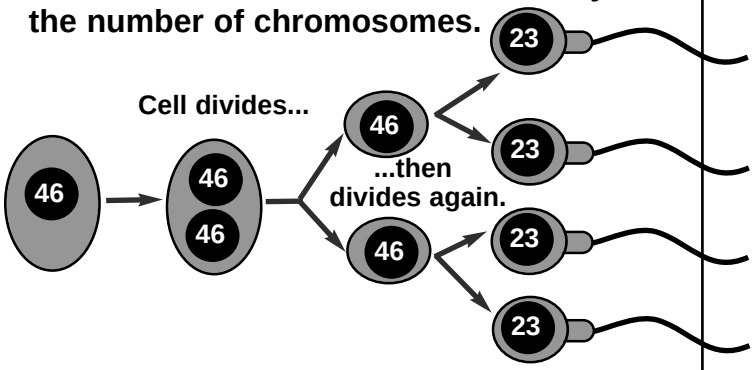
During mitosis, the chromosomes (and the DNA they contain) are first copied, then divided between the "daughter cells".



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

Meiosis Halves the Number of 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.

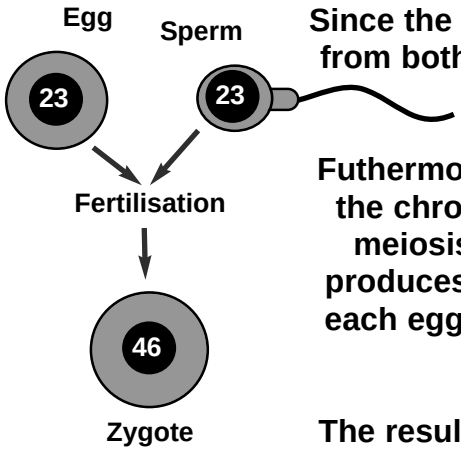
The main point is that both sperm and egg have only half the normal number of chromosomes.

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 of chromosomes 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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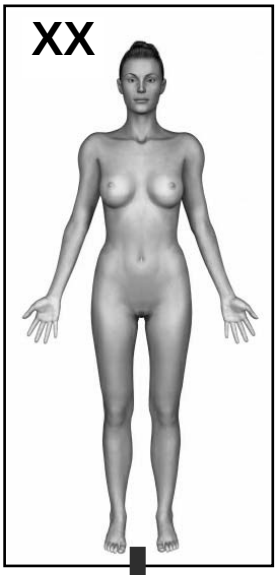
Male or Female? Sex Chromosomes

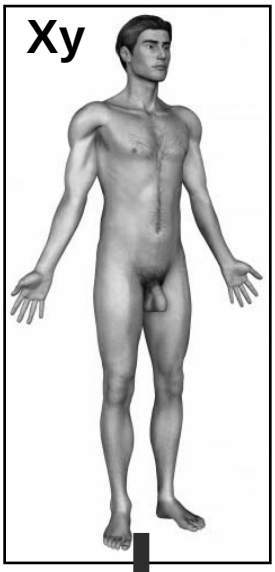
Human body cells have 46 chromosomes which are arranged in 23 pairs. The first 22 pairs are the same for everyone, although of course each person has their own particular set of genes. The 23rd pair of chromosomes are special... they determine your sex.

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.





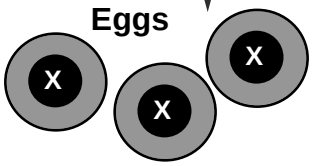
Male

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".

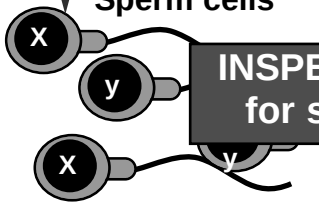
When he makes sperm cells by meiosis, half of them will carry an X, the other half will have a y-chromosome.

Meiosis

Eggs



Sperm cells



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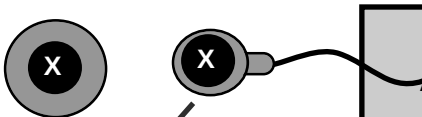
Dad Determines the Sex of the Baby

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

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



Fertilisation

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.

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

Fertilisation

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.

Punnett Squares

A Punnett Square is a way to work out the <u>probabilities</u> 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.

Mother's eggs

Father's sperm	X	X
X	XX	XX
y	Xy	Xy

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

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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 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.**

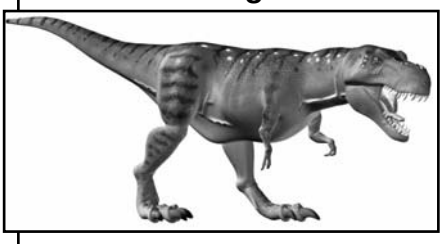
***In a Gamete,* a mutation may kill the egg or sperm cell, or kill the embryo. Some disorders, such as Cystic Fibrosis, can be caused by a mutation which has carried through an egg or sperm to affect the whole person.**
Generally, mutations are not good news!

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!

Complete Worksheet 6 after this page.

keep it simple science

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".

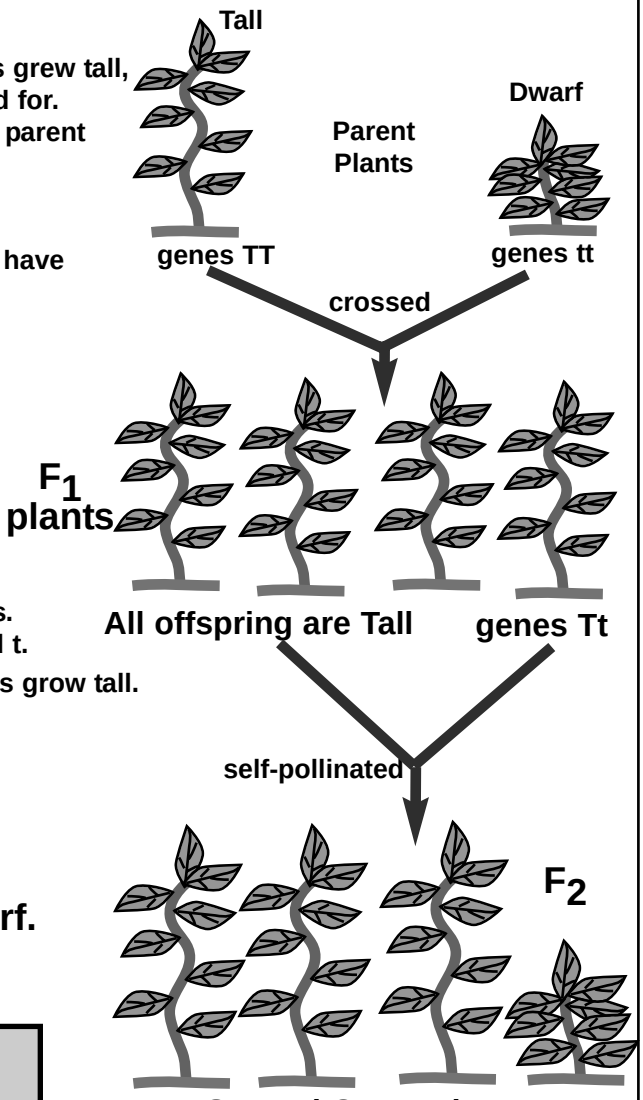
He figured out from the later results, that each plant must have two genes for either tall stem (symbol "T") or for dwarf stem (symbol "t").

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.**



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:

First Generation F_1

Genes of Parents: TT x tt

gametes	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

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.

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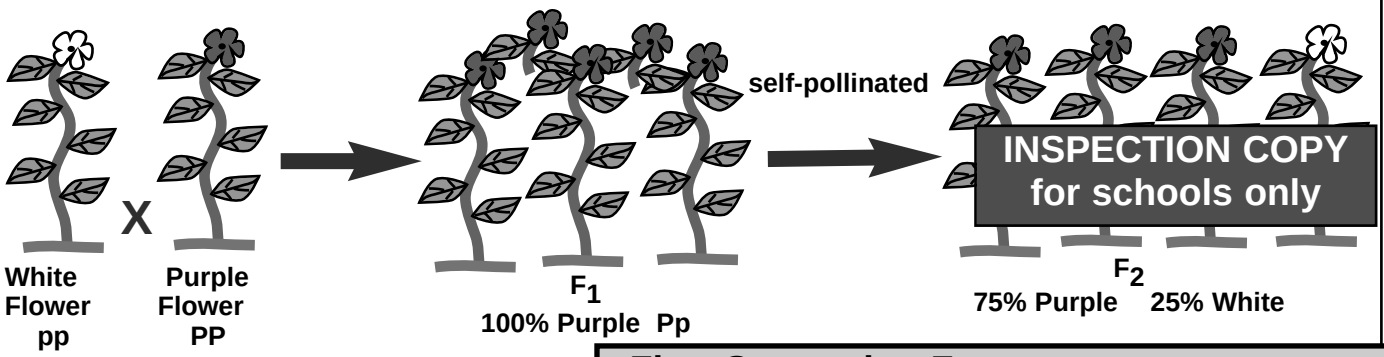
More about Mendel

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	Pp	Pp
P	Pp	Pp

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

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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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**

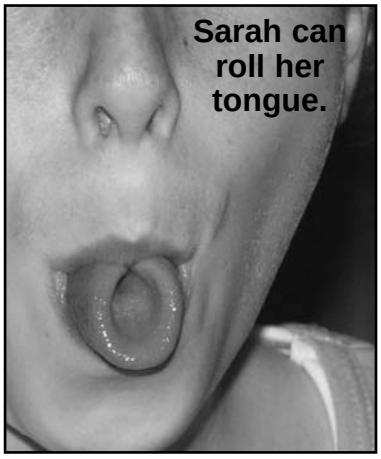
Horizontal connections are "marriage lines".

