Children's ideas about

REPRODUCTION AND INHERITANCE

RESEARCH SUMMARY

This is a brief outline of research setting out the main prior ideas and understandings which teachers might expect to meet among pupils.

Children's ideas about
REPRODUCTION AND INHERITANCE

Before reading this summary of children's prior ideas, it may be helpful to look at the Science Map and The Teacher's View so as to have a useful overall perspective from which to view children's understandings.

Introduction

The research specifically about children's concepts of reproduction is not extensive, but information is also available from studies of their concepts of life. This summary presents the research under the headings:

Reproduction as a criterion for life
Human reproduction
Continuity of life
Biology of reproduction in organisms
Implications for teaching reproduction
Genetics, variation and resemblance
Mechanism of inheritance
Sources of variation
Adaptation
Random chance
Implications for teaching genetics
The studies summarised.

Reproduction as a criterion for life

Children's concepts of reproduction as a criterion for life have been studied by a number of researchers. Carey reports that few children of primary age volunteered reproduction as a criterion for life [1]. Some children in Tamir's study believed that eggs and seeds are not alive although they held that living things develop from living things [2]. Reproduction was applied as evidence of life in inanimate objects by a few of the younger children in several studies [2,3]. These ideas are also referred to in the Research Summary: Living Things.

Human reproduction

The studies by several psychologists into children's understanding of human gender and reproduction have been summarised by Carey [1]. To young children, under about six, gender is socially determined by hairstyle, clothes, names and behaviour. These young children believe that a person can change gender by changing these outward signs, while believing it to be socially unacceptable to do so. By the age of seven or eight, gender constancy has become secure in children's thinking, as they understand it in a developing biological framework and in relation to their understanding of reproduction.

Studies of concepts of the origin of babies have found the same developmental progression amongst the thinking of children aged 3-16 in Hungary, North America, England, Australia and Sweden [1 4 5 6]. Pre-school children believe that any baby has always existed: in a shop, in somebody's tummy, in heaven, in hospital. They don't see questions about origins as meaningful in this or any other topic. From the age of about five they understand that things are made, and put the origin of babies in the context of a purposeful human activity of manufacturing babies from parts. This may be by someone in a shop or factory, or it may include the 'digestive fallacy' of the mother eating components from which to make a baby in her stomach. According to Carey these early concepts represent a psychological understanding of phenomena depending on wants and beliefs, before the child develops any physiological understanding. A transitional stage follows as the child tries to make sense of the social relationship between a mother and father, information about sexual intercourse and ideas of components called sperms and eggs. Animistic notions of deliberate actions of sperms and eggs prevail. Many children hold a literal interpretation of the 'agricultural model' believing that something like a bean seed is deliberately planted in soil inside the mother and others think that an egg like a hens egg is incubated inside the mother. By the age of eleven most children have some idea of the mechanics of sexual intercourse and understand the role of both parents in getting sperms and eggs together to make babies. Two studies [4 5] showed that the percentages of each sample of 11-12 year-olds who had reached this stage were as follows:

North American(Californian, middle class)	100%
North American (mixed sample)	80%
English	63%
Australian	87%
Swedish	97%

By the age of nine few children in most of the samples had reached this stage of understanding, except in the Swedish sample where 83% had. The Swedish children were several years ahead of their counterparts in the other samples at all stages. This suggests that social climate as well as psychological development is significant in children's concept development in this domain. In the absence of any information of genetics, children make sophisticated constructions to explain the production of a new individual from sperm and egg. Of children aged eleven and older 30% articulated a model of pre-formation: that a miniature baby is folded up inside the sperm or the egg and the other gamete triggers its development. This parallels historical explanations.

Continuity of life

Tamir et al investigated the notion of continuity of life in children aged 10-14. Although most could put pictures of seed germination or chick embryology in the correct sequence, and 85% said that the seedling was alive, only 66% said that the seed was alive. It follows that 19% did not understand the continuity of life from seed to seedling. They believed in the possibility of living organisms developing from non-living, stating 'seeds are dead; when we put them in the soil they get food and begin to live' or 'larvae change into pupae which are dead and then we get butterflies'. However, most of the children did understand the continuity of life explicitly stating 'if the seed were not alive it would not be able to grow' or expressing the idea that living organisms originate from other living organisms. In some cases the latter idea did not prevent children from believing that eggs and seeds are not alive. Of a class of agricultural school students in the sample only one classified eggs and seeds as non-living, suggesting that their agricultural experience had an impact on their understanding of the life concept[22].

