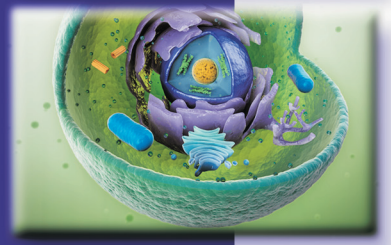
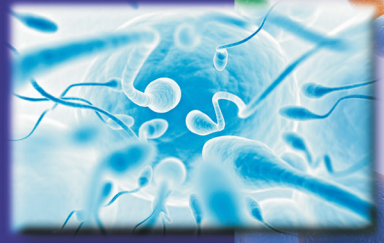
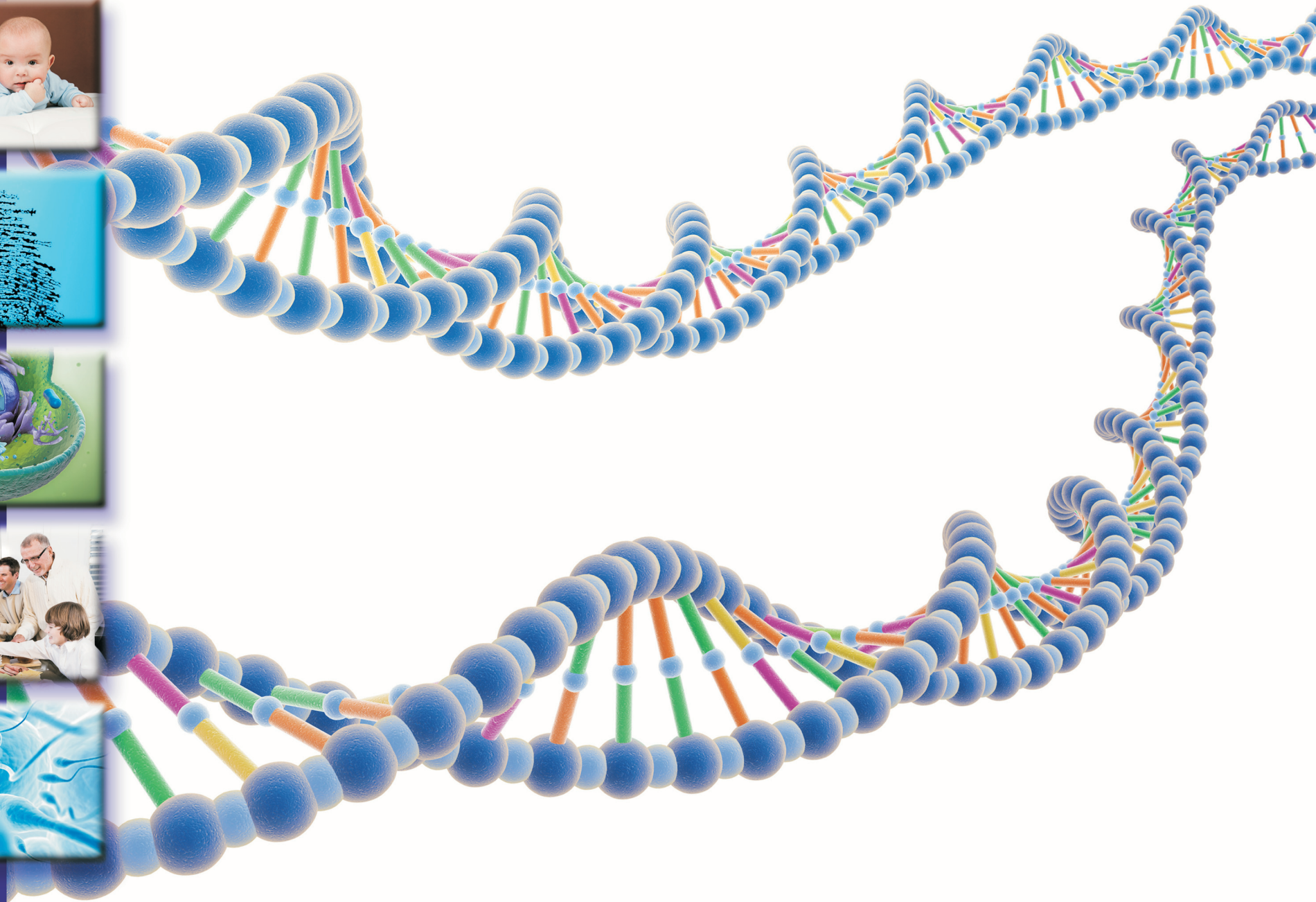
Genetics and Inheritance







EARLY LEVEL | FIRST LEVEL & SECOND LEVEL

Reproduction and Inheritance

Living things produce offspring of the same species.
CfE links - HWB 0-47a, MNU 0-20b, LIT 0-04a

Reproduction and Inheritance

In many cases offspring are not identical with each other or with their parents but have similarities.
CfE links - SCN 1 -14a, MTH 1-15a, MNU 1 - 20b, MTH 1 - 21a, LIT 1 - 10a

Reproduction and Inheritance

Some traits are solely inherited and others result from interactions with the environment.
CfE links - SCN 2-14b, SCN 2-03a, MNU 2-20b, MNU 2-22a, HWB 2-30a, HWB 2-32a, SCN 2-14a, LIT 2-26a.

Genetics and Inheritance

Genetic Information is passed down from one generation of organisms to another

Key Themes:

DNA
Genes
Inherited Characteristics
Reproduction
Technological Advances

Genetic information in a cell is held in the chemical molecule DNA in the form of a genetic code. Genes determine the development and structure of organisms. In asexual reproduction all the genes in the offspring come from one parent. In sexual reproduction one full set of the genes come from each parent

THIRD LEVEL & FOURTH LEVEL

Reproduction and Inheritance
For offspring to inherit traits there must be a reliable mechanism for transferring genetic information from one generation to the next.
CfE links - SCN 3-14a

Reproduction and Inheritance
During sexual reproduction one set of the genetic material is inherited from the egg cell of one parent and one set from the sperm cell of the other parent, whereas in asexual reproduction all the genetic information is inherited from one parent.
CfE links - SCN 4-14b

Reproduction and Inheritance
Hereditary information is contained in genes which are passed from parent to offspring during reproduction.
CfE links - SCN 4-14c

Molecular Genetics
The instructions for specifying the characteristics of an organism are carried in a molecule called DNA (deoxyribonucleic acid). All organisms use the same genetic language for their instructions.
CfE links - SCN 3-14b

Molecular Genetics
Genes are specific nucleotide sequences, located along DNA molecules, that determine particular traits. Genes provide instructions for producing specific proteins. CfE links - SCN 4-14c