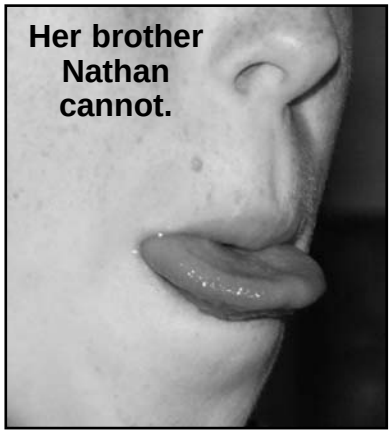
Vertical lines lead to children of that couple.

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.

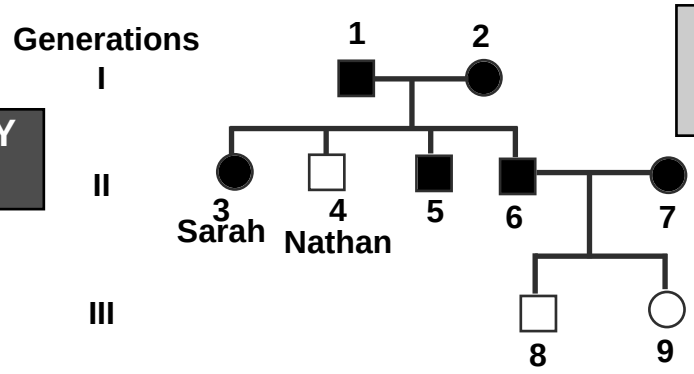




Below is a pedigree diagram of Sarah & Nathan's family, showing how the tongue-rolling trait has been inherited over 3 generations.

Can you tell which gene is dominant?

Can you work out which people carry what genes?



Please complete Worksheet 9 after this page.

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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 <u>dominant gene</u>.

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

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?

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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 & 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.

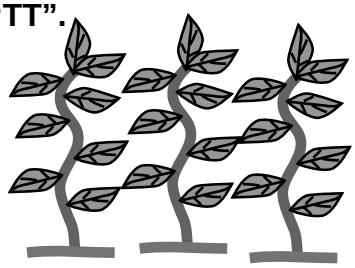
Genes are made of DNA.
The 2 genes for any characteristic are located one on each of the chromosomes in a pair.

Genetics versus Environment

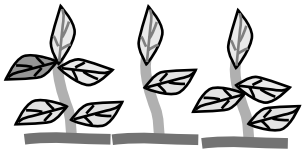
Is every characteristic of every living thing determined entirely by its genes?
No, definitely not! The genes give each organism a "potential" to which it may develop, but the environment determines if that potential is reached.

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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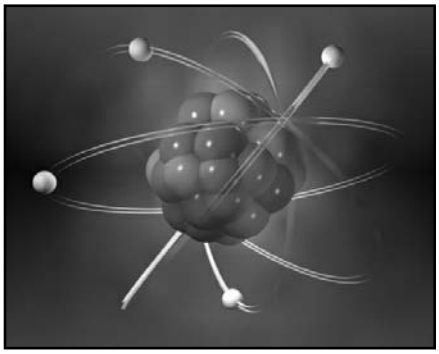
The Theory of Evolution

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 say "it's only a theory... it's not proven". They do not understand what a scientific theory is.

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?)

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

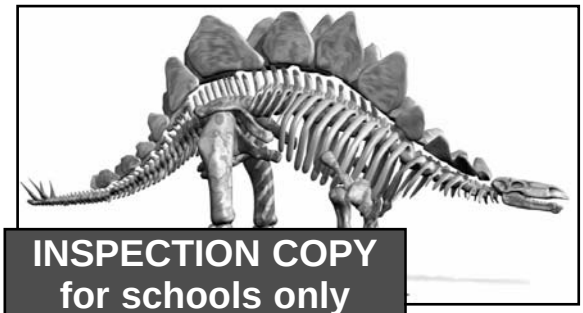
Evidence for Evolution

This is 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 & 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 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.

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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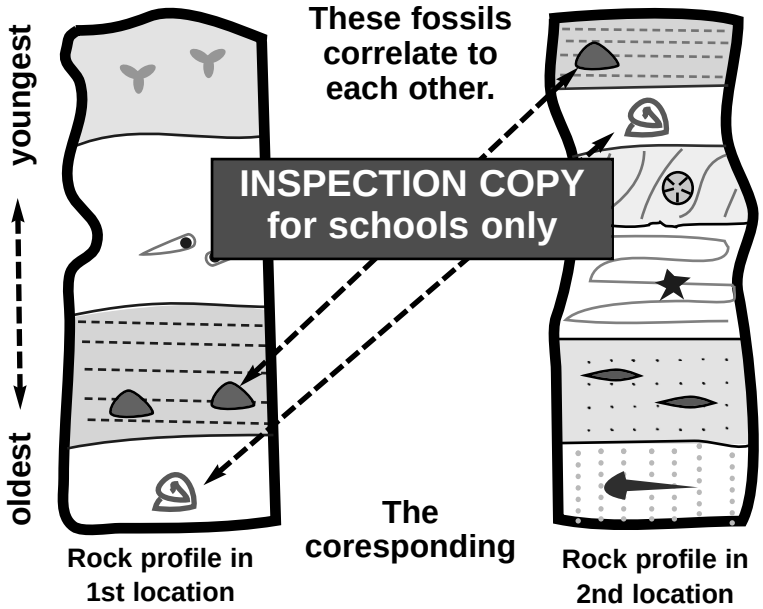
Putting Fossils in Time Order

Most fossils are buried in sediments. Fresh sediment always settles <u>on top</u> 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 <u>correlating</u> fossils from one area to another.



Actual Age of Fossils

Correlating fossils can only give <u>relative</u> 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.

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

Life on Earth Has Changed

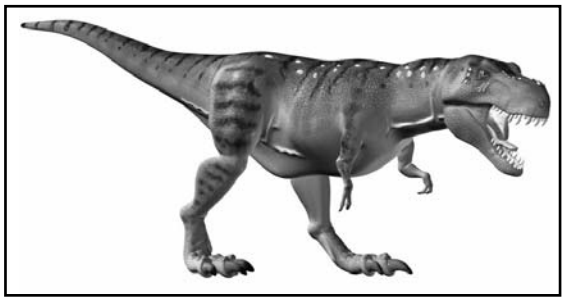
Even the earliest amateur fossil-collectors of 200 years ago noticed that the fossils they found were not the same as modern life-forms. Obviously, the living things of long ago were different to those of today.

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 <u>relative order</u> 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 <u>mass-extinctions</u> 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.

0

CAINOZOIC

Mammals dominant

65

Major Mass Extinctions

MESOZOIC ERA

Age of Dinosaurs

First birds

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

Artist's impression of a meteorite impact which may have caused a mass extinction 65 mya.

250

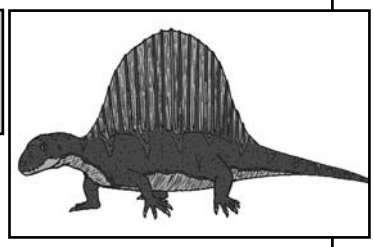
First mammals

PALAEOZOIC ERA

First land animals

Sudden "explosion" of animals with shells and exoskeletons

First plants on dry land



600

First fish

Trilobite fossil, 450 mya.

