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ABSTRACT

This paper describes a study of young children's understanding of what is on the inside of animals--skeletons and other organ systems. The study uses 2-D drawings based on the idea that a drawing is the representational model and is the outward expression of the mental model. The 617 drawings made by participants in the study were awarded one of seven levels according to biological quality with Level 1 meaning no representation of internal structure and Level 7 meaning comprehensive representation with four or more organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular, and circulatory systems. It is concluded that learning about animals and their internal organization begins at home and reflects public understanding of this area, and that biology educators need to find out what this public understanding is and develop that knowledge into biological knowledge as part of students' education. (Contains 12 references.) (MM)

What's Inside Bodies? Learning about Skeletons and other Organ Systems of Vertebrate Animals

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The recent literature on the ways in which science curricula can prepare future citizens is extensive both with regard to science in general (Nuffield Foundation 1998; Reiss, 2000) and for biology in particular (e.g. Thomas, 2000). Our interest is based on the belief that a certain degree of knowledge about internal human anatomy is necessary for people to understand both how their own body works and, thus, some of the ways in which it can be kept healthy. Furthermore, such knowledge helps when communicating with doctors, nurses, midwives and other medical personnel. With the increasing debates about our use of animals and even whether non-human animals have rights, we further believe that citizens should have an understanding of the anatomy and physiology of other organisms, vertebrate and invertebrate.

Surprisingly few studies have looked at people's understanding of what is inside animals - skeletons and other organ systems. Perhaps surprisingly, given the central significance of the endoskeleton for the chordates and the inclusion of the skeleton in many science curricula, comparatively few studies have investigated pupils' knowledge about animal skeletons or the structure of animal organ systems (Driver *et al.*, 1994). Most in depth work has been done only on humans (Gellert, 1962; Williams, Wetton & Moon, 1989; Osborne, Wadsworth & Black, 1992; Cox, 1997; Teixeira, 1998), or on human skeletons only (Guichard 1995).

Much of the research about skeletons or organs has been in the form of interviews or has used drawings in some way. Drawings executed by primary children have been used to explore the understanding of biological concepts held by the pupils (e.g. Braund, 1996) but the creation of images and their relationship to the actual size of the specimen has not been explored. We decided to use drawings because the drawings of the pupil are their expressed model for their educational task which was to create a 2-D representation in the form of a drawing. The drawing is the representational model and is the outward expression of the mental model. In other words, what they draw is the expressed model for what they think is inside the animal.

We decided on a cross-sectional approach in which students of different ages would simply be presented with different animal specimens and asked to draw what they thought was inside the animals when they were alive.

Methods

This study looks at students' understandings of the structure of animal (including human) skeletons and the internal organs found in them. A cross-sectional approach was used involving a total of 175 students in England from six different age groups (ranging from 4 year-olds to 20 year-olds). A total of 572 drawings were made.

On separate occasions, the students were presented with a single dead specimen of a brown rat (*Rattus norvegicus*) (stuffed), a starling (*Sturnus vulgaris*) (stuffed) and a herring (*Clupea harengus*) (fresh). On each occasion the students were then asked to draw what they thought was inside the specimen when it was alive. On the final occasion, the students were asked to draw what they thought was inside themselves. After one or other of us had collected them, we jointly and repeatedly sorted through them, attempting to arrange them in a ranked order which we felt reflected different levels of biological understanding. Our ranking was informed both by previous work in the field (especially Osborne, Wadsworth & Black, 1992; Guichard, 1995; and Cox, 1997) and by our own knowledge of anatomy. No notice was taken of the student's ages in determining this ranking.

Results

The students made a total of 617 drawings. After we had collected all the drawings, we jointly and repeatedly sorted through them, attempting to arrange them in a ranked order which we felt reflected different levels of biological understanding. We were also extremely keen to provide a scoring system which gave as little credit as possible to the 'artistic' quality of the drawing and was as unambiguous as possible to score. Some of the older students professed an inability to draw well and we assured them that this did not matter. No notice was taken of the student's ages in determining the scoring system.