Technology and Genetics
The uniqueness of the DNA structure makes it possible for scientists to create a profile of an individual's DNA and use it as a means of personal identification. DNA analysis opens up the potential to know more and more about individuals.
CfE links - SCN 3-14b, SCN 3-12b, TCH 3-01a, SOC 3-15a, LIT 3-08a, LIT 3-06a, MNU 3-22a, MNU 3-20a, SCN 3-20a, SCN 3-20b

Technology and Genetics
Before individual genes on DNA could be identified researchers studied organisms to assess the relative influences of genes and the environment. Advances in technology have increased the reliability of the information obtained and the amount and type of information that can be gathered and analysed.
CfE links - SCN 4 -14c, SCN 4 - 20a
TCH 4 - 01a, MNU 4 - 22a, SOC 4 - 05a, HWB 4 - 15a, HWB 4 - 16a, LIT 4 - 06a

NATIONAL 4 & 5

Reproduction and Inheritance
Many features of human heredity are explained by the fact that human cells contain two copies of each chromosome (one inherited from each parent) and therefore two copies of each gene. During cell division the paired chromosomes are duplicated and two new cells formed with paired chromosomes identical to the original cell. When gamete cells (mature sexual reproductive cells, such as a sperm or egg) are produced the replicated paired chromosomes are selected at random, sorted into two single sets and each set allocated to a new gamete.

Molecular Genetics
The majority of an organism's DNA is located in the nucleus of an organism's cells in a packaged form called a chromosome. DNA is unpackaged and the molecule unwinds so that it can be replicated during cell division and when its instructions are required for the production of proteins.
CfE links - SCN 4-14c

Reproduction and Inheritance
In sexual reproduction the inheritance of different types of alleles of the same gene affects the traits observed in offspring. Some alleles are dominant, while others are recessive and remain masked unless the two inherited alleles are identical.

Reproduction and Inheritance
There are patterns of correlation between alternative forms of the same gene and the traits observed in offspring. The probability of offspring inheriting certain traits can be predicted if it is known which forms of the genes both parents have.

Technology and Genetics
Advances in technology make it possible to alter the genetic makeup and create organisms by DNA manipulation, rather than using the traditional method of breeding species for particular characteristics.

Molecular Genetics
Alternative forms of the same gene are known as alleles and an individual inherits two alleles for each gene, one from each parent.

NATIONAL 6 & 7

Reproduction and Inheritance
During the production of the sex cells the selection of chromosomes at random and on occasion, chromosome mutations and abnormalities, create genetic variation.

Reproduction and Inheritance
The inheritance of traits is often complex and can be determined by one or many genes, and a single gene can influence more than one trait. Understanding the patterns of correlation between inherited alleles makes it possible to: group populations into distinct categories, predict traits in offspring and trace heredity.

Molecular Genetics
Proteins are the central elements that mediate genetic effects and connect genes to traits. Protein interactions at the molecular and cellular level result in the patterns observed at the macro level. The overall structure and properties of the protein, determined by the amino acid sequence, affords and constrains its function.

Molecular Genetics
Genes work by coding for proteins. The sequence of nucleotides on the gene is translated into the sequence of amino acids in the specific protein encoded by the gene. Protein production is regulated and a variety of proteins can be produced from the same gene.

Molecular Genetics
Changes to genes (mutations) and the cell environment (e.g. toxins) can alter the structure and function of proteins produced by cells, and can change how an organism looks and functions (phenotype). Some changes can be neutral, some beneficial and others harmful to the organism.

Molecular Genetics
The genome is the complete DNA sequence of the organism's nuclear DNA. An important property of DNA is that it can replicate itself making it possible for each cell to have exactly the same DNA. Variation in DNA can serve as a way to identify individuals and species, and can provide information on evolutionary relationships and origins.

Technology and Genetics
Advances in technology develop and expand our understanding of genetic phenomena and this enhanced understanding often leads to further technological advances and new technologies. The developments and new technologies in genetics have an impact on society requiring citizens to make informed choices.

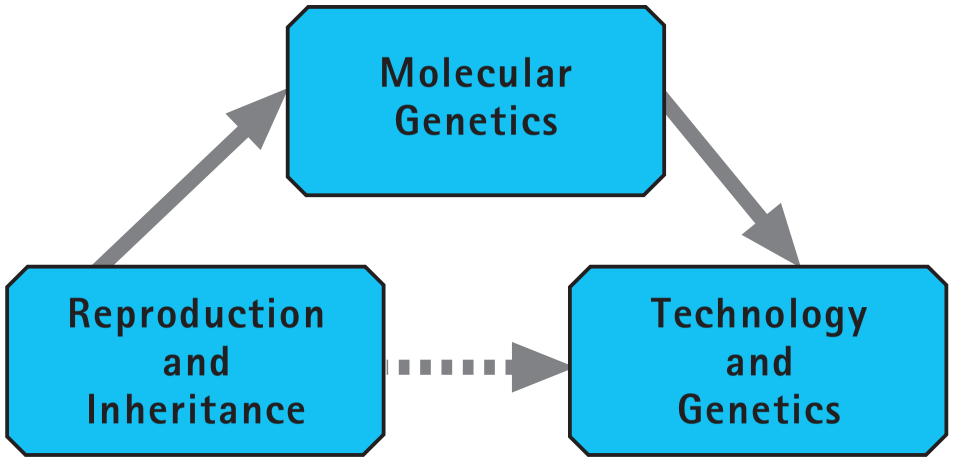
Genetics and Inheritance

Genetic information is passed down from one generation of organisms to another

Key themes:

- DNA
- Genes
- Inherited Characteristics
- Reproduction
- Technological Advances

Broad overview of the progression in Genetics and Inheritance



Storyline

Genetic information in a cell is held in the chemical molecule DNA in the form of a genetic code. Genes determine the development and structure of organisms. In asexual reproduction all the genes in the offspring come from one parent. In sexual reproduction one full set of the genes come from each parent.

Living things produce offspring of the same species, but in many cases offspring are not identical with each other or with their parents. Plants and animals, including humans, resemble their parents in many features because information is passed from one generation to the next. Other features, such as skills and some behaviours, are not passed on in the same way and have to be learned.

The information that is passed between generations is in the form of a code represented in the way that the parts of a large molecule called DNA are put together. A gene is a length of DNA; and hundreds or thousands of genes are carried on a single chromosome (packaged DNA in cells). In the human body most cells contain 23 pairs of chromosomes with a total of about twenty five thousand genes. These provide the information that is needed to make more cells in growth and reproduction.