First appearance of fossils of jellyfish and worm-like creatures

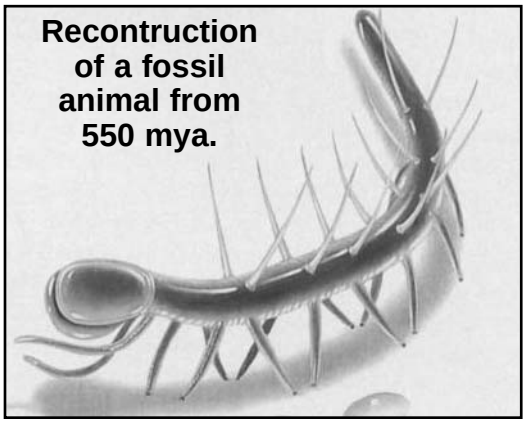
All life-forms were single-celled, although many grew in colonies and mats called "stromatolites"

Millions of years ago

PRECAMBRIAN TIMES

1,000

Recontruction of a fossil animal from 550 mya.



Please complete Worksheets 10 & 11 before going on.

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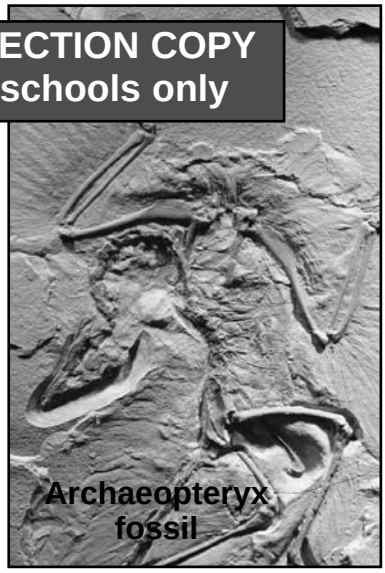
2. Transitional Fossils

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)

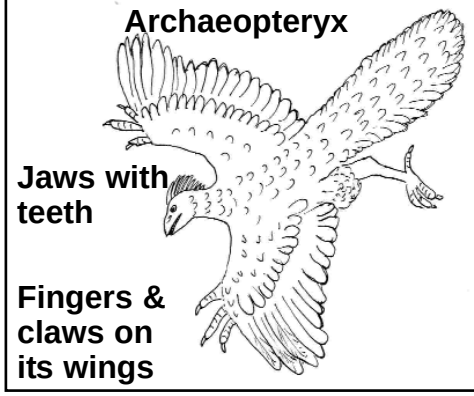


Archaeopteryx is the most famous transitional fossil. It dates from 150 mya. Its bones are those of a small dinosaur, but it is covered with feathers.

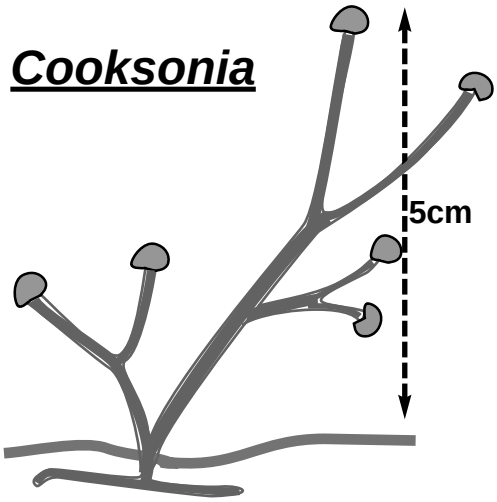
It probably could not fly well, but may have climbed trees and then glided down.

This was a dinosaur-bird.

Reconstruction of Archaeopteryx



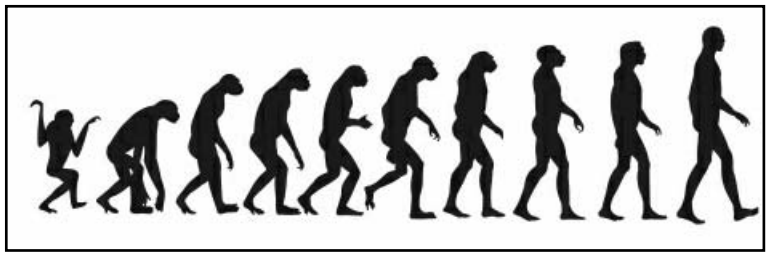
Cooksonia



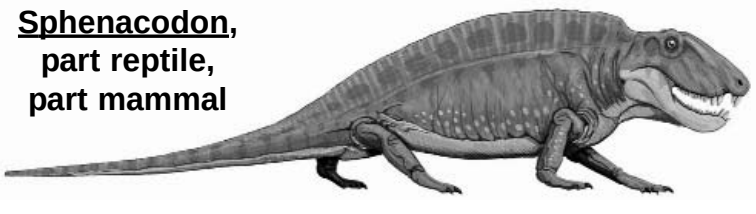
From about 420 million years ago, this plant seems part seaweed and part moss. It has features of a seaweed, but also some primitive features of later, land-living plants. It may have been one of the first plants to live on land.

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.



Sphenacodon, part reptile, part mammal



This is a reconstruction of an animal which was quite common about 280-300 mya. Obviously related to the reptiles, its fossils also reveal many primitive, but unmistakable, mammal-like features.

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3. Selective Breeding

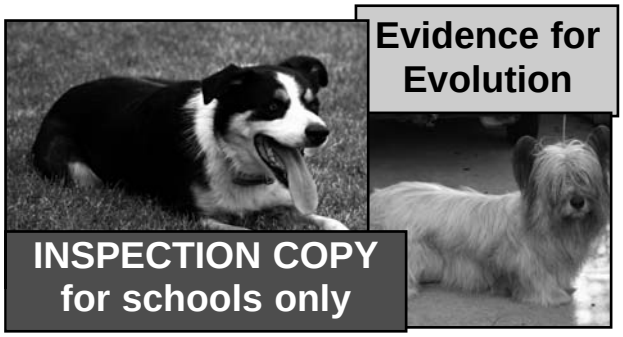
People wonder how one organism can just "turn-into" another. Well, that never happens! No individual animal evolves during its life-time. The changes occur from one generation to another, as certain features are "selected" in favour of others. Humans have been doing it to plants & animals for centuries.

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.

Evidence for Evolution



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

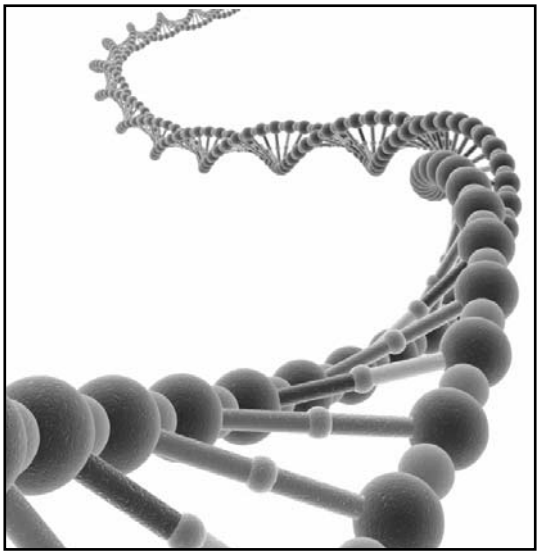
Selective Breeding proves that a species can be changed. Humans can do it artificially, but in the wild it happens naturally.

4. Cell Chemistry

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.

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5. Comparative Anatomy

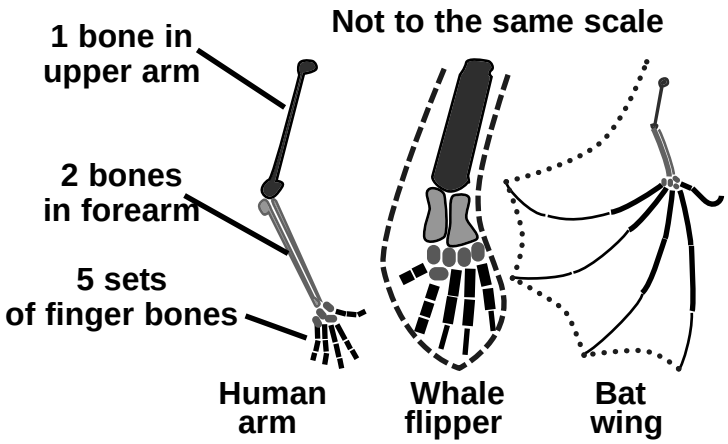
Many living organisms have basic structures which show that they have evolved from a common ancestor.

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.

