1:Previous Research-A Review

Processes of life such as growth, reproduction, movement, feeding, excretion, respiration and sensitivity are fundamental to any biological knowledge and the core concept of *living thing*. Studies of the development of the child's understanding of the processes of life have invariably focused on two aspects. Initial research examined animistic thinking by children and their concept of life and the criteria they deploy for establishing whether an object is 'living' or 'not alive'. Later studies examined the child's perception of the inside of the body and the processes of life themselves. Somewhat surprisingly most of this work has been undertaken by those working in the field of psychology, nutrition and nursing and does not appear to be generally well known amongst science educationalists. Good summaries can be found in Carey (1985) and Mintzes (1984).

Living and Non-living

Perhaps the most well known of these studies are those undertaken by Piaget (1929) who established a framework based around the criterion of movement. Piaget's technique was to use the clinical interview and present the subject with an object and ask the question, 'Is it alive?' and if the child's answer was 'Yes', he asked 'How do you know?'. From his results, he distinguished the following stages of development in the concept of what constituted a 'living object'.

Stage 0	*No Concept* Random judgements or inconsistent or irrelevant justifications
Stage 1	*Activity* Things that are active in any way (including movement) are alive
Stage 2	*Movement* Only things that move are alive
Stage 3	*Autonomous Movement* Things that move by themselves are alive
Stage 4	*Adult Concept* Only animals (or animals and plants) are alive

Piaget's early work was developed into a standardised interview procedure by Russell and Denis (1939) and the area has been the focus of many replication studies, the most

notable being that of Laurendeau & Pinard (1962). They tested 500 subjects between the ages of 4 and 12 and agreed with Piaget's conclusions apart from finding no evidence for a distinction between stages 1 & 2.

Further studies in the field have generally given results which support this interpretation (see Jahoda (1958), Looft and Bartz (1969) for reviews). That this interpretation is open to question has come from studies which have adopted a different methodology and attempted to focus on what children conceive the 'attributes of life' to be and how these develop. Such studies have opened a rich field for exploration of which the research here merely represents a continuation.

One of the earliest studies was undertaken by Looft (1974) who asked children "Does a frog breathe or need air?" "Does a chair need food or nutrition?" "Do automobiles reproduce or make more things just like themselves?" Looft also asked his subjects if the items used in the question were 'alive'. His important discovery was that although some students could correctly assign all of these objects to 'living' or 'not living', there was a lack of a full understanding of the attributes of life. Such work does not contradict the earlier studies and could be considered to supportive in that it shows that children are clearly not using the 'attributes of life' as the prime criterion for deciding the issue of whether an object is alive/not alive. However, it does reveal a disparity between a child's and adult's concept of an animate object, and that children lack domain-specific biological knowledge.

A further study, by Smeets, investigated whether children were capable of correctly attributing six life traits (die, grow, feel, hear, know, talk) to animate and inanimate objects. He found that these processes of life were often incorrectly attributed to inanimate objects.

Working in a different tradition, in which the conceptual development of children is studied from a psychological perspective, Carey (1985) chose to examine the development of children's understanding of alive/not alive and their accompanying biological knowledge between the ages of 4 and 12. Carey argues that the use of the framework 'alive', 'not alive' is simplistic forcing a categorisation which is not meaningful to the child. The inevitable failure to categorise is due to a lack of biological knowledge. She argued that such knowledge gradually improves between these ages resulting in a domain-specific restructuring, and it is this restructuring which results in the improvement of children's abilities to respond to the question of whether an object is alive/not alive. In a similar study to Smeets, she specifically chose unfamiliar animals. e.g aardvarks, dodos, garlic presses, clouds. She tested 9 subjects each from

ages 4,5,7 and adults and found that at no age were animal properties attributed to inanimate objects. Hence her results contradict the findings of Smeets.

Her most striking finding was the under-attribution of animal properties to animals other than people, in particular breathing and eating, which led to a failure to attribute these properties to all animals. Carey postulated three mechanisms for children's reasoning:- deductive inference based on some narrow concept of an animal; the application of a definition which would involve checking for the component parts associated with the process i.e mouth for eating, nose for breathing, and inductive projection based on comparison with humans. She concluded that, although all three types of reasoning contribute, the primary basis of their reasoning was the third mode- inductive projection. Her argument was that the evidence showed that there was a major restructuring of domain specific knowledge by the child reached the age of 10. This enabled the child to conceptualise the human body in terms of an integrated functioning of internal organs and perceive other living things in similar terms.