When a cell divides as in the process of growth and replacement of dead cells, this genetic information is copied so that each new cell carries a replica of the DNA of the parent cell. Sometimes an error occurs in replication, causing a mutation, which may or may not be damaging to the organism. Changes in genes can be caused by environmental conditions, such as radiation and chemicals. These changes can affect the individual but only affect the offspring if they occur in sex (sperm or egg) cells.

In sexual reproduction, a sperm cell from a male unites with an egg cell from a female. Sperm and egg cells are specialised cells each of which has one of the two versions of each gene carried by the parent, selected at random. When a sperm and egg cell combine one full set of genes in the fertilised egg is from the sperm cell and one full set is from the egg cell. As the fertilised egg divides time and time again this genetic material is replicated in each new cell. The sorting and recombining of genetic material (the process in which DNA is exchanged between chromosomes that contain the same sequence of genes) when egg and sperm cells are formed and then fuse results in an immense variety of possible combinations of genes, and in differences that can be inherited from one generation to another. These variations provide the potential for natural selection, because some variations result in organisms being better adapted to certain environmental conditions.

Asexual reproduction, which occurs naturally in a wide range of organisms including bacteria, insects and plants, leads to populations with identical genetic material unless a mutation occurs. Biotechnology has made possible the production of genetically identical organisms through artificial cloning in a range of species including mammals.

More is being learned all the time about genetic information by mapping the genomes (the complete genetic information of an organism) of different kinds of organisms. When the sequences of genes are known, the genes that give organisms certain characteristics can be identified and it is possible to selectively change genetic information to produce desired features. In gene therapy studies specific genes can be delivered using special techniques into cells to replace, swap or repair the 'normal' gene and potentially cure diseases.

[Adapted from Principles and Big Ideas in Science edited by Wynne Harlen]

Glossary of terms

Asexual reproduction - *the formation of offspring from the cell(s) of a single parent.*

Allele - *an alternative form of a gene.*

Base pair - *two complementary DNA nucleotide bases from opposite strands of the DNA molecule that pair up to produce the double helix structure (with the base pairs forming the rungs on the spiral ladder like structure).*

Biotechnology - *the industrial use of living cells, usually microorganisms, or of their isolated enzymes.*

Chromosome - *a single piece of coiled DNA packaged into a large thread-like structure that is found in cells. Humans have 46 chromosomes (23 pairs inherited from each parent).*

Cloning - *the growth of identical cells from a single cell or the development of an animal or plant from a single body cell.*

Differentiation (differentiate) - *the increasing specialisation of organisation of the different parts of an embryo as a multicellular organism develops; the development of cells with specialised structure and function from unspecialised precursor cells.*

DNA - *deoxyribonucleic acid, the large molecule that carries genetic information as a set of coded instructions. It is made up of two entwined strings (the double helix) of nucleotide subunits that contain the bases (chemical molecules): A - adenine, T - thymine, G - guanine and C – cytosine.*

Fertilisation (fertilised) - *the union of male and female gametes (e.g. sperm and egg cells) to form a cell with two sets of chromosomes.*

Gamete (sex cell) - *a reproductive cell (e.g. sperm or egg cell) with one set of chromosomes.*

Gene - *the fundamental unit of inheritance. Genes are sequences of chemical units (bases) on the DNA molecule found at specific locations and most contain information for making proteins.*

Genetic code - *the order of the chemical units (nucleotide bases) of the DNA molecule determines the order of the chemical units of the proteins (amino acids). There are 64 three-letter 'words' in the code.*

Genome - *the complete genetic information of an organism found in nearly every type of cell.*

Molecule - *made up of atoms held together by chemical bonds, a molecule is the smallest particle in a chemical element or compound that has the chemical properties of that element or compound.*

Mutation - *a change in the amount or the structure (sequence of nucleotides) of DNA of an organism. Mutations can have a positive, negative or neutral effect.*

Nucleus - *the area of the cell were almost all DNA is found. Its function is essential to the survival of the cell.*

Nucleotide - *a small molecule that joins with other nucleotides to form chains of nucleotides called nucleic acids (such as RNA and DNA). Each nucleotide is composed of a pentose sugar, a phosphate group and a base.*

Nucleotide Base - *the structural unit of a nucleic acid that may be involved in pairing (see base pairs); the major nucleotide bases in DNA are adenine (A), guanine (G), cytosine (C) and thymine (T), and in RNA uracil (U) replaces thymine.*

Organism - *any living thing.*

PCR (polymerase chain reaction) - *technique for selectively replicating a particular section of DNA (in a laboratory vessel or other controlled experimental environment) to produce a large amount of a particular DNA sequence.*

Protein - *a large molecule composed of amino acids (molecules that contain both amino and carboxylic acid functional groups) that performs a specialised job in the cell and is specified by a gene.*

RNA - *ribonucleic acid, the large linear molecule which is made up of a single chain of nucleotide subunits that contain the bases: A - adenine, U - uracil, G - guanine and C - cytosine.*

Radiation - *energy radiated in waves or particles e.g. electromagnetic radiation or emissions from radioactive sources.*

Replication - *the process in which an entity makes a copy of itself.*

Short Tandem Repeats (STRs) - *occur when a pattern of two or more nucleotides are repeated and the repeated sequences are directly adjacent to each other on the DNA molecule. The pattern can range in length from 2 to 50 base pairs. They are independent of genes and can not be used to identify genes, e.g. eye colour.*

Sex marker - *a portion of a gene that occurs on both the X and Y-chromosome that is used to identify gender.*

Sexual reproduction - *reproduction involving the formation and fusion of two different types of reproductive cell (e.g. sperm and egg).*

Species - *in sexually reproducing organisms a group of interbreeding individuals not normally able to interbreed with other such groups.*

Trait - *a distinct visible or otherwise measurable physical or biochemical characteristic, which may be either heritable or environmentally determined or both.*

Early progressing into First Level

Question: *Are we, and other organisms, alike in every way?*

Big Idea: *Offspring resemble their parents and the characteristics that distinguish them can be described in terms of a combination of traits.*

Reproduction and Inheritance

The story begins in the early years by observing and comparing the offspring of familiar animals, to one another and their parents. All animals have offspring, usually with two parents involved. When animals and plants reproduce sexually they produce offspring of their own type which are similar, but not exactly the same (e.g. kittens in a litter will usually have different markings). Exploring the likenesses and differences between offspring and their parents reveals traits (characteristics that distinguish individuals and plants from another) in animals and plants e.g. hair, eye and flower colour, and height.