Eventually, we agreed on the following order for the biological quality of each drawing:

Level 1 No representation of internal structure

Level 2 One or more internal organs (e.g. bones and blood) placed at random

Level 3 One internal organ (e.g. brain or heart) in appropriate position

Level 4 Two or more internal organs (e.g. stomach and a bone 'unit' such as the ribs) in appropriate positions but no extensive relationships indicated between them

Level 5 One organ system indicated (e.g. gut connecting head to anus)

Level 6 Two or three major organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular and circulatory

Level 7 Comprehensive representation with four or more organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular and circulatory.

This scoring system requires a definition of organ systems. We used the following definitions for the eight organ systems:

Skeletal system	Skull, spine, ribs and limbs
Gaseous exchange system	Two lungs, two bronchi, windpipe which joins to mouth and/or nose
Nervous system	Brain, spinal cord, some peripheral nerve (e.g. optic nerve)
Digestive system	Through tube from mouth to anus and indication of convolutions and/or compartmentalisation
Endocrine system	Two endocrine organs (e.g. thyroid, adrenals, pituitary) other than pancreas [scored within digestive system] or gonads [scored within urinogenital system]
Urinogenital system	Two kidneys, two ureters, bladder and urethra *or* two ovaries, two fallopian tubes and uterus *or* two testes, two epididymes and penis
Muscular system	Two muscle groups (e.g. lower arm and thigh) with attached points of origin
Circulatory system	Heart, arteries and veins into and/or leaving heart and, at least to some extent, all round the body.

As is apparent, we therefore used the same, human definitions for organ systems when scoring each drawing, whether it was of a human, a rat, a starling or a herring. Our reasoning was that had we chosen to score each drawing on species-specific criteria (for example, air sacs in the starling), we would simply have shown that students know less about what is inside non-humans that they know about what is inside humans. Given the almost complete absence in current English biology curricula of any non-human anatomy, this finding is an obvious one. Instead, what we are looking at in part is the extent to which students presented their knowledge of internal human anatomy within their drawings of a rat, a starling or a herring. At the same time, we also made a complete list of every occasion on which a drawing showed some non-human internal feature.

The two of us then separately and independently scored all the drawings. Having agreed on the level (i.e. 1, 2, 3, 4, 5, 6 or 7), we then, for each of the eight organ systems, decided whether or not the drawing met the criterion for that organ system. If it did, we recorded the appropriate capital letter (S for skeletal, G for gaseous exchange, etc.). If it did not, we then decided whether or not at least one organ was present on the drawing for that organ system. If one was, we recorded the appropriate lower case letter (s for skeletal, g for gaseous exchange, etc.). Each drawing was therefore effectively scored a total of 17 times, once for the overall level, once for the presence or absence of each organ system and once for the presence or absence of at least one organ in each organ system. We agreed on in excess of 95% of scorings. In those cases where our views differed, we discussed each such case until we agreed.

As an illustration of how we analysed the drawings, Figure 1 shows the drawing done by a Year 9 girl (aged 14 years) of what she thought was inside herself. The drawing is scored 6GUsgndumc. In other words, the drawing shows two satisfactory organ systems - namely, the gaseous exchange and urinogenital systems - and seven of the eight possible organ systems - skeletal, gaseous exchange, nervous, digestive, urinogenital, muscular and circulatory - omitting only the endocrine system.

Data were entered into Minitab and Excel for analysis. All statistical tests are 2-tailed.