Evidence for Evolution

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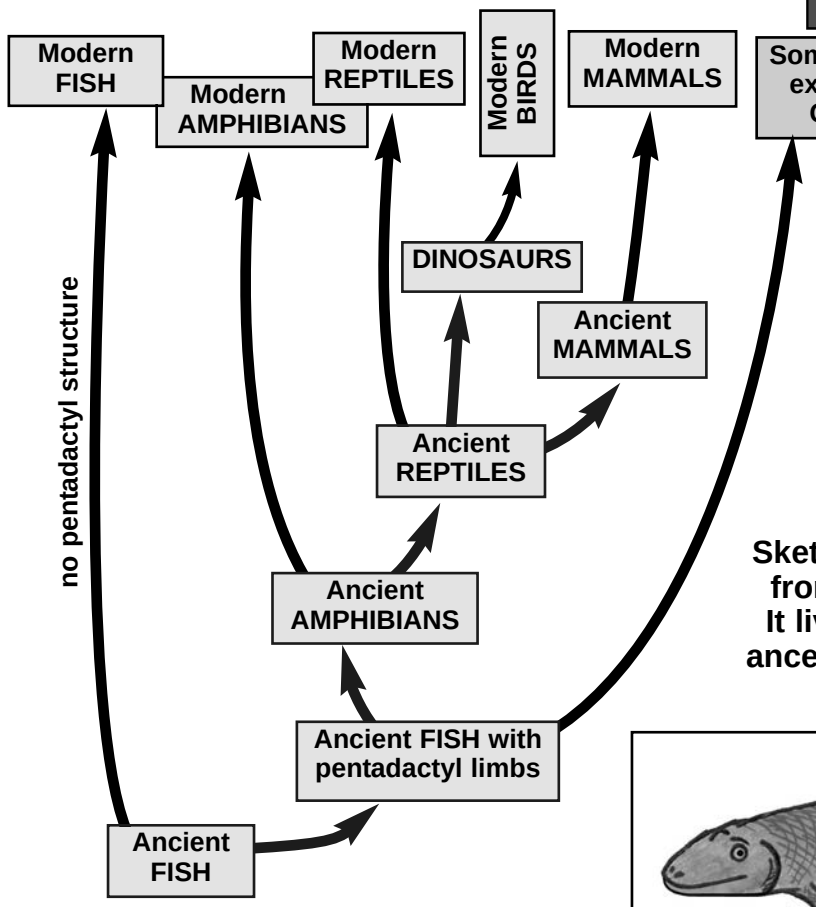
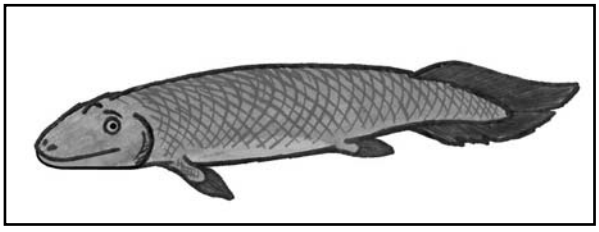
Evolution of Vertebrates



Many fossils have been found which support this scheme.

Please complete Worksheets 12 & 13 before going on.

Sketch of “Tiktaalik” reconstructed from its fossils found in Canada. It lived 375 mya and is a possible ancestor of all modern animals with pentadactyl limbs.



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

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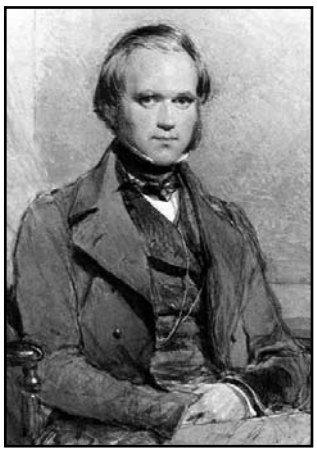
The previous section outlined the evidence that life on Earth has changed, or evolved over time. But HOW can that happen?

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:

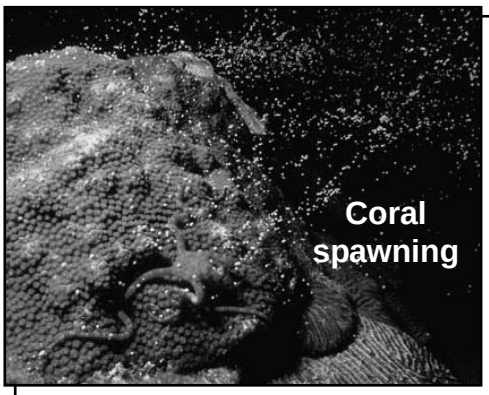
1. All organisms produce <u>more offspring</u> than can possibly survive.

2. In every species there is <u>variation</u>. Each individual is slightly different.

3. <u>Nature selects</u> which individuals survive. Factors such as predators, diseases & climate determine which individuals survive to breed.

4. The <u>survivors breed</u> and pass on to offspring the characteristics which helped them survive.

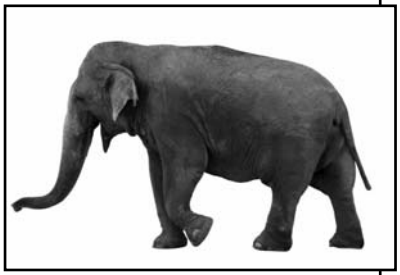
5. This may mean that each succeeding generation is <u>slightly different</u> to the generation before. Gradually, over generations, changes accumulate as "natural selection" keeps choosing survivors. Gradually the population evolves into a new type, and eventually a new species. **More detail follows...**



Coral spawning

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 many do NOT 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.

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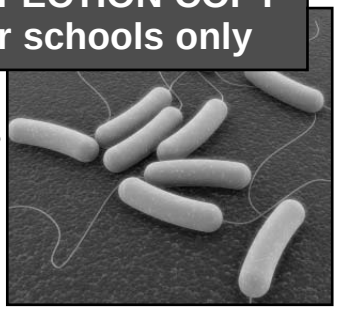
2. Variations

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.

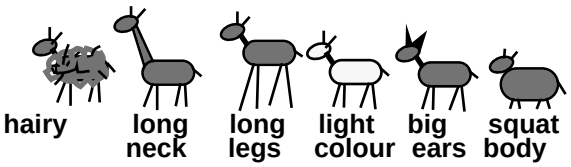
So, most cannot survive AND each individual is different. Sometimes survival might be just a matter of luck, but all those little differences give some individuals a slightly better chance to find food, or survive disease, or avoid a predator...

3. Natural Selection

This is the key to understanding the Theory of Evolution.

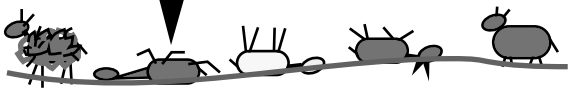
HOW NATURAL SELECTION WORKS

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



Then, the climate changes... winters get colder

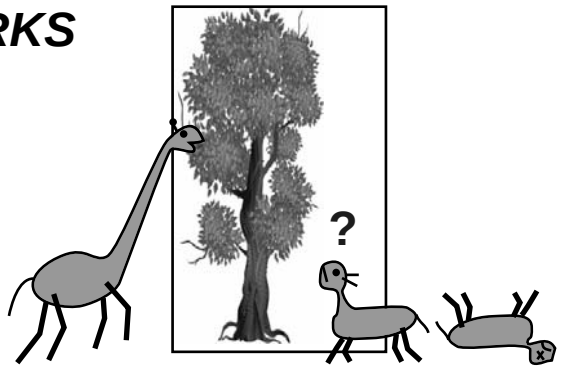
Many die in the harsh winters



hairy survives **Squat survives**

Survivors breed over many generations

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.



Nature chooses the survivors

... and the losers!

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 features, 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 page) 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.

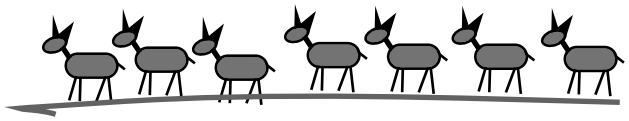
In later generations the whole population looks different because one "type" has become predominant.

Eventually it may become a new species.

The Importance of Variations

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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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.

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.