Common Misconceptions

i. There is a tendency to focus more on the differences between individuals and sometimes the similarities are neglected.

ii. Young people may think that they inherit physical traits from other family members e.g. aunts, uncles, cousins and siblings because people often point out resemblances among relatives.

iii. Young people may not recognise plants as living things.

iv. Young people often see the '=' symbol as an instruction to complete an operation. It is not always appreciated that the '=' symbol signifies 'the same as', but not necessarily 'identical to'. It is not a request to do something and simply states the situation. Emphasis should be put on the equivalence aspect of the '=' symbol by using phrases such as 'is the same as' or 'gives the same result as' in preference to 'makes' or 'leaves'.

Big Ideas & CfE Experiences & Outcomes

Reproduction and Inheritance:
Living things produce offspring of the same species.
HWB 0-47a
MNU 0-20b LIT 0-04a

I recognise that we have similarities and differences but are all unique. HWB 0-47a

I can match objects, and sort using my own and others' criteria, sharing my ideas with others. MNU 0-20b

I listen or watch for useful or interesting information and I use this to make choices or learn new things. LIT 0-04a

By comparing generations of families of humans, plants and animals, I can begin to understand how characteristics are inherited. SCN 1-14a

I can compare, describe and show number relationships, using appropriate vocabulary and the symbols for equals, not equal to, less than and greater than. MTH 1-15a

I have used a range of ways to collect information and can sort it in a logical, organised and imaginative way using my own and others' criteria. MNU 1-20b

Using technology and other methods, I can display data simply, clearly and accurately by creating tables, charts and diagrams, using simple labelling and scale. MTH 1-21a

I can communicate clearly when engaging with others within and beyond my place of learning, using selected resources[1] as required. LIT 1-10a

Reproduction and Inheritance:
In many cases offspring are not identical with each other or with their parents but have similarities.
SCN 1-14a MTH 1-15a
MNU 1-20b MTH 1-21a LIT 1 10-a

[1] This may include images, objects, audio, visual or digital resources.

Curriculum Links, Skills and Interdisciplinary Learning Opportunities

- Gathering information through observation and seeking patterns
- Evaluating by identifying and matching
- Understanding by describing
- Communicating in the activities and through discussion

Matching living things and their offspring, for example through structured play with model representations or picture sorting activities, and then observing the similarities and differences between them. Observing the early stages of development and using the differences between the offspring to distinguish them e.g. following a litter of animals from birth (for example using the Scottish Sealife Centre webcams) or the growth of seeds from parent plants. Fingerprinting, matching and sorting seeds from different species of plants[2] and animals with their offspring, and drawing portraits/taking photographs of humans and other animals and observing the similarities and differences. Activities at early level will be more experiential and as young people move into first level they should progress from describing to sorting and selecting based on criteria.

- Gathering information through observation, seeking patterns and exploration
- Evaluating by comparing and classifying
- Understanding by selecting, describing and sorting based on criteria
- Creating through making
- Communicating through discussion and displaying findings

Identifying similarities and differences (e.g. height, flower or eye colour, no. of leaves and leaf shape, ability to roll tongue, etc) between offspring from the same parents and with their parents (need to be cautious if children are comparing themselves with their parents and siblings), for example construct a family tree using pictures from famous families that go back a couple of generations (e.g. film stars and royalty), or produce then play a game of 'Happy Families'. Classifying the similarities and differences using the phrases 'is the same as' and 'is not the same as' as well as the symbols '=' or '≠' and describing measurable attributes such as 'bigger' or 'smaller', 'more' or 'less', etc. Other activities could involve: the children producing a life size portrait of themselves, discussing the similarities and differences between them then using them to create graphs (e.g. attach the pictures to a wall from tallest to smallest to create a graph, measure the height of the pictures with blocks and colour in squares on graph paper to represent the number of blocks/height); displaying annotated photographs of the growth process, from seed to plant[2]; using computer graphing packages and producing simple tables of the similarities and differences e.g. eye and hair colour; and creating groups for classifying objects and communicating the justification for the choice of group clearly e.g. leaf shape or seed colour. Young people should be encouraged to verbalise what they are doing and did in the activities.

[2] http://www.bbsrc.ac.uk/society/schools/keystage1-2/seeds-plant-growth.aspx

Introducing ideas about Science

- people learn about the world through careful observation
- sometimes more can be learned by people doing something and noting what happens
- similar patterns are found in many places in nature
- it is important to describe things as accurately as possible because it enables people to compare their findings
- one way to describe something is to say how it compares (is like/different) to something else
- when people give different descriptions of the same thing, it is a good idea to make fresh observations and see what the similarities and differences are
- people are more likely to believe ideas if there are reasons for them
- often people can find out about a group of things by studying just a few of them

Learning Outcomes and Assesment Opportunities

Second Level

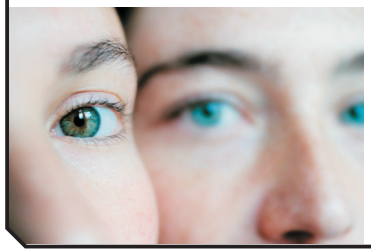
Question: *Why are we, and other organisms, similar to our parents and siblings, but not identical?*

Big Idea: *Some traits are solely inherited and others result from interactions with the environment.*

Reproduction and Inheritance

No individual organism lives forever and reproduction is essential to the continuation of every species. Some traits in offspring are inherited from their parents during reproduction - received by transmission from one generation to another such as physical traits e.g. cleft chin, cheek dimples, free or attached earlobes, rolling your tongue and freckles, and some behaviours. Inherited behaviours are tendencies and offspring inherit the possibility (or predisposition) to exhibit that behaviour. Other traits are environmental - usually skills and behaviours that are acquired by experience in the organism's lifetime and make it compatible with its environmental and survival needs, for example, babies and toddlers are vulnerable to hazardous obstacles because the instinct to avoid pain and injuries is a skill learned during infancy.

There are similarities and differences between offspring and it is the combination of inherited and environmental traits that make each individual unique. Environmental traits are not transferred genetically from one generation to another.



Behaviour in insects and many other species is determined almost entirely by biological inheritance. Research suggests that in humans only a small amount of a person's 'make-up' is purely down to genetics or to the environment, and it is mostly down to a complex combination of genes and the environment (of nature and nurture). Scientists can now look at the complete genetic information of organisms (their genome) to discover the influence of genetics and the effect of the environment on traits.

Certain traits are easy to see, for example, curly hair or straight hair, while other traits are more difficult to observe, for example, whether you have allergies or not (although it may be easy to conduct tests to find out).

Common Misconceptions

i. Young people assume that nearly all characteristics are inherited genetically. There is no recognition that some characteristics are inherited, some a result of environmental conditions and others a combination of both environmental conditions and genetics.