Biology of reproduction in organisms in general

Very little research has been published about pupils' understanding of the biological principles of reproduction in organisms in general.

In a study of Nigerian students, 40% of them, even post-sixteen, did not distinguish between reproduction and the act of copulation in mammals. In accordance with their alternative conception of reproduction, these students did not believe that plants are capable of sexual reproduction. Asexual reproduction was thought to be restricted to micro-organisms[7]. The study did not probe the students' notions of how plants produce offspring with neither sexual nor asexual reproduction available to them! Perhaps it was perceived by students as a matter of no interest, in the same way as plant growth evoked no firm concepts amongst pupils studied by Barker[8].*

Relatively small percentages of the Nigerian students displayed some other

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* *See Research Summary: Growth*

misconceptions: notably 36% thought that a human ovum contains yolk on the same scale as a bird's egg. This may relate to the 'incubation theory' of young children noted in Carey's work, or it may derive from the semantics of using the same word 'egg' in a technical and an everyday sense. Similarly 18% showed confusion between the concepts of male gamete and seminal fluid. This may arise from use of the word sperm, in the singular form, for both of these concepts. The Assessment of Performance team analysed about 800 responses to the questions in their age fifteen survey[9]. They found that pupils more often correctly identified examples of sexual reproduction in animals, than examples of its occurrence in plants. This corresponds with teachers' experience and the findings in Nigerian and Hampshire studies, that many pupils do not believe that flowering plants reproduce sexually. This firmly held conception is very resistant to change by teaching. Biology tuition appears to have little effect in changing 'folklore' concepts of reproduction but it does affect performance on formal aspects of sex education, such as recognising unrealistic anatomical 'plumbing' diagrams, knowledge of hormonal control and the site of fertilisation. Similar conclusions were reached by a group of teachers in Hampshire who undertook an investigation of preconceptions (sic) about reproduction, amongst 11-13 year olds[10]. The Hampshire report is interesting in documenting 'misconceptions' revealed by its pilot questionnaire given to 150 children. These include the notions that:

sexual reproduction must involve mating (similar to the Nigerian finding)
male animals are always bigger and stronger than females
animals consciously plan their reproductive strategies
asexual reproduction results in weakness and sexual reproduction always produces stronger individuals
hermaphroditism is the same as asexual reproduction

Some other conceptions which relate to genetics are mentioned below. Unfortunately the summary analysis of concepts from the main questionnaire does not correspond to this list, so it is not easy to quantify the incidence of these notions. The team found much evidence of anthropomorphism amongst answers about animals.

The Hampshire group also examined many alternative conceptions about twins which are familiar to teachers, and which have been documented by Engel-Clough and Wood-Robinson, such as: twins can be formed from one egg and two sperms, and identical twins can be of opposite sexes[10 11].

Implications for teaching reproduction

The limited literature on children's concepts of reproduction provides little guidance about teaching. The folklore and emotional implications of human reproduction appear to block an understanding of the overall pattern of reproduction in living things. Although pupils can master diagrammatic drawings of the human reproductive system as a piece of formal learning, they do not appear to relate these to understanding the anatomical and physiological implications [9,10]. The Hampshire work shows how teachers can confirm and extend research studies in relation to their own pupils. The authors suggest pupil self-assessment on a diagnostic questionnaire with computer scoring, pre- and post- teach, as a possible teaching tool.

Genetics

Several researchers have studied advanced students' understanding of formal genetics concepts. These studies are not reported in this summary as the scientific goals involved are beyond the expectations for pupils in the middle years of secondary school. However, some of the research into the beliefs held by older students, even undergraduates, indicates alternative conceptions which persist all through school and which are relevant to the topics taught to younger children. Those studies are summarised here along with the few available studies of lower age groups.