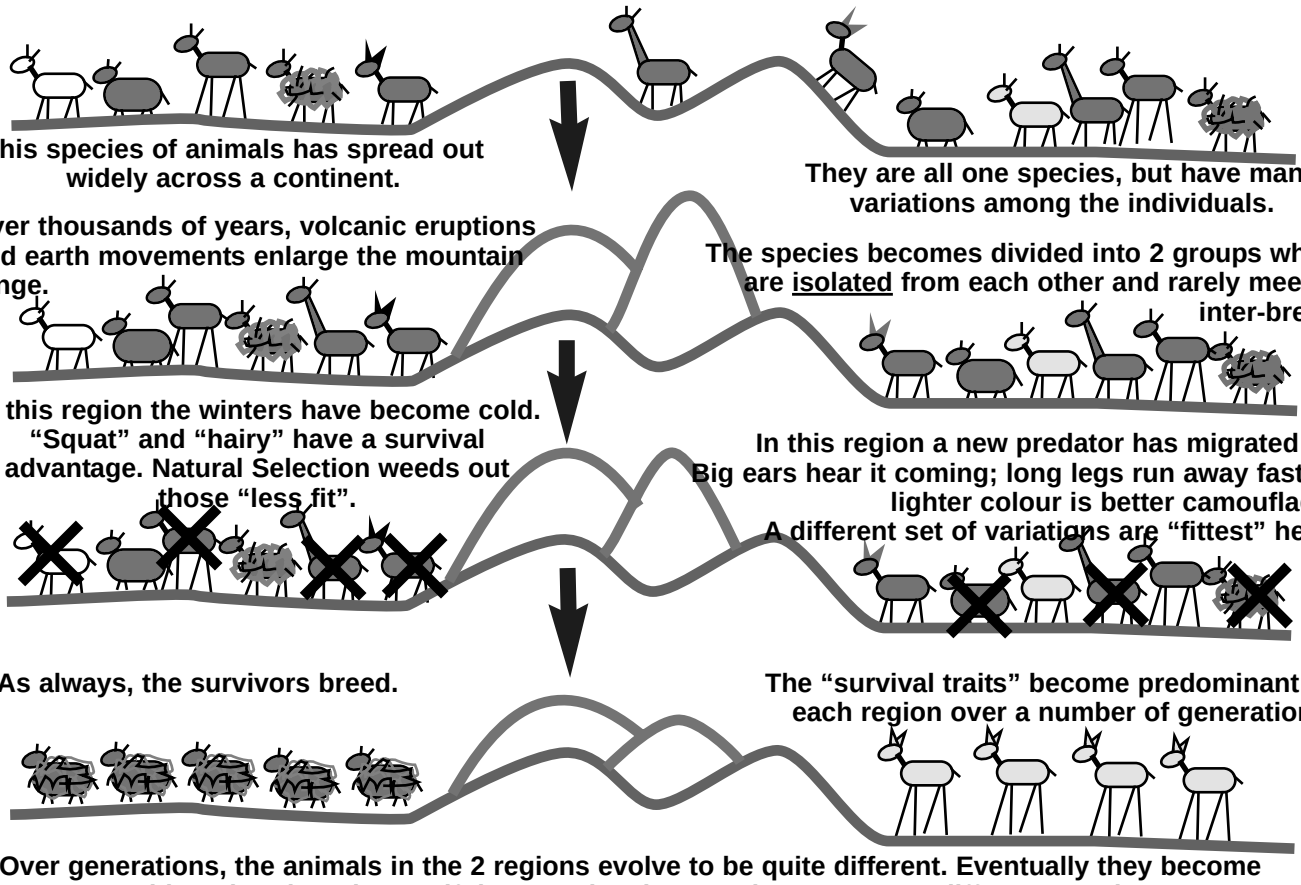
The most recent world-wide mass extinction occurred 65 million years ago. There is evidence that a 10km meteorite from space hit the Earth.

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.

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?



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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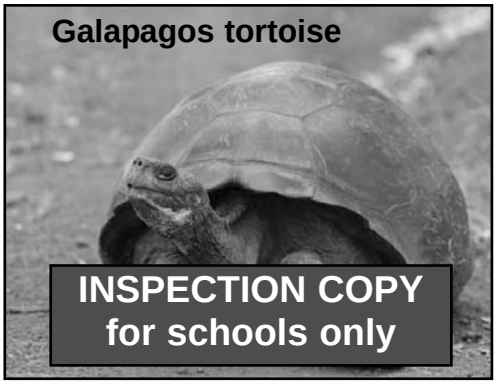
The Importance of Isolation

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

The key to this was the <u>isolation</u> of one group from the other. Isolation allows <u>Natural Selection</u> 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 "<u>selection pressures</u>".

Please complete Worksheets 14 & 15

Biodiversity & Evolution

"Biodiversity" refers to the <u>variety</u> of living things.

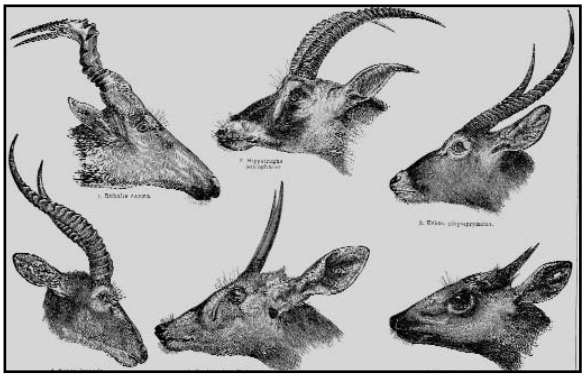
It can refer to the many small variations within a species or refer to how many species there are in a particular ecosystem, or on the entire planet.

Either way, you need to realise that biodiversity is connected to <u>evolution</u>. 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 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.

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The Pepper Moth

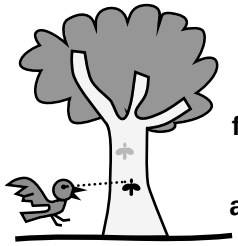
A classic example of "micro-evolution" is the change in the population of the English Pepper Moth which has been studied and documented over the past hundred years.

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.

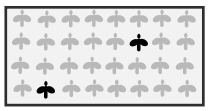
Natural Forest



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

Predators spot the black moths more easily

Lighter-coloured moths survive and breed in greater numbers



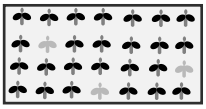
Population ratio. The black form is rare.

Polluted Forest

In polluted forests, the dark-coloured moths are bet-ter camou-flaged.. They are "fittest" for survival and breeding.

Predators spot the lighter moths more easily

Black moths survive and breed in greater numbers



Population ratio. The lighter form is rare.

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.

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Topic 19: Genetics & Evolution
WORKSHEETS

Worksheet 1
DNA & Cell Division

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Fill in the blank spaces.

Living things reproduce their own kind according to the a)..... information stored in the chemical b)..... which is found in the c)..... of every living cell.

DNA molecules are huge, but are very simple in structure. They are made from just d)..... (number) different chemicals called "e)....." joined together in thousands. The precise sequence of these is a f)..... which cells can use to build g)..... and make cell parts, new cells, etc.

Every cell in your body has the complete set of h)..... molecules to specify every part of you. However, each cell only uses i)..... of the information.

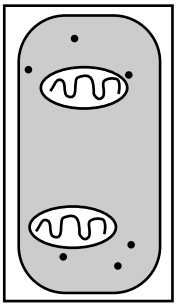
In an early embryo, the cells are all the same. Later, they begin to specialise or "j)....." . Each cell has all the DNA, but only follows k)..... of the instructions, so it becomes a l)..... cell, or a m)..... cell, etc.

Simple cell division is called "n)....." . In unicellular organisms, this is how they o)..... In p)..... organisms it is used for q)..... and to r)..... worn-out or damaged cells.

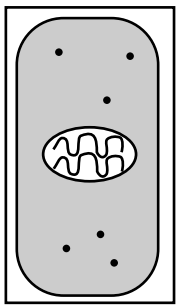
The first step in cell division is to make s)..... of the DNA. Next these copies are t)..... so the cell now has 2 u)..... The cell now divides into two cells, each one only about v)..... Finally, both new cells w)..... to full size before the process starts again.

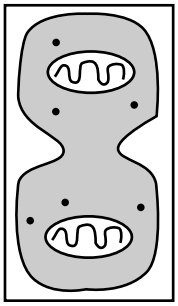
Worksheet 2 Mitosis

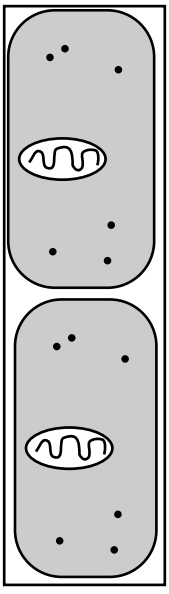
The process of cell division by Mitosis is all jumbled up in these diagrams and captions. Cut them out and re-arrange into correct order. Connect with arrows.

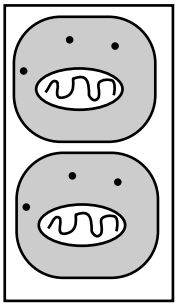


Each new cell grows to full size.



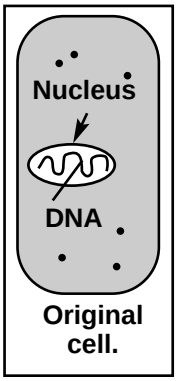






2 half-size cells with identical genetic information.

DNA duplicated.



Original cell.

DNA copies are separated. 2 nuclei form.

Cell divides.

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Worksheet 3

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Sexual & Asexual Reproduction

Unicellular organisms reproduce by simply a)..... Many multicellular organisms can reproduce b)..... as well. Fungi (such as c).....) produce special cells called d)..... which can grow into a new organism. Many plants can reproduce by sending out "e)....." which grow into a new plant.