Big Ideas & Curriculum for Excellence Experiences & Outcomes

Reproduction and Inheritance:
Some traits are solely inherited and others result from interactions with the environment.

SCN 2-14b SCN 2-03a MNU 2-20b MNU 2-22a HWB 2-30a HWB 2-32a SCN 2-14a LIT 2-26a

By exploring the characteristics offspring inherit when living things reproduce, I can distinguish between inherited and non-inherited characteristics. SCN 2-14b

I have collaborated in the design of an investigation into the effects of fertilisers on the growth of plants. I can express an informed view of the risks and benefits of their use. SCN 2-03a

I have carried out investigations and surveys, devising and using a variety of methods to gather information and have worked with others to collate, organise and communicate the results in an appropriate way. MNU 2-20b

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I can conduct simple experiments involving chance and communicate my predictions and findings using the vocabulary of probability. MNU 2-22a

By applying my knowledge and understanding of current healthy eating advice I can contribute to a healthy eating plan. HWB 2-30a

I understand that people at different life stages have differing nutritional needs and that some people may eat or avoid certain foods. HWB 2-32a

By investigating the lifecycles of plants and animals, I can recognise the different stages of their development. SCN 2-14a

By considering the type of text I am creating, I can select ideas and relevant information, organise these in an appropriate way for my purpose and use suitable vocabulary for my audience. LIT 2-26a

Curriculum Links, Skills and Interdisciplinary Learning Opportunities

- Gathering information through observation, asking questions and social interaction
- Applying knowledge to different contexts
- Evaluating by selecting and classifying
- Understanding by selecting and explaining
- Communicating through creating texts, discussion and displaying findings

Identifying and differentiating between inherited and environmental traits, for example: looking at the effect of the environment (dark, different soils, etc.) has on growing seeds from the same plants; using activities (e.g. creating 'handy' family trees[3] with inherited physical characteristics on the fingers of one handprint and environmental traits on the fingers of the other) to explore the traits of individuals and to find out the things that make them unique; investigating the traditions and characteristics of different ethnic groups; examining how lifestyle and diet can affect traits (e.g. smoking and malnutrition in pregnancy can result in babies born with lower birth weights and smaller organs, and unhealthy eating as well as lack of physical activity is contributing to the rising level of obesity in the UK); and creating Reebops[4] and writing about their characteristics (inherited and environmental). During these activities there will be opportunities to look at chance and the probability of exhibiting certain traits (e.g. play traits games[3] and find out which traits are the most common in the class and/or compare yourself with others using the Wellcome Trust Centre for Human Genetics database[5]).

[NB: Be careful when looking at inherited characteristics and comparing learners, especially with members of their families. Some traits considered either recessive or dominant[6], such as tongue rolling and eye colour, are not as straight forward as they were formerly believed to be and are actually a combination of mechanisms, therefore it is possible for two parents who can't roll their tongue to have a child who can and parents with blue eyes to have a brown eyed child.]

Learning Outcomes and Assesment Opportunities

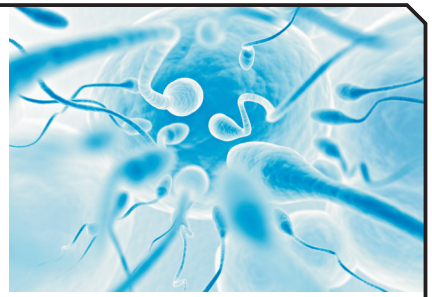
[3] learn.genetics.utah.edu/content/begin/traits/activities/ [4] www.ise5-14.org.uk/Prim3/New_Guidelines/Newsletters/46/Reebop_1.htm and http://cbe.wisc.edu/cbe_pubs/reebops.html
[5] uniqueness.well.ox.ac.uk/language_set/introduction.php [6] http://learn.genetics.utah.edu/content/begin/traits/activities/pdfs/Inherited%20Human%20Traits%20Quick%20Reference_Public.pdf

Third Level

Question: *How do we, and other organisms, inherit traits from our parents?*

Big Idea: *Heredity is the passage of genetic information from one generation to another. For offspring to inherit traits there must be a reliable mechanism for transferring genetic information from one generation to the next. A molecule called DNA (deoxyribonucleic acid) is passed from adult organisms to their offspring during reproduction. This molecule contains the instructions for an organism to develop, grow, survive and reproduce. The sequence of nucleotides on the DNA molecule is unique to an individual, with the exception of cloned (identical) organisms which share the same DNA. DNA analysis opens up the potential to know more and more about individuals.*

Reproduction and Inheritance



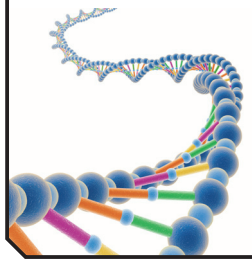
Genetic information is passed from one generation to another. Sexually reproduced offspring are never identical to their parents. Many species, of animals and plants, including humans reproduce sexually. Specialised cells from a female (egg cell/ova) and male (sperm) fuse together to begin the development of a new individual. The new individual receives genetic information from both parents. When a sperm and egg unite one set of the genetic material in the fertilised egg is from the sperm cell and one set is from the egg cell. If a fertilised egg (egg and sperm united) splits to form more than one individual then the offspring have the same genetic information and are genetically identical.

Following fertilisation, cell division produces a small cluster of cells with the same genetic information copied in each new cell. This cluster of cells then differentiates to form an embryo in which each new cell continues to have the same genetic material - a replica of the DNA in the fertilised egg.

Molecular Genetics

The instructions for specifying the characteristics of an organism are carried in the DNA (deoxyribonucleic acid) molecule. DNA provides the information required for cell function, cell growth and reproduction. The chemical and structural properties of DNA explain how the genetic information that underlies inheritance is both encoded (in a sequence of building blocks) and replicated (by a templating mechanism).

DNA is a large polymer and the instructions for genetic inheritance are stored in a code made up of four building blocks called nucleotide bases. A strand of DNA contains millions of these four nucleotide bases. It is the order, or sequence, of the nucleotide bases on the strand that provides the information for producing the proteins that build and maintain an organism. The sequence of nucleotides on the DNA molecule is unique to an individual, with the exception of cloned (identical) organisms (such as plants, Dolly the Sheep and identical twins) which share the same DNA.