Variation and resemblance

Most research in this area assumes that the subjects hold concepts of variation within a species and of offspring resembling their parents. Hackling and Treagust did investigate fifteen year-old students' understanding of these concepts and found that 94% understood that one's characteristics come from parents, 50% understood that inheritance and reproduction occur together and 44% understood that one gets a mixture of features from both parents [12]. Deadman and Kelly found that their students recognised that intra-specific variation occurs, but that they regard it as a response to environmental conditions rather than to inheritance. Pupils had firm ideas of transmission of characteristics from generation to generation. The boys believed in blending inheritance, and regarded characteristics from the male parent as being stronger in their expression [13]. Other studies have found similar notions regarding lack of equality of parental contribution. The pupils in both Engel-Clough and Wood-Robinson's and in Kargbo et al's samples tended to favour the mother as providing the main contribution, or to support same-sex inheritance (daughters inheriting from mothers and sons from fathers) [10,11,14].

Mechanism of inheritance

In Kargbo's study of children aged 7-13, half gave naturalistic explanations of the mechanism of inheritance: nature makes offspring resemble parents. Some referred to environmental factors, some to somatic factors such as the brain or blood, and only four subjects (amongst the older children) implied any genetic principle. The children's responses to the nineteen questions in the test instrument, convinced Kargbo and his colleagues that the pupils were not giving insignificant, unconsidered answers, but that children have established frameworks to make sense of their observations of inheritance [14].

Several researchers have found that pupils even before specific teaching, know the word 'gene', and less frequently 'chromosome'. They understand little of their nature or function, not appreciating that there is a chemical basis to inheritance [11,12,13]. Lucas' survey of adults' understanding of scientific concepts revealed that half the respondents volunteered that genes are responsible for the similarities between parents and offspring, but one third could not offer any explanation of the phenomenon. People who had studied science had no more knowledge of this topic than other people of the same educational level. Half of Lucas' sample chose correctly on the mechanism of sex determination, compared to a quarter incorrectly and a quarter 'don't know's. Again science education background made no difference to this knowledge, but gender did, with more women than men choosing correctly [15].

Sources of variation

Several studies, involving students of all ages, point to very persistent alternative conceptions about the source of variation. Students invariably attribute phenotypic variation to environmental factors alone. Sexual reproduction is not recognised as the source of variation in a population. Two APU questions probed this concept amongst fifteen year-olds, many of whom were studying biology. On one question, only 14% mentioned sexual reproduction or natural variation, even though the question said that environmental conditions were kept constant. On the other question, only 1% gave an accurate explanation of variation correctly involving reproduction [9]. Hackling and Treagust found that the influence of environmental factors was more frequently comprehended (in 56% of responses) than the influence of genes (in 30% of responses) [12]. Studies with advanced high school and college students have shown that large proportions do not understand the interaction of genes and environment [16]. Lack of a precise concept distinguishing sexual reproduction from asexual reproduction, as revealed by the research reviewed above, precludes an understanding of the origins of variation [7,9,10].

Adaptation

Adaptation is a term used with a number of different meanings. All of the research has found that most students regard adaptation in terms of individuals changing in major ways in response to their environment, in order to survive. They see adaptation in a naturalistic or teleological sense: to satisfy the organism's need or desire in order to fulfil some future requirement [13]. In Engel-Clough and Wood-Robinson's study, two thirds of 12-14 year-olds and half of sixteen year-olds gave teleological interpretations of examples of adaptation. Only 10% of the whole sample gave scientifically acceptable explanations. The rest merely restated the questions in some tautological form [17]. Students show confusion between an individual's adaptation during its lifetime and inherited changes in a population over time. In other words, they believe in the inheritance of acquired characteristics. This Lamarckian belief is clear from many surveys of students both before and after instruction in genetics and evolution [11 13 14 18 19]. Brumby found that only 18% of students, even after studying 'A' level Biology, could correctly apply a process of selection to evolutionary change. Most gave a Lamarckian interpretation that individuals can adapt to change in the environment if they need to, and that these adaptations are inherited. Brumby considers that pre-existing Lamarckian ideas can block the understanding of a Darwinian explanation [20].

Random chance

Although they have some idea of randomness (sometimes an offspring is like its mother, sometimes father, sometimes mixed) [14], pupils rarely show evidence of applying the concept of chance and probability to inheritance and evolution [12 13 16]. The concepts of chance, randomness and probability are not held by many students even after advanced courses. Many could predict mathematical probabilities of outcomes in isolated theoretical examples, but could not relate this to examples of situations in human families [16].