Regardless of the details, asexual reproduction always:
- **involves only f)..... parent.**
- **involves g)..... cell division.**
- **results in offspring which are genetically h)..... to each other and to their i).....**

Sexual reproduction always involves j)..... parents and a special cell division called "k).....".

During this division, the number of chromosomes is reduced to l)..... of the number in a body cell. The special cells are known generally as "m).....", being n)..... cells in males and o)..... in females.

During sexual reproduction, the 2 gametes join together ("p).....") to form a new offspring cell called a "q).....". It then grows by r)..... cell division into an embryo. The number of s)..... in the offspring is restored by the joining of the t)..... at u).....

Worksheet 4
Comparing Processes

Complete each table of comparison

Student Name.....

Table 1	Asexual Reproduction	Sexual Reproduction
No. of Parents	a)	b)
Type of Cell Div. involved	c)	d)
Are offspring same as each other? (genetically)	e)	f)
Are offspring same as parent(s)? (genetically)	g)	h)

Table 2	Mitosis	Meiosis
No. of cells produced	a)	b)
No. of chromosomes in new cells (compared to original)	c)	d)
Are new cells the same as each other? (genetically)	e)	f)
Are new cells the same as parent cell? (genetically)	g)	h)
Type of Reproduction	i)	j)

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Worksheet 5

Student name.....

Genes & Chromosomes

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Fill in the blank spaces.

A unit of inheritance is called a "a).....". Each simple characteristic of every organism is controlled by a gene inherited from the parent(s).

Each gene is actually a molecule of b)..... These molecules are huge, but are simple in structure. They are composed of only c)..... (number) chemical units called "d)....." joined in thousands in long, coiled chains. The exact e)..... of these is a f)..... which the cell can "read" to build g)..... molecules to make cell parts, or to develop in a cetain way.

The DNA molecules are packed into structures called h)..... visible during cell division.

Each i)..... may contain 1000's of j)..... packed with protective proteins in structures that are often k).....-shaped.

In humans, a body cell contains l)..... chromosomes, arranged in 23 m)..... One pair are the "n)..... chromosomes" which determine if you are o)..... or ..... Females have a matching pair described as p)..... Each egg passes on q)..... from each pair, so all eggs contain one r).....

Males have sex chromosomes s)..... Sperms cells contain either t)..... or ..... Which type of sperm cell u)..... the egg determines the v)..... of the baby.

Worksheet 6

Student Name.....

Replication & Mutations

Answer the following questions.

1. What is "DNA replication" and when does it occur?

2. Why is it important that DNA replication is done accurately?

3. What is a "mutation"?

4. What things can cause mutations?

5. a) If mutation occurs in a body cell, and the cell dies, is this a problem for the organism?

b) If the mutated cell does not die, what might happen?

c) When can a mutation affect every cell in an organism?

6. In general terms:
a) is mutation usually good or bad for an individual?

b) is mutation good or bad for the survival of a species?

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Worksheet 7

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Genetic Crosses

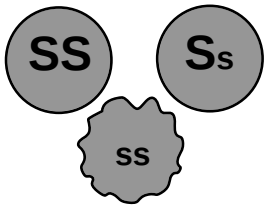
Student Name.....

1. Fill in the blank spaces.

Another characteristic that Mendel studied was seed shape. He found that there are 2 alleles:

Gene "S" causes smooth seeds.

Gene "s" causes wrinkled seeds.



Smooth is a)..... over wrinkled, which is b).....

Possible Genotypes & Phenotypes

c)..... = wrinkled

Ss = d).....

SS = e).....

A plant with genotype Ss was crossed with a plant with wrinkled seeds.

f) Genotypes of these plants? ..... x .....

Complete the Punnett Square by filling in the blank spaces.

wrinkled seed parent gametes

Ss parent gametes	g).....	.....
h).....	i).....	.....
.....	.....	.....

Phenotypes of Offspring — **Smooth seeds : wrinkled seeds**

j) percentages .....% : .....%

k) ratio ..... : .....

2. Some fruit-flies have bodies covered in hairs, some are "hairless".

hairless

hairy

If you cross "pure-breeding" hairy flies with "pure-breeding" hairless flies, the offspring are 100% hairy.

a) Which characteristic is dominant? .....
b) Suggest a suitable symbol for this gene. .....
c) Which characteristic is recessive? .....
d) Suggest a suitable symbol for this gene. .....

Complete the Punnett Squares for the following crosses.

e) Hh x Hh

gametes	.....	.....
.....	.....	.....
.....	.....	.....

Offspring Phenotypes — Hairy : hairless

ratio ..... : .....

f) Hh x HH

gametes	.....	.....
.....	.....	.....
.....	.....	.....

Offspring Phenotypes — Hairy : hairless

percent ..... : .....

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Worksheet 8

Genetics Problems

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Student Name.....

For each genetic cross described, fill in:
a) the genotypes of parents (if not given)
b) the genes passed on in gametes.
c) the genotypes of offspring (in the body of the Punnet Square table).
d) the phenotypes of the offspring, as percentages, fractions or a ratio, as instructed.

1. In mice, black fur (B) is dominant to albino (b). ("albino" produces white fur).

a) Show the details of crossing a pure-breeding black mouse (BB) with an albino.
b) The offspring from this cross were allowed to mate among themselves. Work out the result in the F_2 generation.

Parents: ..... x .....

gametes ....

.....		
.....		

Phenotypes of Offspring Black : Albino

percentages ..... : .....

Parents: ..... x .....

gametes ....

.....		
.....		

Phenotypes of Offspring Black : Albino

ratio ..... : .....

2. In fruit flies, a gene "H" causes hairs to grow on the body. Gene "h" causes no hair to grow.


Work out the details of the cross:

Parents: Hh x hh

gametes ....

.....		
.....		

Phenotypes of Offspring hairy : hairless

percentages ..... : .....

3. Another set of alleles in fruit flies controls wing shape. A gene "N" produces normal wing shape, while "n" causes "vestigial wing" which is short, stubby and useless for flying.
(insects with vestigial wings are not called flies... they are "walks")

Normal wing fly **Vestigial wing**


Work out the outcome of this cross.

Parents: Nn x Nn

gametes ....

.....		
.....		

Phenotypes of Offspring Normal : vestigial

ratio ..... : .....

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Worksheet 9

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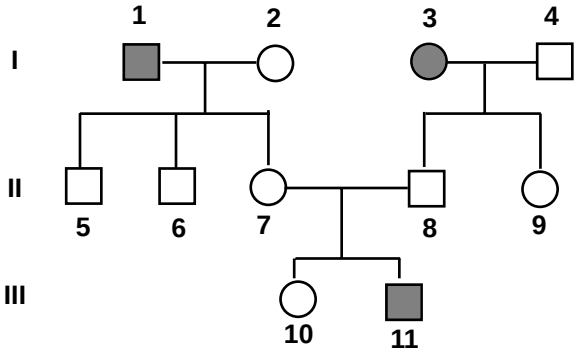
Pedigrees

Student Name.....

In humans, some people have little fingers that are straight, while others have curved little fingers. This characteristic is inherited by simple Mendelian inheritance. Study the pedigree diagram, then answer the questions which follow.

Shaded shapes represent curved little fingers.



1. Is the curved little fingers trait dominant or recessive? Explain your answer referring to specific individuals above.

2. Assign the letters "S" and "s" appropriately to the 2 alleles operating in this pedigree.

3. Extra information: individuals 2 & 4 are homozygous.
Using the symbols chosen, work out the genotypes of everyone in the pedigree, as far as is possible.

4. Couple 1 & 2 had children who all have straight fingers. Was there any chance they might have had a child with curved little fingers? Explain your answer.

5. Person 5 later married a girl with curved little fingers. Use a punnett square to predict the finger shapes of their children.

6. In fact, person 5 and his wife had 2 beautiful little girls both with straight fingers. Is this possible? Is your prediction wrong?

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Worksheet 10 Fossils & Earth History

Student Name.....

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Fill in the blank spaces.

A fossil is the a)..... or ..... of a b)..... from ages past. Fossils are usually found in c)..... rocks. They may be actual remains, such a d)..... or just an imprint or even a e)..... from an animal walking through mud.

The study of fossils is called f).....

Older fossils are always g)..... in the rock layers because younger sediments always settle h)..... This allows fossils to be placed in i)..... time order. Actual age can be measured by the j)..... in some rocks.

When fossils are arranged in time order, a pattern emerges: recent fossils are k)..... to modern living things. Older fossils are l)..... like modern life. Very old fossils are all m)..... and ..... creatures.