Lucas et al (1979) identify a number of methodological errors in these studies. They argue that the increasing facility with age may just reflect an increasing familiarity with the everyday objects used. Secondly there are conceptual difficulties with the 'attributes of life' used which are strongly biased towards humans and ignore plants. The consequence is a tendency to over-rely on an anthropomorphic framework which would result in category errors. Finally, like Carey they argue that the method of interviews used force criteria on the children which are not necessarily those which the child would spontaneously use.

Lucas et al's response was to use a technique which avoided some of these mistakes by showing children a black and white photograph of an 'object' which had been found on a beach. Children were then asked 'How could you find out if the object was alive? Write down as many ways as you can think of' The study was done with 944 students from Grade 2 (age 6) to Grade 10 (Age 14). Their research identified five broad categories which students spontaneously used for establishing whether the object was living - expert advice, external structure, internal structure, physiological functions and behaviour. No children used one category only and although the work confirmed the use of the criterion of spontaneous movement found in earlier studies, the most revealing aspect was the lack of predominance of this criterion. At all grade levels, more than 40% of pupils suggested a criterion based on external structure. In addition, an increasing proportion at higher grade levels used a criterion based on internal structure and/or physiological functions. The authors argue that previous work has ignored the 'richness of children's responses to a highly complex question' and that the

context of the data gathering can have an important effect on the nature of the response obtained.

In summary, early studies would seem to have attempted to reduce the child's view of the world to a description which later work has shown to be simplistic. The evidence is that there are several facets to the criteria deployed by children, not least of which is their biological knowledge.

Human internal organs

The most well-known study is that of Gellert (1962) in which she asked 96 children, age 4 to 16, to list what they have inside them. In an extensive study, she investigated where children thought the major organs are found inside the body, what the role of each is and what would happen if if one lacked such an organ. The overriding conclusion of her study was the development in knowledge between infants/lower juniors (5-8) and upper juniors (9+). The former group came up with approximately 3 things inside people whilst the latter were able to list 8. The younger group predominantly think in terms of what they have seen put in, and coming out i.e. food and blood whilst the older group add a wide variety of internal organs. Another important finding was that when asked, "What do you think is the most important part of the body?", the younger group responded with external parts e.g. hair, nose, feet, eyes whilst by age 10, children respond with internal bodily organs.

Gellert also showed that young children's understanding of defecation is one which sees the process of social necessity, necessary so that we will not get too full or burst. Only when children reached the age of 13/14 did they see the process as the elimination of waste or noxious substances by the body.

Further studies undertaken since then have confirmed this analysis (Wellman & Johnson (1982), Contento (1981). In particular what they show is a lack of understanding by very young children, age 5-6, of what happens to food. Most know that it goes to the stomach but imagine that it stays there unchanged or is broken into smaller bits. Contento's work showed a strong relationship between Piagetian stages and such understanding. All the children at a pre-operational level considered food to remain unchanged when eaten, whereas children at a concrete level recognised that food changes but the majority did not know how.

Gellert's study clearly showed that the heart was the first internal organ that children were aware of, partly because it has a clearly detectable presence in that it 'beats'. By the age of 10 or 11 well over half this age group realised that the heart is a pump and circulates blood around the body. Again very few of the younger children under 7 in Gellert's study had heard of lungs or could begin to explain their function. Only by the age of 10 did they show an understanding of the role of the lungs in exchanging gases and the circulation of air/oxygen to the rest of the body.

Crider (1981) has attempted to place some kind of theoretical framework on these descriptive lists which one author has described as the 'conceptual ecology' of the classroom (Driver, 1989). She argues that when the young child comes to know an internal organ, each is assigned a single function e.g the lungs are for breathing. From such ideas the child moves to perceiving an inter-relatedness of the organs which are perceived as containers with channels connecting them. The final stage involves the development of a particulate understanding which sees matter such as food as being reducible to a microscopic level at which it can be transported around the body. Crider argues that this is achieved by the age of 11 for many pupils but in view of the research on children's understanding of the particulate nature of matter (Brook, Briggs and Driver, 1984) which shows that the majority of the children are incapable of understanding such an idea, this argument must be open to question.