An important property of DNA is that it can replicate, or make copies of itself. DNA is made up of two strands joined together in a double helix (like a spiral ladder) that can separate and each separate strand of DNA can serve as a pattern for replicating the molecule. DNA is extraordinary reliable at replicating. It must replicate faithfully to ensure the continuation of the species, but make some mistakes to enable evolution. In sexual reproduction, organisms inherit DNA from both the male (in the sperm) and female parent (in the egg). One set of genes contains 300 billion base pairs of DNA and during replication there are around 200 mutations per generation, therefore offspring inherit around 400 mutations. However, only 1-2 % of DNA is involved in genes and the chances of inheriting a defect are very low and most mutations have no consequences.

Technology and Genetics

DNA profiling is the collection, processing and analysis of the unique sequences of molecules on the DNA strand. The uniqueness of the DNA structure makes it possible for scientists to create a profile of an individual's DNA and use it as a means of personal identification. To produce a DNA fingerprint or DNA profile a small sample of skin tissues or cells, body fluids, or hair (with attached roots) is required. Profiles are now constructed using PCR (polymerase chain reaction) technology and detecting differences in the number of short tandem repeats (STRs) - areas containing repeats of sequences located on different chromosomes which can distinguish us as unique individuals. In the UK a complete DNA profile of an individual consists of 10 STRs (and a sex marker) and comes with a random match probability (the probability of a specific STR profile occurring randomly in a population). DNA profiling is considered one of the most reliable and conclusive methods of personal identification available to today's scientists. The probability of two individuals DNA matching has been estimated at less than one in a billion[7]. It is routinely used in the field of forensic science and it has also become an important tool in genealogy. Although the technology is reliable, like any technique that relies on humans processing and interpreting samples, there is the potential for human errors during the processing of the DNA. DNA evidence does not solve a crime or establish a suspect's guilt. It is simply another form of circumstantial evidence.

There are concerns about the use of genetic information and genetic privacy. In March 2009 an estimated 4,859,934 individuals had their DNA profiles held in the UK DNA database[8]. At that time the database held samples from people, including children, who have been arrested (for any offence including not wearing a seatbelt) and not all of them will have been charged with a crime. In Scotland, DNA samples taken during criminal investigations from people who are not charged or later acquitted are destroyed.

The analysis of DNA is a technology led area that has generated an abundance of data that requires people with the biology and mathematics knowledge to interpret it. Analysis of DNA can reveal if an individual has any genetic diseases or disorders and their predisposition to developing particular conditions (some conditions are a result of the interaction of genes and the environment, e.g. obesity and certain cancers, and not all individuals with the predisposition develop the condition). It opens up the potential to know more and more about individuals (e.g. their risk of developing a condition) and countries around the world (in the UK there is a moratorium on the use of unfavourable predictive genetic test results by insurance companies) are putting in place legislation to protect individuals. Another area where there are ethical and legal concerns is around the patenting of genetic material.

Common Misconceptions

i. Same sex only inheritance - i.e. sons take after their fathers and daughters take after their mothers.
ii. Characteristics are inherited only from the mother during gestation.
iii. Certain characteristics are always inherited from the mother and the others from the father.
iv. Combined/blended characteristics are inherited from both parents.

[7]The probability of the DNA profiles of two unrelated individuals matching is on average less than 1 in 1 billion (1,000,000,000).
Postnote, February 2006, Number 258, **The National DNA Database**; Parliamentary Office of Science and Technology.
[8]**Annual Report 2007-09**; National DNA Database.

Big Ideas & Curriculum for Excellence Experiences & Outcomes

Reproduction and Inheritance:
For offspring to inherit traits there must be a reliable mechanism for transferring genetic information from one generation to the next.
SCN 3-14a

I understand the processes of fertilisation and embryonic development and can discuss possible risks to the embryo. SCN 3-14a

I have extracted DNA and understand its function. I can express an informed view of the risks and benefits of DNA profiling. SCN 3-14b

I have explored the role of technology in monitoring health and improving the quality of life. SCN 3-12b

I have collaborated with others to find and present information on how scientists from Scotland and beyond have contributed to innovative research and development. SCN 3-20a

Molecular Genetics:
The instructions for specifying the characteristics of an organism are carried in a molecule called DNA (deoxyribonucleric acid). All organisms use the same genetic language for their instructions.
SCN 3-14b

Through research and discussion, I have contributed to evaluations of media items with regard to scientific content and ethical implications. SCN 3-20b

I can find the probability of a simple event happening and explain why the consequences of the event, as well as its probability, should be considered when making choices. MNU 3-22a

I can work collaboratively, making appropriate use of technology, to source information presented in a range of ways, interpret what it conveys and discuss whether I believe the information to be robust, vague or misleading. MNU 3-20a

From my studies of technologies in the world around me, I can begin to understand the relationship between key scientific principles and technological developments. TCH 3-01a

I can use my knowledge of current social, political or economic issues to interpret evidence and present an informed view. SOC 3-15a

To help me develop an informed view, I am learning about the techniques used to influence opinion and how to assess the value of my sources, and I can recognise persuasion. LIT 3-08a

I can independently select ideas and relevant information for different purposes, organise essential information or ideas and any supporting detail in a logical order, and use suitable vocabulary to communicate effectively with my audience. LIT 3-06a

Technology and Genetics:
The uniqueness of the DNA structure makes it possible for scientists to create a profile of an individual's DNA and use it as a means of personal identification. DNA analysis opens up the potential to know more and more about individuals.

SCN 3-14b SCN 3-12b TCH 3-01a SOC 3-15a LIT 3-08a LIT 3-06a MNU 2-22a
MNU 3-20a SCN 3-20a SCN 3-20b SCN 3-20a

Curriculum Links, Skills and Interdisciplinary Learning Opportunities

- Gathering information through asking questions, sourcing texts and social interaction
- Applying knowledge to different contexts and developing vocabulary
- Evaluating by selecting information, making informed judgements, appraising and prioritising
- Understanding by summarising, prioritising and through discussion
- Communicating through creating texts, discussion and displaying findings
- Developing investigative and laboratory skills

Finding out about DNA[9], extracting it and being aware of the genetic language by using coded[10] DNA to identify traits and select them at random to create 'organisms'. Exploring through debates[11] the ethical and moral issues surrounding the uniqueness of DNA and the information it can now reveal thanks to advances in technology. Making informed choices about how much information you want to know about you e.g. explore the issues surrounding genetic testing by using sealed boxes (create personalised boxes/packaging in technology) to represent taking genetic tests[12]. Predicting and discussing where the future may lead[13] and the decisions that might have to be made.