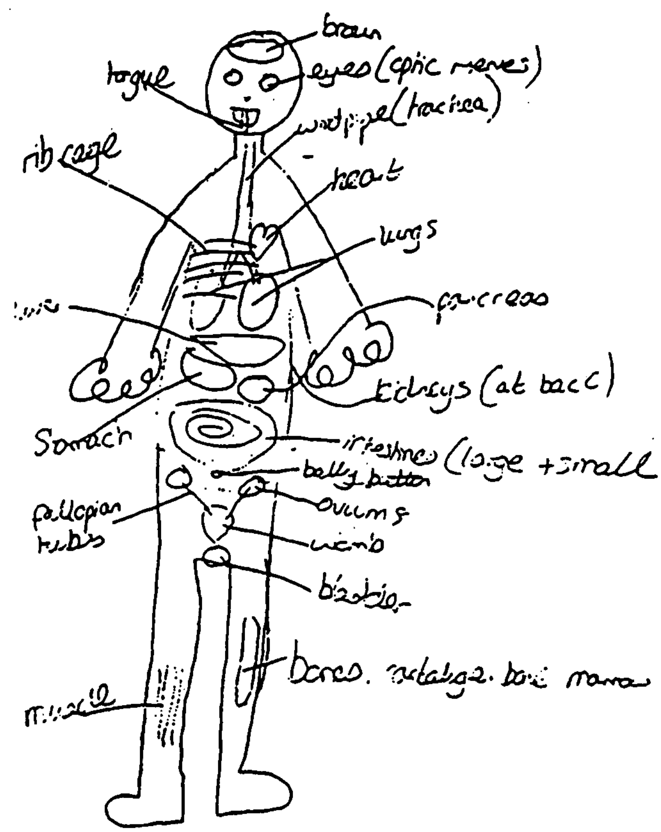

Figure 1

Students' Understandings of Organ Systems

Lumping together all the data, and thus ignoring differences between the drawings resulting from student age, gender, degree of biology specialism or the species being drawn, Figure 2 shows for each organ system the percentage of students whose drawing displayed an organ system as defined above in the Analysis section above. Two main findings are clear. First of all, for each of the eight organ systems, only a small minority of drawings show the organ system drawn sufficiently completely to be classified by us as an organ system. By way of illustration, in Figure 1 - one of the better drawings done by the 14 year-olds - just two of the eight organ systems are shown sufficiently to be classified as organ systems.

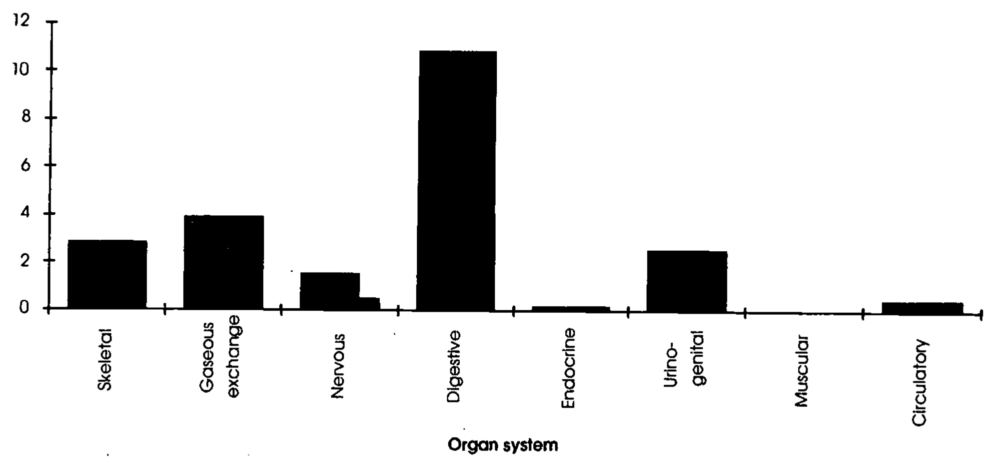

Figure 2 The percentage of pupils whose drawing displayed an organ system as defined in the paper.

Secondly, there are statistically significant differences between the eight organ systems in terms of how well they are represented ($c^2 = 192$; 7 df; $p << 0.001$). The best drawn organ systems is the digestive system represented in 11% of the drawings. At the other extreme, none of the drawings represented the muscular system, only 0.2% the endocrine system and only 0.5% the circulatory system as defined by us.

Students' Understandings of Organs

Again, lumping together all the data, and thus ignoring differences between the drawings resulting from student age, gender, degree of biology specialism or the species being drawn, Figure 3 shows for each organ system the percentage of students whose drawing represented an organ (rather than the entire organ system) as defined above in the Analysis section.