It seems that life began almost 4 n)..... years ago. For most of this time, all life was o).....-celled and lived in the p)..... More complex life appeared only about q)..... million years ago.

Scientists have given names to different periods of Earth history according to the different r)..... which lived then. There is evidence of sudden s)..... extinctions in the past. These are always followed by the appearance of many t)..... in the fossil record.

Worksheet 11 Relative Dating of Fossils

Student Name.....

The diagrams represent sedimentary rock profiles from 3 different areas.

1. What is the youngest fossil in each area? **area 1** **area 2** **area 3**

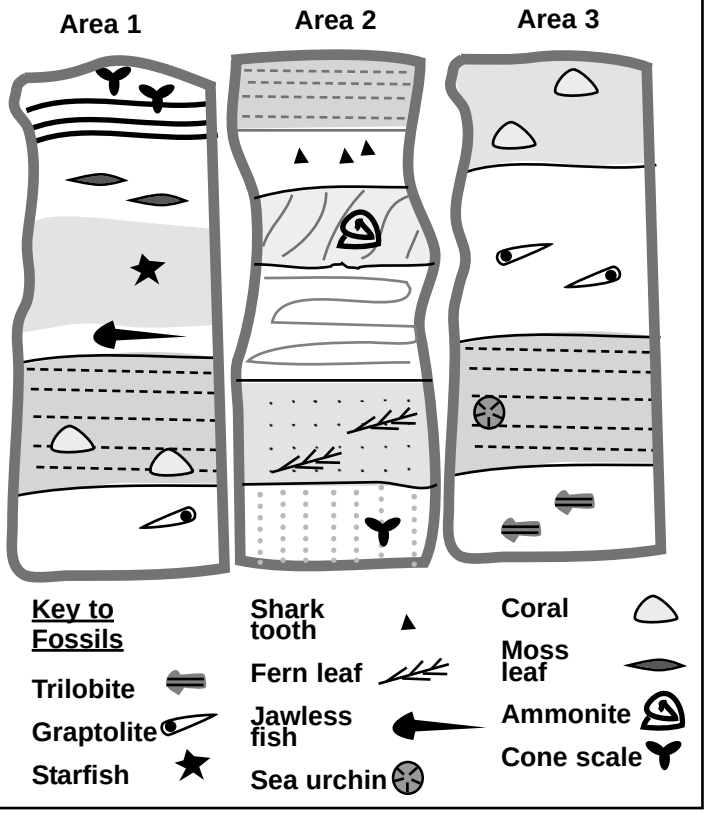
....

2. What is the oldest fossil in each area? **area 1** **area 2** **area 3**

....

3. Cut out each profile diagram and slide them vertically to correlate any fossils that match up.

4. From your correlated profiles, write the names of all the fossils in age order. Start with the oldest.



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Worksheet 12

Student Name.....

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Evidence for Evolution

In Science, a "theory" is an a)..... for a set of observed b)..... Every scientific theory can (in principle) be proven c)..... Evolutionary theory could be proven false by finding a d)..... which is "out of place".

The main sets of evidence supporting the idea of Evolution are:

1. <u>The fossil record</u>, which shows that life has changed from e)..... to ..... and that life-forms have become more and more similar to f).....

2. "<u>g)..... fossils</u>" such as the dinosaur-bird "h).....".

These give us a glimpse of one type of life i)..... into another.

3. <u>Selective Breeding</u> proves that a species j)..... by selection of which ones k)..... the next generation.

4. <u>l)..... Anatomy</u> often reveals evidence that different organisms evolved from a m)..... .....

5. The study of various cell n)....., such as DNA, reveals many similarities between quite different life-forms. This gives further evidence of descent from a o)..... .....

Worksheet 13 Practice Questions

1. Place these Earth history events in correct time order.
Age of dinosaurs, first land plants, first birds, mammals take over, first land animals, first fish.

2.
a) Describe the animal "archaeopteryx".

b) What is the significance of fossils such as archaeopteryx?

3. Humans have carried out selective breeding on many species such as dogs. What does this prove?

Student Name.....

4. a) What does "pentadactyl" mean?

b) The bone structure of a dog's paw, a seal's flipper and a frog's leg are all the same. What does this suggest about their evolution?

5. Descibe some chemical evidence that suggests a common ancestor for all living things.

6. A human embryo has structures that are the same as the <u>gill arches</u> in a fish. (These later develop into the bones of the inner ear.)
What does this suggest?

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Worksheet 14 Theory of Evolution

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A. List the 5 points of Darwin's Theory of Evolution by completing each statement.

1. All organisms produce .....

.....

2.
In every species there is .....
3. Nature (environmental factors) selects

.....
4.
The survivors .....
and pass on their .....
5.Each generation is .....
because there has been selection of who ..... As these changes accumulate, the species .....

B. List 3 "environmental factors" which might contribute to natural selection.

C. "Survival of the fittest" doesn't just mean to survive. What does it mean?

D.
i) When a species evolves, does any individual change during its life time?

ii) When do differences appear?

Worksheet 15 Evolution Questions

Student Name.....

1. a) Why is variation important in a population?

b) What might happen to a species with no variations at all?

2. a) Where do new variations originally come from?

b) How does sexual reproduction contribute to variation?

3. a) List 3 environmental changes that might result in extinction of a species.

c) What may cause a "mass extinction"?

4. Explain how one species, which is living in 2 or more isolated groups, might evolve to become several different species.

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Topic Test

Genetics & Evolution *(2 pages)*

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Answer all questions in the spaces provided.

1. (5 marks)
Match each description to an item from the list. To answer, write the letter (A,B,C, etc) of the list item beside the description.

Description	matches with	List Item
a) Part of a cell where DNA is located		.....
b) Cell division which produces gametes.		.....
c) Thread-like structure containing genes.		.....
d) Cell division involved in asexual reproduction.		.....
e) Change to DNA during replication.		.....

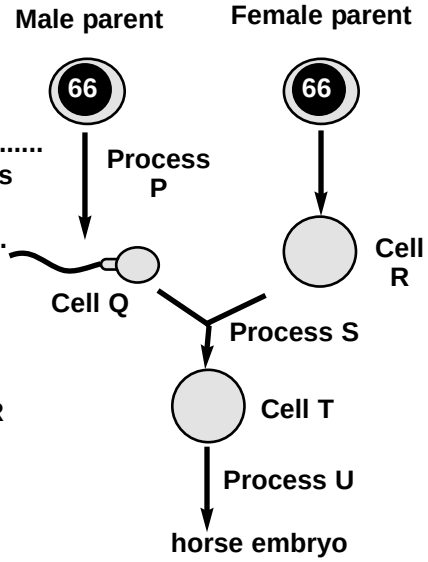
List Items Not all will be used. Some may be used more than once.

A. mitosis
B. meiosis
C. nucleus
D. mutation
E. gene
F. chromosome

2. (3 marks)
a) What is cell "differentiation"?

b) For cells to take different roles, does this mean each cell has different genetic "instructions"?

3. (8 marks)
This diagram summarises the process of sexual reproduction in a horse. The circle shapes represent various cells. The number of chromosomes in a horse body cell is 66.



a) Name the process "P".

.....

b) Name cell types

Q = ...

R= .....

c) How many chromosomes would cells Q & R each have?

.....

d) Name cell "T" and state how many chromosomes it has.

....

e) Name process "S" .....

f) Name process "U" .....

4. (5 marks)
In Mendel's pea plants a gene for purple flowers (P) is dominant to white flowers (p). A plant with genotype Pp was crossed with a white flowering plant.

Predict the outcome by filling in the Punnet Square.

Parents: ..... x .....

gametes ....

.....		
.....		

Phenotypes of Offspring **Purple : White**

ratio ..... : .....

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5. (5 marks)
Match each description to an item from the list. To answer, write the letter (A,B,C, etc) of the list item beside the description.

Description	matches with	List Item
a) Traces of a living thing from long ago.		.....
b) When a species no longer exists.		.....
c) Fossil which is "in-between" in evolution of a new type.		.....
d) Process of environment choosing who survives or dies.		.....
e) 5-finger limb structure, common to most vertebrates.		.....

List Items Not all will be used. Some may be used more than once.

A. extinct	D. transitional
B. fossil	E. natural selection
C. pentadactyl	F. diprotodon

6. (4 marks)
a) In what general type of rock are fossils most commonly found?

b) In a particular cliff-face containing fossils, how do you tell which are older and younger?

c) When fossils representing the whole of the history of life on Earth are compared, what general pattern or trend is apparent?

d) How does modern Science explain that pattern or trend?

7. (4 marks)
a) Name a "transitional fossil", and describe it.

b) What is the significance of transitional fossils to the Theory of Evolution?

8. (2 marks)
Give an outline of a piece of evidence which suggests "descent from a common ancestor".