Learning Outcomes and Assesment Opportunities

[9]www.exploredna.co.uk/ and www.biology.ed.ac.uk/projects/GeneJury/learningzone_whoseDNA.html
http://www.bbsrc.ac.uk/web/FILES/Resources/fullbooklet.pdf
[10]teach.genetics.utah.edu/content/heredity/html/recipe.html and www.societyofbiology.org/education/educational-resources/genetics/hgl
[11]archive.planet-science.com/sciteach/index.html?page=/sciteach/debating/ and www.beep.ac.uk/content/15.0.html
[12]www.sciencemuseum.org.uk/educators/classroom_and_homework_resources/resources/do_you_want_to_know_a_secret.aspx
[13]extra.shu.ac.uk/cse/geneticfutures/dream.htm

Fourth Level

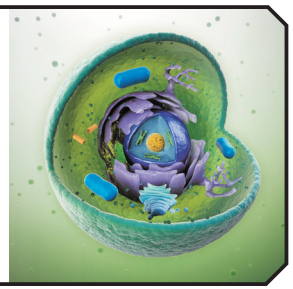
Question: *Why do we, and other organisms, only inherit some traits from our parents?*

Big Idea: *Hereditary information is contained in genes which are passed from parent to offspring during reproduction. During sexual reproduction one copy of a gene is inherited from each parent and each copy will be different. In asexual reproduction all the genes are inherited from one parent and the offspring are an exact copy (clone) of the parent. Genes are specific nucleotide sequences located along DNA molecules that provide instructions for producing specific proteins and determine particular traits. The majority of an organism's DNA is located in the nucleus of an organism's cells in a packaged form called a chromosome. DNA is unpackaged and the molecule unwinds so that it can be replicated during cell division and when its instructions are required for the production of proteins. Before individual genes on DNA could be identified researchers studied organisms to assess the relative influences of genes and the environment. Advances in technology have increased the reliability of the information obtained and the amount and type of information that can be gathered and analysed.*

Reproduction and Inheritance

Some organisms reproduce asexually. Asexual reproduction differs from sexual reproduction in that it does not require two parents. The offspring are produced from a single parent through cell division and are genetically identical to their parent, inheriting all their genetic information from them.

Genes - the fundamental units of inheritance - are the instructions that determine particular traits. During sexual reproduction one copy of a gene is inherited from each parent and each copy can be different. Each individual has the same set of genes, but the variant of each gene may be different. It is this genetic information - the precise genetic constitution of an organism - that is its genotype.



Molecular Genetics

The majority of DNA is located in the area of the cell called the nucleus. Since the nucleus is very small, and because organisms have many DNA molecules per cell, each DNA molecule must be tightly packaged. The packaged form of the DNA molecule is called a chromosome and each DNA molecule in a cell forms a single chromosome. Not all organisms have the same number of chromosomes, but each species has a definite number present in each cell and most cells have two matching sets of chromosomes. DNA is a two stranded molecule and spends a lot of time in its chromosome form. However, during cell division the DNA molecule unwinds into the two separate strands so it can be copied, then an original strand and newly copied strand are transferred to a new cell. This is critical when normal cells divide because each new cell needs to have an exact copy of the DNA present in the original cell. DNA also unwinds so that its instructions can be used to make the proteins that carry out the functions of life.

The instructions on the DNA molecule that determine particular traits are called genes. Each gene is a length of DNA that contains a specific sequence of nucleotides, they are arranged in a line along the length of the DNA molecule, and work by providing instructions for the production of specific proteins.

The location of genes on the same chromosome means that certain traits are usually inherited together. There may be hundreds or thousands of genes on a single DNA molecule, with a total of about twenty five thousand genes in the human body. Most genes that an individual has are the same as other individuals in the species, but a small number of genes are slightly different.

Technology and Genetics

Before individual genes could be identified researchers studied organisms to determine the relative influences of genes and the effect of the environment on particular traits. For example, identical and non-identical twins that had been raised together in similar environments were studied (identical twins that happened to be growing up in different households were also studied). Where characteristics differed more in the non-identical twins this was considered most likely due to differences in their genes. Advances in technology have enabled researchers to study the genes of organisms as well as the organism, increasing the reliability of the information obtained and the amount and type of information that can be gathered and analysed. Genetics is a rapidly advancing field. The work of the Human Genome Project and subsequent research is evolving our knowledge and understanding of genetics, and is changing practices in medicine and molecular engineering. Enhanced knowledge and understanding in genetics is likely to have a substantial impact on the lives of individuals in future; particularly in relation to their medical care.

Common Misconceptions

i. Students have difficulties understanding the relationship between chromosomes, DNA, genes and nucleotide bases.
ii. The role of genes is often misconstrued as determining one trait in all its observed complexity rather than providing the instructions for proteins whose functions and interactions result in the traits we see.

Big Ideas & Curriculum for Excellence Experiences & Outcomes

Reproduction and Inheritance:
During sexual reproduction one set of the genetic material is inherited from the egg cell of one parent and one set from the sperm cell of the other parent, whereas in asexual reproduction all the genetic information is inherited from one parent. SCN 4-14b

Reproduction and Inheritance:
Hereditary information is contained in genes which are passed from parent to offspring during reproduction. SCN 4-14c

Molecular Genetics:
Genes are specific nucleotide sequences, located along DNA molecules, that determine particular traits. Genes provide instructions for producing specific proteins. SCN 4-14c

Molecular Genetics:
The majority of an organism's DNA is located in the nucleus of an organism's cells in a packaged form called a chromosome. DNA is unpackaged and the molecule unwinds so that it can be replicated during cell division and when its instructions are required for the production of proteins. SCN 4-14c

Technology and Genetics:
Before individual genes on DNA could be identified researchers studied organisms to assess the relative influences of genes and the environment. Advances in technology have increased the reliability of the information obtained and the amount and type of information that can be gathered and analysed. SCN 4 -14c SCN 4 - 20a
TCH 4 - 01a MNU 4 - 22a SOC 4 - 05a HWB 4 - 15a HWB 4 - 16a LIT 4 - 06a

Through evaluation of a range of data, I can compare sexual and asexual reproduction and explain their importance for survival of species. SCN 4-14b

I can use my understanding of how characteristics are inherited to solve simple genetic problems and relate this to my understanding of DNA, genes and chromosomes. SCN 4-14c

I have researched new developments in science and can explain how their current or future applications might impact on modern life. SCN 4-20a

By applying my understanding of probability, I can determine how many times I expect an event to occur, and use this information to make predictions, risk assessment, informed choices and decisions. MNU 4-22a

I can compare traditional with contemporary production methods to assess their contribution in the world around me and explain the impact of related technological changes. TCH 4-01a

I can present supported conclusions about the social, political and economic impacts of a technological change in the past. SOC 4-05a

I can independently select ideas and relevant information for different purposes, organise essential information or ideas and any supporting detail in a logical order, and use suitable vocabulary to communicate effectively with my audience. LIT 4-06a

Curriculum Links, Skills and Interdisciplinary Learning Opportunities

Comparing reproductive strategies[14] and starting to explore how traits are passed from one generation to another[15].