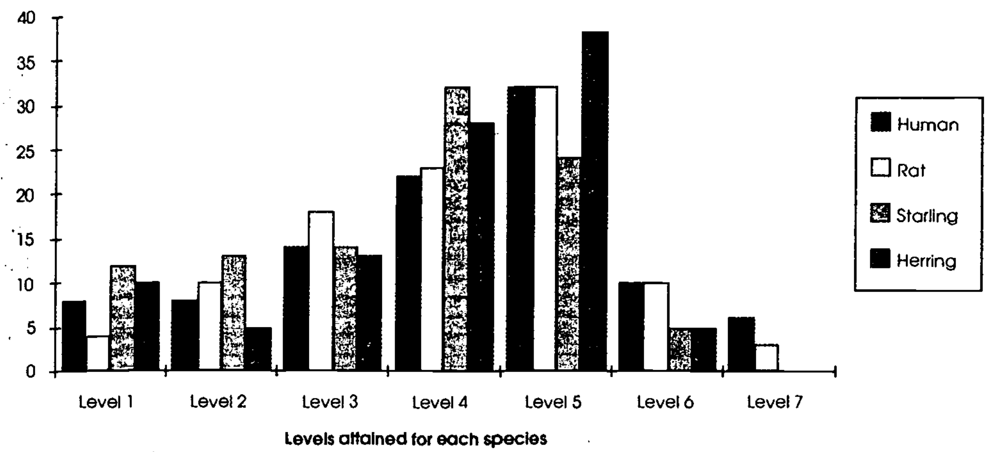

Figure 3 The percentage of pupils whose drawing defined an organ rather than the whole organ system for each type of specimen.

Not surprisingly, students do much better at this than at representing whole organ systems. For example, 51% of the drawings showed some portion of the skeletal system and 51% showed an organ (nearly always the heart) in the circulatory system. At the other extreme, only 0.5% of the drawings showed a part of the endocrine system. However, we do acknowledge that this last result is undoubtedly largely caused by our very narrow definition of what counted as being part of the endocrine system. In particular, we excluded the pancreas (which we classified as belonging to the digestive system) and the ovaries and testes (classified as belonging to the urinogenital system).

As was the case with whole organ systems, there are highly statistically significant differences between the likelihood of students drawing organs from the different organ systems ($c^2 = 505$; 7 df; $p \ll 0.001$). There are also certain clear differences between the rankings in Figures 2 and 3, notably with respect to the circulatory system which is poorly represented as a whole system (Figure 2), yet components of which are very frequently drawn (Figure 3). Indeed, there is no significant correlation between the rankings of how well represented whole organ systems and partial organ systems are ($r_s = 0.38$; $0.2 < p < 0.5$).

The Levels at which the Drawings are Drawn and Species-specific Differences

The data below show the percentage of drawings at each level, differentiated by the species being drawn:

Level	Human (n = 158)	Rat (n = 158)	Starling (n = 165)	Herring (n = 136)
1	1%	1%	4%	0%
2	9%	9%	12%	16%

3	5%	14%	10%	8%
4	50%	53%	51%	62%
5	16%	14%	18%	12%
6	13%	8%	5%	1%
7	6%	1%	0%	0%

Two main things are apparent from the above data. First, the modal level for each of the four species drawn is level 4. Secondly, any differences between species are probably small, with a suggestion that, as might be expected, the highest levels (levels 6 and 7) are more likely when pupils are drawings themselves. However, this conclusion is rendered problematic by the fact that different students were present on different occasions.

For this reason, Figure 4 shows the data just for the 78 students who were present on every occasion. (The proportion of drawings at levels 5, 6 and 7 is larger than in the overall sample as the biology undergraduates were particularly likely to be present on all four occasions and, obviously, produced many of the best drawings.) There is still a suggestion that drawings of humans (and perhaps rats) are more likely to be awarded levels 6 and 7 than the other taxa. If a c^2 test is applied to the raw data, the distribution of 6s and 7s across the four taxa (human = 16%; rat = 13%, starling = 5%; herring = 5%) is just significantly non-random ($c^2 = 7.84$; 3 df; $0.025 < p < 0.05$).