Implications for teaching genetics

A number of studies have made recommendations for teaching genetics and evolution, mainly involving a change in emphasis and sequencing of traditional courses. There is a need for establishing an understanding of intraspecific variation and the respective effects of genetic and environmental contribution to the phenotype, including subtle and minor environmental effects. The nature of sexual reproduction including the equal contribution of each parent to the characteristics of the offspring and the variation between offspring need to be understood, before progressing to any quantitative instruction in genetics. More than in any other field of science there is a need to help pupils move away from anthropomorphic explanations if they are to understand the orthodox scientific explanations in this area [12 13 17].

Teaching the monohybrid ratio is detrimental to students' understanding of the role of chance, which should be emphasised. The idea of phenotypic ratios is of historical interest but has limited applicability to human genetics, which is the main relevance of genetics teaching [12]. The concept of dominance is an oversimplification which does not adequately explain the realities of human genetics, so perhaps should be avoided altogether. Analysis of pupils' own family trees, for example with respect to tongue-rolling, could cause embarrassment and distress. Oxford points this out, explaining that the usual school treatment of this trait as a classic case of dominance (ignoring penetrance) is inaccurate and misleading [21].

The studies summarised

Nagy studied children's concepts of the origin of babies in Hungary (n=60, aged 4-7) in USA (n=30, aged 5-10) and in England (n=300, aged 8-11) [6]. The same ideas were investigated by Bernstein and Cowan in North America (children aged 3-12) [4] and by Goldman and Goldman in North America, England, Australia and Sweden (n=838, aged 5-15) [5]. Okeke and Wood-Robinson studied a sample of 120 Nigerian students aged 16-18, investigating the students' concepts of growth, reproduction and transport [7]. English pupils' concepts of reproduction were investigated by the APU survey of nearly eight hundred fifteen year-olds [9] and by a Hampshire study of 516 children aged 11-13 [10]. Concepts of inheritance and adaptation have been probed by a number of studies. A pioneering piece of research in the 1970s was Deadman and Kelly's study of 52 English 11-14 year-old schoolboys [13]. Brumby studied 150 Australian first-year medical students and 63 English first-year higher education students [18 20]. The studies of Hackling and Treagust in Australia (n=48, fifteen year-olds) [12], Engel-Clough and Wood-Robinson in England (n=84 aged 12-16) [11 17], and Kargbo, Hobbs and Erickson in Canada (n=32 aged 7-13) [14] have produced similar findings from around the world. Other work in the USA reinforcing these findings across the age range comes from Lawson and Thompson (n=131 aged thirteen) [19] and Hickman, Kennedy and McInerny (n=913 advanced high school and college students) [16].

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LIFE CYCLE

Children's Prior Ideas

Although they hold the concept that living things develop from living things, many children believe that eggs and seeds are not alive, but that they give rise to living organisms. This anomaly may be due to the meaning they attach to the word 'alive'.

(See Reproduction and Inheritance Research Summary)

The Challenge for Pupils

It is a tremendous challenge for children to appreciate the spiral of life cycles enabling the continuity of life through time. It involves far more than memorising life-cycle diagrams or even observing the changes in organisms through an annual or seasonal cycle, although such a practical study may be a useful starting point.

A practical study of the complete life cycle of an organism in a fairly short time may help to establish the concept of continuity, with life persisting in a dormant seed or egg. A study of Rapid Cycling Brassicas (Fast Cabbages) would demonstrate a life cycle within half a term and help to show the persistence of life through the seed. Finding ways to kill seeds and prevent their germination may show children that untreated seeds are alive. However, this would not automatically convince children of the continuity of life over many generations - this concept may need constant reinforcement.

A 'personalised' approach to the idea of the human life cycle requires great sensitivity but is an effective route to understanding the continuity of life through the life cycles of all species. Children, like many adults, find it difficult, and even disturbing, to imagine that they once existed as a zygote the size of the dots around the edge of a two pence coin (or a pin point). Appreciating that their parents and grandparents were alive before they existed is important not only in history lessons: it is vital for a grasp of the reality of the human life cycle.

A full acceptance of the significance of the human life cycle may help children to appreciate the magnitude of their own significance in the continuity of life. However, it is important to recognise that humans are unique and exceptional animals; there is an extra dimension to their continuity, through culture. Individuals may make important contributions to the continuity of 'humankind' through service to others, creative work and so on, even if they do not reproduce.