Johnson & Wellman (1982) also conducted a study of children's understanding of the nature and location of the brain. Their study looked at what children perceived to be its function and what activities require a brain. In summary, awareness of the brain as an internal organ begins at age 4 where its function is recognised for thinking. What was not recognised was that involuntary motor acts such as walking, coughing, sleeping required activity by the brain. Children of age 5 saw the brain as being autonomous from a whole range of body parts e.g eye, mouth, ear, but by age 10 nearly 80% saw the brain as helping the body parts. Essentially young children see the brain as a mental organ which has no specific physiological function. Children's understanding of nerves consequently is very limited other than that they are an integral part of the body with no specific function. Only after age 9 were some children able to assign them a specific function related to conducting messages, controlling activity or sensing pain.

One notable point that emerges from Johnson & Wellman's study is the effect of instruction about the brain to a group of 11 year old children. Their research took place before this group studied a unit on the brain. They investigated their understanding after the unit had been taught and found that the teaching sequence had had absolutely no effect on their learning.

Other Processes

The other two processes extensively studied are birth and death. The two most significant studies of birth are by Bernstein and Cowan (1975) and Goldman and Goldman (1982). Bernstein and Cowan classified children's progression into 6 levels of understanding from that of the youngest children, level 1, whose explanation for babies was that babies had always existed, to children at level 6, who explained conception in terms of the fertilisation of the egg and the combination of genetic material. Level 4, at which the child recognises that the 'seed' from the father is united with the egg from the mother, is the one that is independent of animism and artificialism. Goldman and Goldman's cross-cultural study of North American, English, Australian and Swedish children revealed that English children were significantly weaker at attaining a level 4 understanding by age 11. It is of course interesting to note that Swedish children were the best and found to be four years ahead of their peers in other countries.

North America	England	Australia	Sweden
80	63	87	97

Table 1.2: Percentage of children attaining a level 4 understanding of the process of reproduction by age 11. (Goldman & Goldman, 1982)

Carey argues that the data show clearly that young children see the production of babies only in terms of the intentionality of their parents and have no knowledge of the function of the body in the process. By age 10 they make a clear distinction between the role of the body and the role of the parents.

The problems posed by death in families and the effect on children have led to some very extensive research by psychologists. Again Carey (1985) summarises much of the wide-ranging literature. Psychologists essentially identify three phases. In the first stage (age 5 and under), children have no concept of the cessation of biological function and death is seen in terms of a separation which is neither final or inevitable. In the second stage, the child now recognises the finality of death but sees death as being caused by an external agent e.g. guns, knives, 'Father Death', poisons. In the final stage, which occurs for most children around age 9 or 10, death is seen as an inevitable biological process . Whilst death cannot be separated from the human and emotional perspective, Carey argues that it is the irreversibility of the process which leads to the emotional impact and that children's level of understanding of death by age 9/10 shows

that they have developed the biological knowledge to appreciate the significance of death from an adult perspective as such an irreversible process.

Conclusions

Clearly the existing body of research in this domain is extensive but, as noted, not well known to science educators and much of it pre-dates the work of the 'alternative conceptions' movement. Many of the studies have attempted to place their findings within the context of a Piagetian developmental perspective i.e. pre-operational, concrete and formal. Carey (1985) argues that there is little to be gained by such a process because such a structure is a description of children's logic which fails to accurately interpret the nature of children's thinking and secondly it 'commits one to the claim that there is something which limits the understanding of digestion or the origin of babies.' Instead she develops a case that the evidence suggests a restructuring of domain-specific knowledge which enables a shift in conceptualisation of the processes of life.

Whilst it it is not the intention to enter into this debate here, the research reported in this document is an attempt to explore the demands of the English & Welsh national curriculum and add to this body of knowledge in a form which is hopefully more accessible to the large number of primary teachers who will be confronting the teaching of these scientific concepts. The research reported adopted a constructivist perspective. Hence it used many of the techniques used in previous research and adapted others to elicit children's ideas and so yield a broad picture of children's intuitive understandings of these biological concepts. This elicitation was followed by an intervention process which provided an opportunity to generate conceptual conflict with children's existing ideas. Finally, a second elicitation was undertaken to examine what changes had occurred in children's understanding of the processes of life.

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2:Methodology

Sample

a. Schools

Six schools from the London area were chosen for this research from three local authorities (Inner London, Newham and Barnet). One teacher from each school participated in the project. Each school was allocated to one member of the research team[1] who worked closely with the teacher throughout the research phase.

The majority of the schools were selected by the research officer who had already been working in the locality providing support to primary schools in the development of primary science work in her previous post.

b. Teachers

Most of the teachers invited to participate in the project were those known to the researchers from the previous work. This was advantageous in providing a pre-existing relationship and link between researcher and teachers which could be developed. Teachers were able to use this relationship to express their uncertainties about the work and ask for clarification. Unfortunately, the local authority was unable to release any of the teachers due to the difficulties experienced during this phase in obtaining any supply cover in the London area. This meant that all meetings had to take place during the teachers' own time after school, and this had the effect of curtailing the extent of the teacher contribution to the research on this topic.