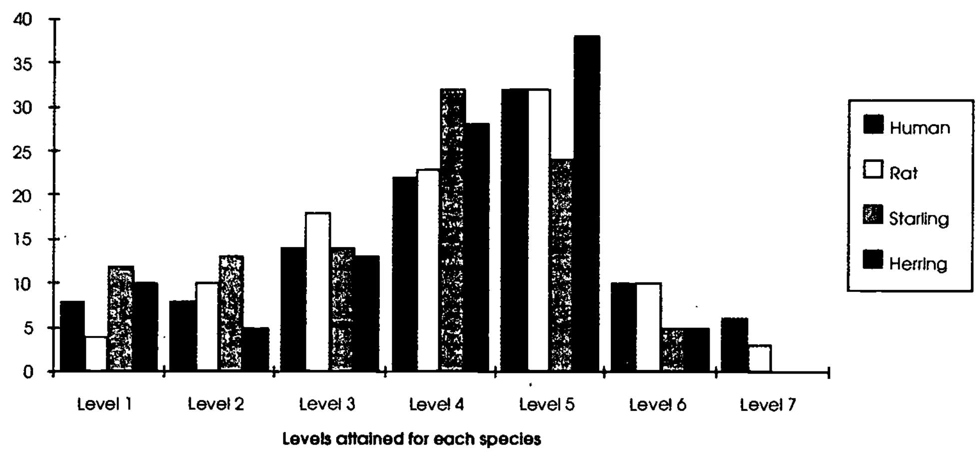

Figure 4 The data for the 78 pupils who were present on each occasion.

Closer examination of the drawings reveals much of interest with respect to what the students drew about the non-human animal. For instance, if we concentrate on just the drawings done by the Yr. 6 pupils - that is, 10 and 11 year-olds in their last year of primary schooling, Figure 5 shows a boy's drawing of the rat. The boy has successfully drawn bones in the rat's tail in addition to showing a range of organs found in the same places in humans and rats. Other Yr. 6 pupils had rat drawings with bones, nerves or muscles in the tail.

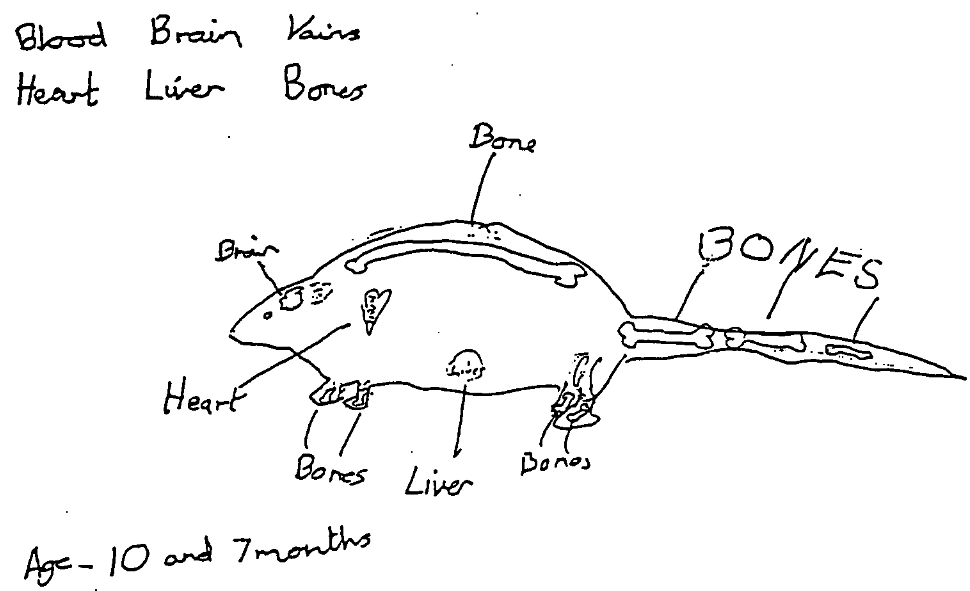

Figure 5

Figure 6 shows a drawing of the starling by a Yr. 6 girl. Noteworthy non-human features include the labelling of bones in the tail and the presence of giblets - presumably learned from domestic birds such as chicken. The genital area is labelled 'Rude bits'. (Elsewhere we have shown from an analysis of the drawings done by the Yr. 6 children of themselves, that 44% (eight in all) of the boys drew and/or labelled reproductive organs, in every case male reproductive organs. About the same proportion or possibly more, 64% (nine in all), of the Yr. 6 girls drew and/or labelled reproductive organs but strikingly most of these (seven out of nine) drew or labelled *male* reproductive organs (Reiss & Tunnicliffe, submitted).) Other Yr. 6 starling drawings portrayed tail feather muscles and showed a worm that had been eaten.