Many pupils may be frightened of the idea of their own mortality but it needs to be sensitively addressed in the context of the continuity of human life.

That reproduction of any living thing, not just humans, is a marvellous and wonderful event is something which is rarely discussed in the teaching context. Acknowledging that they are the product of such a wonderful event and that they are significant in the continuity of life may heighten the child's self esteem and motivation.

MEANING OF REPRODUCTION

Children's Prior Ideas

Children recognise that living things produce young ones, but they do not spontaneously apply the idea of reproduction as a criterion for life.

Although they hold the concept that living things develop from living things, many children believe that eggs and seeds are not alive, but that they give rise to living organisms. This anomaly may be due to the meaning they attach to the word 'alive', that is, showing signs of life.

Many children identify the word 'reproduction' with the act of copulation in mammals.

(See Reproduction and Inheritance Research Summary)

The Challenge for Pupils

The word 'reproduction' is familiar to children. The challenge is to separate it from its social and emotional implications, and to both refine its use and to extend it to the reproduction of a wide variety of organisms. Pupils may like to 'research' a wide range of examples from video, TV, library and live specimens, and to communicate their findings to the class.

One challenge for pupils is to acknowledge the continuity of life. ◈THINK LINK◈

The idea of continuity of life is connected with the notion of the continuity of cells (see Living Things and Growth). Pupils' concept of 'alive' may be different from the scientific concept, and the issue of 'what do we mean by 'alive'?' needs revisiting throughout the science course. (See Learning Guide: Living and Non-Living in 'Living Things', and Learning Guide Microbes as Living Things in 'Microbes'.)

Sorting pictures to decide which of them show examples of reproduction could provide a stimulus for discussing the life concept in the context of reproduction (see Additional Materials).

A further challenge arises in understanding the logic that all living things come from pre-existing living things, but not all living individuals give rise to others. Children know that not all individual people, animals and plants produce young, so they may dispute 'reproduction' being used as a criterion of life. The occurrence of reproduction identifies life; its absence does not signify non-life. Reproduction is essential to the continuous life of the species but not to the life of an individual. Children need to confront and discuss these ideas to work their way towards an understanding of them.

MODES OF REPRODUCTION

Children's Prior Ideas

Most children identify the word 'reproduction' with copulation in mammals.

They relate their use of the word 'reproduction' to sexual reproduction and they think that sexual reproduction must involve mating. Although they may know about fertilisation, few children hold the concept that fertilisation is the criterion of sexual reproduction.

Many children do not believe that sexual reproduction happens in organisms which do not have distinct male and female individuals (for example, earthworms). Hence they assume that reproduction is asexual in these organisms.

Most children do not believe that plants can reproduce sexually. Many think that all plant reproduction is asexual. Others do not regard seed production as reproduction at all.

Some children believe that asexual reproduction is peculiar to microbes.

Many children believe that a miniature baby is folded inside a sperm or egg and that the other gamete triggers its development.

Many children do not believe that inheritance and reproduction occur together.

They do not recognise that sexual reproduction is a source of variation in a population.

Children often believe that sexual reproduction is 'better' because they think that it produces strong individuals and that asexual reproduction results in weakness.

(See Reproduction and Inheritance Research Summary)

The Challenge for Pupils

Children need to clarify the meaning of the word 'reproduction' (see Learning Guide Meaning of Reproduction) before proceeding to distinguishing different modes. In order to address the significance of the different modes of reproduction, in terms of variation, children must first acknowledge the assumption that organisms produce offpring of the same 'kind' as themselves. Children will need to have established a concept of the cell before understanding the cellular significance of reproduction. (See Learning Guides: Cells and Species in 'Living Things'.)

The challenge is to move from the descriptive study of reproduction in plants, humans and other animals which they have experienced in early stages of school work, to understanding its significance. They need to make sense of their experiences and build upon existing awareness of reproduction (which is probably an amalgam of ideas about pollen, bees, seed dispersal, human sexuality and bacterial multiplication) and incorporate them into an overall scheme. If human, plant, animal and microbe reproduction are taught in separate parts of the science course, it is necessary to give children an opportunity to focus on the commonality of all reproduction. Then they can try to identify which examples are asexual and which are sexual and to recognise the similarities between all cases of sexual reproduction (for example, recognising similarities between pollen and sperm). A display of specimens supplemented by pictures may be useful, but it is difficult to observe organisms doing reproduction (except yeast). We can only observe outcomes in the form of such things as potatoes, seeds, locust nymphs.