Learning Outcomes and Assesment Opportunities

[14]http://teach.genetics.utah.edu/content/begin/traits/ReproductiveStrategies.pdf
[15]www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/duk_/activities/duk_genetics_mary_act/duk_genetics_mary_act.xml
and http://teach.genetics.utah.edu/content/begin/dna/findagene.pdf
and http://www.woodrow.org/teachers/biology/institutes/1997/makeface/teacinfo.html

National Levels 4 & 5

Question: *Why do we, and other organisms, not have the same traits as our siblings?*

Big Idea: *Across generations there are patterns of gene transfer that affect the traits offspring inherit. Many features of human heredity are explained by the fact that human cells contain two copies of each chromosome (one inherited from each parent) and therefore two copies of each gene. Individuals all have the same genes and chromosomes, but chromosomes can have different versions of specific genes (alleles). The inheritance of different alleles affects the traits observed in offspring. Some alleles are dominant, while others are recessive and remain masked unless the two inherited alleles are identical. Patterns of correlation between alternative forms of the same gene make it possible to predict offspring inheriting certain traits when the forms of the parents' genes are known and to breed offspring with particular traits.*

Common Misconceptions

Big Ideas, Curriculum Links and Useful Resources

Reproduction and Inheritance:
Many features of human heredity are explained by the fact that human cells contain two copies of each chromosome (one inherited from each parent) and therefore two copies of each gene. During cell division the paired chromosomes are duplicated and two new cells formed with paired chromosomes identical to the original cell. When gamete cells (mature sexual reproductive cells, such as a sperm or egg) are produced the replicated paired chromosomes are selected at random, sorted into two single sets and each set allocated to a new gamete.

Reproduction and Inheritance:
In sexual reproduction the inheritance of different types of alleles of the same gene affects the traits observed in offspring. Some alleles are dominant, while others are recessive and remain masked unless the two inherited alleles are identical.

Molecular Genetics:
Alternative forms of the same gene are known as alleles and an individual inherits two alleles for each gene, one from each parent.

Reproduction and Inheritance:
There are patterns of correlation between alternative forms of the same gene and the traits observed in offspring. The probability of offspring inheriting certain traits can be predicted if it is known which forms of the genes both parents have.

Reproduction and Inheritance:
Advances in technology make it possible to alter the genetic makeup and create organisms by DNA manipulation, rather than using the traditional method of breeding species for particular characteristics.

Curriculum Links, Skills and Interdisciplinary Learning Opportunities

Further information on curriculum content can be accessed on the SQA website[16]. Useful resources include the magazines: Big Picture - Genes, Genomes and Health (Issue 11: January 2010) produced by the Wellcome Trust[17] and Biological Sciences Review -aimed at advanced level biology students[18].

Learning Outcomes and Assesment Opportunities

[16]http://www.sqa.org.uk/sqa/2565.html
[17]http://www.wellcome.ac.uk/Education-resources/Teaching-and-education/Big-Picture/All-issues/Genes-Genomes-and-Health/index.htm
[18]http://www.philipallan.co.uk/biologicalreview/index.htm

National Levels 6 & 7

Question: *How do we, and other organisms, express traits and how do changes in genetic inheritance occur?*

Big Idea: *Inherited traits can be determined by one or many genes, and a single gene can influence more than one trait. Cellular and molecular mechanisms are responsible for the patterns of gene transfer across generations and result in genetic variation. Unless a mutation occurs all of the cells in an organism contain the same genetic information. Cells are able to regulate which information is used (expressed) and the proteins that are produced.*

Common Misconceptions

i. Understanding that genes contain information is not enough to be able to explain how the genetic information brings about its effects on specific traits. It is important to understand what the information specifies and how it translates in to instructions.

ii. Students are often unaware of the centrality of proteins in genetic traits. They do not conceive of the genetic informational content being expressed as the makeup of proteins. They do not distinguish the role of genes (DNA) as carrying information for the make up of proteins and instead attribute their role to coding for the structure and function of cells, tissues and organs at higher organization levels.

Big Ideas, Curriculum Links and Useful Resources

Reproduction and Inheritance:
During the production of the sex cells the selection of chromosomes at random and on occasion, chromosome mutations and abnormalities, create genetic variation.

Molecular Genetics:
Genes work by coding for proteins. The sequence of nucleotides on the gene is translated into the sequence of amino acids in the specific protein encoded by the gene. Protein production is regulated and a variety of proteins can be produced from the same gene.

Reproduction and Inheritance:
The inheritance of traits is often complex and can be determined by one or many genes, and a single gene can influence more than one trait. Understanding the patterns of correlation between inherited alleles makes it possible to: group populations into distinct categories, predict traits in offspring and trace heredity.

Molecular Genetics:
Proteins are the central elements that mediate genetic effects and connect genes to traits. Protein interactions at the molecular and cellular level result in the patterns observed at the macro level. The overall structure and properties of the protein, determined by the amino acid sequence, affords and constrains its function.

Molecular Genetics:
Changes to genes (mutations) and the cell environment (e.g. toxins) can alter the structure and function of proteins produced by cells, and can change how an organism looks and functions (phenotype). Some changes can be neutral, some beneficial and others harmful to the organism.

Technology and Genetics:
Advances in technology develop and expand our understanding of genetic phenomena and this enhanced understanding often leads to further technological advances and new technologies. The developments and new technologies in genetics have an impact on society requiring citizens to make informed choices.

Molecular Genetics:
The genome is the complete DNA sequence of the organism's nuclear DNA. An important property of DNA is that it can replicate itself making it possible for each cell to have exactly the same DNA. Variation in DNA can serve as a way to identify individuals and species, and can provide information on evolutionary relationships and origins.

Curriculum Links, Skills and Interdisciplinary Learning Opportunities

Further information on curriculum content can be accessed on the SQA website[19]. Useful resources include the magazines: Big Picture - Genes, Genomes and Health (Issue 11: January 2010) produced by the Wellcome Trust[20] and Biological Sciences Review -aimed at advanced level biology students[21].

Learning Outcomes and Assesment Opportunities

[19]http://www.sqa.org.uk/sqa/2565.html
[20]http://www.wellcome.ac.uk/Education-resources/Teaching-and-education/Big-Picture/All-issues/Genes-Genomes-and-Health/index.htm
[21]http://www.philipallan.co.uk/biologicalreview/index.htm

STEM-ED Scotland

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