The teacher's normal style of working varied, between individuals who made sole use of classrooms organised around groups using a topic approach and an 'integrated' day, and those who preferred to keep the class working together on a common theme. Teachers were encouraged to integrate the activities into their existing mode of working as there was a limitation to the amount of change of teaching style that could be expected of them.

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1 The research reported here was undertaken by the authors, Pam Wadsworth (full-time) and Jonathan Osborne (part-time) during 1989.

Many of the difficulties experienced and expressed by teachers with a topic are associated with a lack of confidence in their own understanding of the background science. In particular, this results in an concern about the level of understanding that it would be reasonable to expect a child to achieve. Whilst teachers understood that the research project was attempting to provide some insight into the latter question, it was clear that the degree of uncertainty was a source of anxiety for teachers.

Names of the participating schools are provided in Appendix 1.

c. Children

Despite the limitation to a particular locale, the schools used reflect the wide variation seen in the London area between schools based in deprived areas and those with a substantial middle-class catchment area. Hence the children used in the sample represent children with a wide range of ability and ethnic background. All children in the classes of the participating teachers were used for the pre- and post-intervention elicitation activities. Inevitably there were some children who were not present for both phases of the activity and the data collected from these children have not been used.

For the purpose of analysis, the children have been grouped by age into infants (5-7), lower juniors (8-9) and upper juniors (10-11). In case of any doubt surrounding the particular grouping of a child, the year of schooling was used to decide the appropriate cohort for a child. Data was generally obtained by individual interview though some of the data from lower and upper junior children was obtained through written responses.

d. Liaison

During the data-collection phase of the project, the research was conducted by two people working part-time with the schools and the relevant teachers. Each member of the team was allocated a particular school. The researchers would meet on a regular basis to plan and co-ordinate the research, exchange information and develop materials.

The Research Programme

Classroom work on the topic of 'processes of life' took place over a relatively long period in the school year which can be summarised as follows.

Pilot Exploration	Sept 89
Pre-Intervention Data Collection	Oct 89
Intervention	Nov 89
Post-Intervention Data Collection	Dec-Jan 90

The pilot exploration phase was based on interviews with a small number of children (20). These interviews used a wide range of questions to explore the nature of children's understanding of the processes of life and associated concepts. In addition, drawings and answers to written questions were employed to examine how valuable and reliable such sources were for eliciting children's meanings and understanding. The exploratory nature of this phase was required to supplement what little literature there was available on the nature of young (5-11) children's understanding of this topic and to explore how suitable the questions were for eliciting children's understanding of the concepts. Some of the questions devised for probing children's ideas were modifications of methods that had been used previously by other researchers. At the end of this phase, the data were examined to determine which were the most valuable lines of approach for eliciting children's ideas about this topic. The other valuable feature of this phase was that it provided time for developing a relationship with the teacher and the children so that they could become accustomed to the mode of working required.

Essentially, the classroom elicitation techniques were refined by the pilot process and the experience provided an opportunity for teachers and researchers to develop familiarity with the material and with each other. Data on children's ideas were then collected from children in classrooms using the selected activities. These questions and activities are shown in Appendix 2. The main methods of elicitation relied on a mixture of interviews, written answers and children's drawings. All the data from infant children were collected by interview and drawings as these children found it very difficult to provide written answers to questions.

The intervention activities were designed in consultation with the teachers and from an examination of the data collected previously. The data suggested several areas of interest for possible conceptual development and a framework of activities was designed which could be used by children to test their own ideas and explore their thinking in this domain. This was not presented as a prescriptive framework, but simply as a range of exercises and activities which could be used by children. Teachers

and children were free to try other lines of investigation they wished to pursue. After the completion of the intervention phase, another set of elicitations was used with the children based on the same questions to those used in the elicitation prior to the intervention.