Earlier teaching may have established an idea that asexual reproduction involves only one parent, and that sexual reproduction involves two. This contributes to the difficulty of acknowledging sexual reproduction in flowering plants where only one parent may be sufficient. A way in to recognising sexual reproduction of flowering plants is by studying a species which has separate male and female plants, such as Campion (Silene) or a willow species.

Pupils are often satisfied with learning a technical term and applying it correctly. The challenge is to recognise that the distinction between the two modes of reproduction lies in the concept of fertilisation and that this has significance in producing variation (see below). The key distinction is in 'joining of cells ' or 'no joining'. By referring to a wide range of examples of reproduction they could be encouraged to recognise that these are all strategies for continuity, but with the potential for stability (asexual) or variation (sexual).

Children may approach the significance of the two modes of reproduction within the commonality of reproduction through discussion of such questions as:

How is it that all the puppies in a litter or children in a family, are not identical?
How is it that identical twins are identical?
How have different breeds of dogs and different varieties of potatoes come about?
How do farmers make sure they keep producing exactly the same variety of potato?

(See Additional Material: Diagnostic Questions)

Such a sequence of questions may provoke the question of whether the origin of identical twins is a case of asexual reproduction. An interesting challenge!

SEXUAL INHERITANCE

Children's Prior Ideas

Many children believe that a miniature baby is folded inside a sperm or egg and that the other gamete triggers its development.

Many children do not believe that inheritance and reproduction occur together or that an individual gets a mixture of features from both parents.

Even those children who recognise the role of both parents do not believe in equality of parental contribution. They think of inheritance as a blending of characteristics with one sex, usually the same-sex parent, contributing more to the mixture.

(See Reproduction and Inheritance Research Summary)

The Challenge for Pupils

It is a challenge for children to extend their knowledge of sperms and eggs in humans to a wider view of the occurrence and significance of gametes. They need to understand that the concept of 'gametes' applies to all sexually reproducing organisms, both animals and plants. Moreover, they need to extend their knowledge of gametes joining in fertilisation to the significance of this as a transfer and combination of information. The challenge here is to make the link between reproduction and inheritance. The ideas of the life cycle and of genes need to be brought together. (See Learning Guides: Life Cycle and Genes.)

THINK LINK (See Additional Materials: Historical Notes on Ideas about Sexual Reproduction.)

The recognition of gametes as microscopically visible entities which carry and combine information helps in establishing the idea that genes within gametes are material entities.

Implicit in the understanding of gametes is the acceptance that they are individual cells, with an infra-structure suited to their function. (See Learning Guides: Cells, and Structure and Function in 'Living Things'.) The understanding that, despite the disparity in size between a sperm and an egg, each gamete has one, equal sized nucleus, is important in explaining the equal contribution of each parent to the offspring.

By thinking about 'combination' by sexual reproduction in successive life cycles, children may raise for themselves the problem of potential 'doubling up' of genetic information generation after generation. This will lead to recognising the necessity of halving the genetic information in the formation of gametes.

In facing the challenge of understanding variation due to the combination of gametes, most pupils are able to envisage the large number of permutations from two alternatives of each of a few characteristics. However, it is an enormous step to go beyond this. It is too complex to explain, at Key Stage 3, how all the gametes from one parent are not identical. The ability to deal with the concept of segregation at meiosis is not likely to be available to pupils until a later stage.

REPRODUCTION AND INHERITANCE

GENES

Children's Prior Ideas

Most children recognise family resemblances in humans, and understand that a person's characteristics come from their parents.

However, children invariably attribute the difference between individuals to different environmental factors only.

Those who know about genes, think of genes as conferring similarities and of the environment as causing differences.

The majority of students, even on advanced courses, believe in the inheritance of acquired characteristics. They believe that features developed during the lifetime of an individual, due to environmental effects, are passed on to the offspring of that individual.

Children up to age thirteen tend to attribute inheritance to 'nature', blood', 'brain'. Although they may know the word 'gene' or 'chromosome' they have no idea of what these are. Particularly they do not appreciate the chemical basis of inheritance.