9. (6 marks)
a) List the 2 (unrelated) facts about living things which are the starting point for Darwin's theory.

b) Give an outline of what is meant by "natural selection".

c) It is often said that evolution is all about "survival of the fittest". What is "survival" really all about?

d) Why is it important for a species to have a lot of "variation"?

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Answer Section

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Worksheet 1

a) genetic b) DNA
c) nucleus d) 4
e) nucleotides f) code
g) proteins h) DNA
i) part j) differentiate
k) part l) muscle
m) nerve n) mitosis
o) reproduce p) multicellular
q) growth r) replace
s) a duplicate copy
t) separated u) nuclei
v) half-size w) grow

Worksheet 2

Refer to the original diagram on p4 (photo-copy) or slide 8 (OnScreen)

Worksheet 3

a) dividing in 2 b) asexually
c) mushrooms d) spores
e) runners f) one
g) mitosis h) identical
i) parent j) two
k) meiosis l) half
m) gametes n) sperm
o) eggs p) fertilisation
q) zygote r) mitosis
s) chromosomes t) gametes
u) fertilisation

Worksheet 4

<u>Table 1</u>

a) 1 b) 2
c) mitosis d) meiosis
e) yes f) no
g) yes h) no

<u>Table 2</u>

a) 2 b) 4
c) same d) half
e) yes f) no
g) yes h) no
i) asexual j) sexual

Worksheet 5

a) gene b) DNA
c) 4 d) nucleotides
e) sequence f) code
g) protein h) chromosomes
i) chromosome
j) genes or DNA molecules
k) thread-shaped or X-shaped
l) 46 m) pairs
n) sex o) male or female
p) XX q) one chromosome
r) X-chromosome s) Xy
t) X or y u) fertilises
v) sex

Worksheet 6

1.
It is the copying of the DNA which occurs just before a cell division.
2.
It must be accurate or else the “daughter cells” would receive altered DNA instructions which might make them act abnormally, or be unable to function.
3.
An accidental change to DNA (a gene) or to a chromosome.
4.
Some chemicals or radiation
(or they just happen by accident)
5.
a) Usually not. A single dead cell in a multicellular organism is totally insignificant and happens all the time.
b) It may develop into a cancer cell and become life-threatening.
c) If it occurs in a gamete, which then is involved in fertilisation, it can affect the whole offspring.
6.
a) Generally bad, because if there is any effect it usually is detrimental.
b) Good. Mutations create new variations which contribute to species survival and evolution.

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Worksheet 7

1.

a) dominant
b) recessive
c) ss
d) smooth
e) smooth
f) Ss x ss
g) s, s
h) S, s
i) Ss, Ss,ss,ss
j) 50% : 50%
k) 1 : 1

2.

a) hairy
b) H
c) hairless
d) h
e)

Parents: Hh x Hh

gametes

	H	h
H	HH	Hh
h	Hh	hh

Phenotypes of Offspring: hairy : hairless
3 : 1

f) Hh x HH

	H	h
H	HH	Hh
H	HH	Hh

Offspring: hairy : hairless
100% : 0

Worksheet 8

1. a) BB x bb

	b	b
B	Bb	Bb
B	Bb	Bb

Offspring: Black : albino
100% : 0

b) Bb x Bb

	B	b
B	BB	Bb
b	Bb	bb

Offspring: Black : albino
3 : 1

2. Hh x hh

	h	h
H	Hh	Hh
h	hh	hh

Offspring: hairy : hairless
50% : 50%

3. Nn x Nn

	N	n
N	NN	Nn
n	Nn	nn

Offspring: Normal : vestigial
3 : 1

Worksheet 9

1. Recessive. Couple 7 & 8 have straight fingers, but had a child (11) with curved little fingers. This can only happen if both parents are carrying a "hidden" gene... therefore it must be recessive.

2. S = Straight, s = curved.

3.
1=ss, 2=SS, 3=ss, 4=SS, 5=Ss, 6=Ss, 7=Ss, 8=Ss, 9=Ss, 10=SS or Ss(uncertain), 11=ss

4. No chance of curved-finger children, because all children must receive a "S" gene from mother who is "SS".

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Worksheet 9 (cont.)

5. Ss x ss

	s	s
S	Ss	Ss
s	ss	ss

Children straight : curved
50% : 50%

6.
It is quite possible. Prediction is not wrong.
In a large sample of offspring there should be approximately 50-50. However, in small samples, random chance can result in ratios that are not in agreement with the prediction.

Worksheet 10

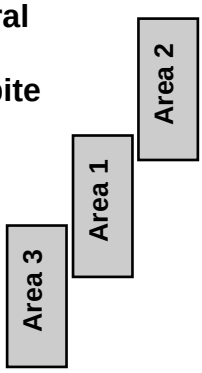
a) remains or trace **b) living thing**
c) sedimentary **d) bone / shell / tooth**
e) footprint **f) Palaeontology**
g) lower **h) on top**
i) relative **j) radio-activity**
k) more similar **l) less**
m) small & simple **n) billion**
o) single-celled **p) sea**
q) 600 million **r) life-forms**
s) mass extinctions
t) new species

Worksheet 11

1. Cone scale, shark tooth, coral

2. Graptolite, cone scale, trilobite

3.
They need to be arranged as suggested by this diagram.



4.
Trilobite, sea urchin, graptolite, coral, jawless fish, starfish, moss leaf, cone scale, fern leaf, ammonite, shark tooth.

Worksheet 12

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a) explanation **b) facts**
c) false **d) fossil**
e) simple to complex
f) modern life-forms
g) Transitional **h) archaeopteryx**
i) evolving **j) can be changed**
k) breed **l) Comparative**
m) common ancestor
n) chemicals **o) common ancestor**

Worksheet 13

1.
first fish, first land plants, first land animals, Age of dinosaurs, first birds, mammals take over

2.
a) A dinosaur-bird, a dinosaur with feathers.
b) They give us a fossil glimpse of a stage in the evolution of one type of life into another.

3.
It proves that a species can change when there is selection of which individuals are allowed to breed.

4.
a) Literally, “5 fingers”.
b) That they all evolved from a common ancestor which had that structure.

5.
All living things use the same genetic code in their DNA.

6.
Common ancestry. We still retain some features of our remote ancestors.

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Worksheet 14

A.

1. All organisms produce more offspring than can possibly survive.
2. In every species there is variation.
3. Nature selects which individuals survive
4. The survivors breed and pass on their survival traits.
5. Each generation is different because there has been selection of who survived to breed. As these changes accumulate, the species evolves.

B. Climate, predators, disease.

C. It means to survive and breed.

D. i) No.
ii) In the next generation, which receive a slightly different proportion of each "variation".

Worksheet 15

1.
a) Variations increase the chance that some individuals might survive a change in the environment.
b) Without variations, all individuals could be wiped out in a changed environment, so the species becomes extinct.

2.
a) Mutations
b) It mixes genes from 2 parents to produce new combinations of features.

3.
a) Change of climate, a new predator, a new disease.
b) World-wide climate change is the most likely cause.

4.
Each isolated group may be acted on by different environmental factors. Natural selection chooses different "survival features" in each place, so each group evolves differently. Eventually each group may become a different species.

Topic Test

1.
a) C b) B c) F d) A e) D

2.
a) Differentiation is when cells specialise and take on different functions. e.g. muscle cell or nerve cell, etc.
b) No, all body cells have the same DNA instructions. To specialise, each one follows a different <u>part</u> of the total DNA.

3.
a) meiosis
b) Q = sperm, R = egg
c) 33
d) zygote, 66
e) fertilisation
f) mitosis (or growth)

4. Pp x pp

	p	p
P	Pp	Pp
p	pp	pp

Offspring **Purple : white**
1 : 1

5. a) B b) A c) D d) E e) C

6.
a) Sedimentary

b) Older fossils lower down, younger fossils above.

c) There is a trend from simple to more complex, or from less like modern types to more and more resembling modern life.

d) Life changes by a process of evolution. This constantly causes living things to change to become better able to survive their environment.

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Topic Test (cont.)

7.

a) Archaeopteryx was a dinosaur-bird.

b) Transitional fossils show us a fossil glimpse of a stage in the evolution of one type into another.

8.

The "pentadactyl" limb structure is common to most vertebrates even though various animals might use them as legs, flippers or wings. The same bone structure used in such different ways suggests that all types descended from a common ancestor which had that structure.

9. a)

1. All species produce more offspring than can possibly survive.

2. All species have variations among individuals.

b) The factors of the environment ("nature") select which individuals survive and which don't.

c) Those individuals with better "survival features" are the ones who survive to breed. It's all about reproduction.

d) So that when the environment changes there is a better chance that some will survive to breed, rather than the species becoming extinct.