Defining 'The Processes of Life'

Any attempt to develop a child's concepts needs to be based on a definition of what a preferred understanding would be. In the earlier research, a list of concepts was compiled by the team to provide a map of ideas considered an *a priori* necessity for the development of the scientist's world view. However, in this instance, the National Curriculum Order had been published and the framework of the research changed. The Order defined, in a set of attainment targets, learning objectives for children to achieve through the age range in a progressive, developmental fashion. Whilst the Order and their articulation of the targets within it are open to debate, they represented at the time, the standard objectives that many teachers would be using for their teaching. Hence the decision was made to adopt these statements as guidelines of what it might be reasonable for a child to be expected to know. This does not imply that the team necessarily accepted these statements as reasonable expectations but they did constitute a set of aims for many teachers and their children. Therefore the research set out to ask whether they were reasonable expectations.

The National Curriculum then was defined in terms of a set of attainment targets and programmes of study. The attainment targets (Fig 2.1) represented assessment objectives on a 10 point scale. An able infant is expected to achieve level 3 by age 7 whilst an average child would achieve level 2. A able junior should achieve level 5 by the age 11 whilst an average child level 4. The programmes of study (Fig 2.2) merely defined the set of experiences that should enable the attainment targets to be achieved.

The purpose of this list is to provide a framework or point of reference for the research where these statements represent a collection of ideas that children *may* develop by age 11. The principal difference between this research and earlier work on light and electricity, is that this is an externally defined list. One of the aims of the research is to examine to what extent, as a consequence of the experiences that were provided by this research programme, such ideas develop in children and at what ages.

Level	Attainment Target
1	Pupils should: • be able to name or label the external parts of the human body/plants, for example, *arm, leg/flower, stem*
2	• know that living things reproduce their own kind • know that personal hygiene, food, exercise, rest and safety, and the proper use of safe medicines are important. • be able to give a simple account of the pattern of their own day.
3	• know that the basic life processes: feeding, breathing, movement, behaviour, are common to human beings and the other living things they have studied. • be able to describe the main stages of the human life cycle.
4	• be able to name the major organs and organ systems in flowering plants and mammals. • know about the factors which contribute to good health and body maintenance, including the defence systems of the body, balanced diet, oral hygiene and avoidance of harmful substances such as tobacco, alcohol and other drugs. • understand the process of reproduction in mammals • be able to describe the main stages of flowering plant reproduction.
5	• know that living things are made up from different kinds of cells which carry out different jobs. • understand malnutrition and the relationships between diet, exercise, health, fitness and circulatory disorders. • know that in digestion food is made soluble so that it can enter the blood. • understand the way in which microbes and lifestyle affect health • be able to describe the functions of the major organ systems.

Fig 2.1: Attainment Target 1-5 of the English & Welsh National Curriculum (DES, 1989)[1]

The programmes of study were as follows.

1 Since the publication of this Order, a revised publication has been produced by the Department for Education in 1991. The work reported here was based on the original Order. The summary and conclusions of this work are based on the new order (DES, 1991)

Key Stage 1[1]	Children should be finding out about themselves, developing their ideas about how they grow, feed, move and use their senses and about the stages of human development. Using suitable books, pictures and charts, they should be introduced to ideas about how they keep healthy through exercise and personal safety. Children should be introduce to the role of drugs as medicines.
Key Stage 2	Children should investigate some aspects of feeding,support, movement and behaviour in relation to themselves and other animals. They should be introduced to the functions of the major organs systems and to basic ideas about the processes of breathing, circulation, growth and reproduction. They should explore ways in which good health can be promoted in relation to their own daily routine, using a range of secondary sources chosen by the teacher. They should be introduced to the fact that while all medicines are drugs, not all drugs are medicines; and they should begin to be aware of the catastrophic effect on health resulting from an abuse of drugs. They should investigate the effects of physical factors on the rate of plant growth, for example, *light intensity, temperature and the amount of fertiliser.*[2]

Fig 2.2: Programmes of Study for the English & Welsh National Curriculum in Science at Key Stage 1 & 2.

These ideas also provide a framework for examining children's ideas allowing three questions to be addressed.

a) How different were the conceptions held by many children from such a framework and how disparate were their ideas?

b) What development was observable in children's ideas across the age range?

c) What potential did the planned intervention have for the development of children's ideas towards the scientist's view?

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1 The term key stage refers to the period of education. Key stage 1 is from age 5-7 (two years) and Key stage 2 is from age 7-11 (four years).

2 Italicised parts of these documents are provided only as exemplars.

This list was also used as a reference point for the development of the intervention. Given such a framework of objectives, the intervention task was to develop activities which would assist the formation of a fuller understanding of this domain in children. The activities were devised using simple materials familiar to children. Their primary role was to provide a focus for discussion of children's thinking and to challenge their existing ideas. Other considerations in designing activities were that the materials should be simple, easy to manipulate and safe to handle.