(See Reproduction and Inheritance Research Summary)

The Challenge for Pupils

An initial challenge is to recognise that there is some control and co-ordination of the characteristics of an individual, and then to accept that the totality of these characteristics is determined by a large number of separate 'controllers' or genes.

When they are introduced to the 'genetic code' or 'inherited information' pupils face the difficulty of moving from the idea of spoken information to that of information coded in a material form. Analogies are often useful especially when the pupils think of them for themselves. The coded messages on an audio or video tape, or a computer programme on a disk are possible analogies for the genetic code.

In thinking about codes, they will recognise that any code consists of units of information. In moving towards an understanding of genes as the carriers of coded information, pupils at this stage need to accept the idea of many different genes each carrying different units or bits of information.

Thinking in analogies of copying, transmission and transcribing of information technology codes may be as far as pupils will go in understanding the genetic coding. By bringing these ideas together with the concept of continuity of cells (see Cells, Development and Replacement Learning Guide in 'Growth') and the notion that cells have an infra-structure (see Learning Guide in 'Living Things') pupils may gradually come to a more sophisticated understanding.

Once children have heard the words 'genetic code' and 'genes' they need to bring together a number of ideas to get some understanding of what genes are and what they do. It involves recognising that cells have an infra-structure (see Cells Learning Guide in 'Living Things'), and that genes are part of it, that is, genes are substances (see Material Substances Learning Guide in 'Materials').

A challenge for even the most able pupils is to grasp the scale of a gene. They need to understand that there are very many, very small and different items in the nucleus. The large number of items and the small space into which it has to be packed, means that the items must be on the same scale as molecules, that is genes are parts of material substances. (See Introduction: Size and Scale.)

Teachers will have their own opinions as to whether it is helpful to introduce the idea of chromosomes at this stage, but children who have heard of chromosomes may want to know how they relate to genes. At this stage, a structural relationship, explained by a necklace analogy, is the only one likely to be understood by pupils. However, an explanation of sex determination using the terminology of X and Y chromosomes may be a way into understanding segregation and recombination of genes at a later stage.

'NATURE AND NURTURE'

Children's Prior Ideas

Most children recognise family resemblances in humans, and understand that a person's characteristics come from their parents.

However, children invariably attribute the difference between individuals to different environmental factors only.

Those who know about genes, think of genes as conferring similarities and of the environment as causing differences.

The majority of students, even on advanced course, believe in the inheritance of acquired characteristics. They believe that features developed during the lifetime of an individual, due to environmental effects, are passed on to the offspring of that individual.

(See Reproduction and Inheritance Research Summary)

The Challenge for Pupils

Children may have beliefs about the origins of variation which they will need to confront repeatedly in order to move towards the scientific view. (See Additional Materials - Diagnostic Tasks.)

A survey of a range of characteristics within the class or year group is an activity traditionally used to generate data for statistical analysis. This data base can be exploited further for consideration of the origin of variation. Children will need to recognise that some of their characteristics are inherited (for example eye colour), and that some are environmentally determined (for example anaemia in an iron-deficient person, a grazed knee on a child who has fallen). They will also need to recognise that for some features the causes are difficult to identify. The challenge is to account for what they see in themselves and other species in terms of genetics, environment or, in most cases, a combination of both causes. Teachers will recognise the need for sensitivity in discussing the attributes of children and their families, especially in noting those which are unusual within the class or which may appear to be defects.

Pupils will be familiar with experiments to study the effects of different environmental factors on the growth of plants. They will be familiar with the notion of a fair test, and that similar plant specimens from the same source must be used in such experiments. By thinking about the source of 'similarity' in plant or animal specimens, that is, genetic identity or similarity, combined with the effect of environmental manipulation, pupils may be helped to recognise the interaction of the two sets of factors.

A major challenge lies in recognising that the effects of the environment and of the genes can interact, yet the environment usually cannot affect the genes themselves and so cannot be passed on to subsequent generations. As an example, children readily accept that an athlete's fitness depends both on their genetic 'programme' and on environmental factors - their training. It is very difficult for them to accept that the component of fitness developed due to the environment cannot be inherited by the athlete's children when they are committed to the idea that acquired characteristics are passed on to offspring. However, by focusing on examples such as a grazed knee which are obviously not inherited, pupils may be helped to overcome this commitment.