Finally, Figure 7 shows a Yr. 6 girl's drawing of the herring. Her drawing shows that she knows that there are muscles in the tail ('tail mucciel') and that the herring has 'Gills'. However, she also includes 'Lungs'. Many other Yr. 6 fish drawings showed gills. Three pupils drew and labelled 'egg dispenser' and two pupils clearly thought little of a fish's mental abilities. One boy drew and labelled 'small brain' and one girl wrote next to the brain the brain 'memory of two seconds'.

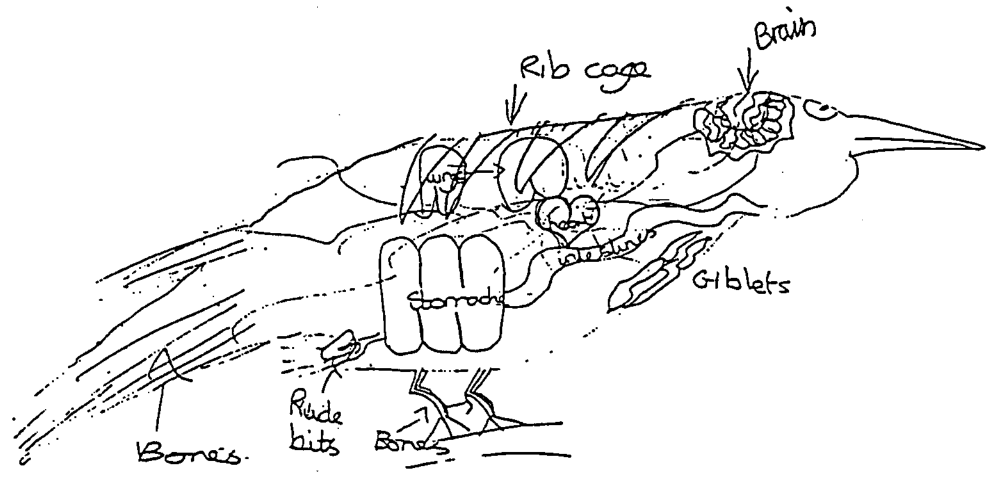

Figure 6

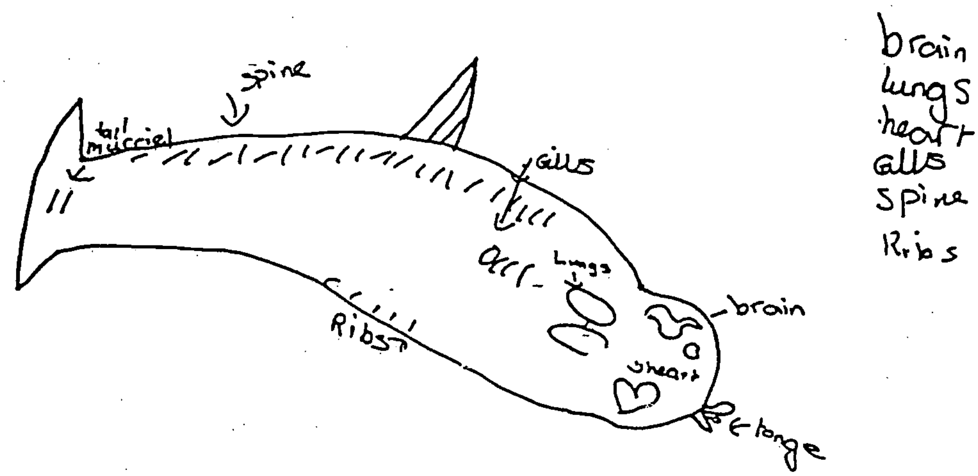

Figure 7

The analysis suggests that, as would be expected, older students have a better knowledge of the animals' internal anatomies. However, even among the undergraduates (who were biology specialists) only a minority drew what we have decided is level 7. Gender differences do not appear important.

The students' knowledge of human internal structure is significantly better than their knowledge of rat, bird and fish internal structure. In England, where this study was carried out, such taxon-specific knowledge is probably largely a reflection of the anthropomorphic bias in today's curriculum: almost no non-human animal structure and function, sadly, is currently taught to 5 to 16 year-olds.

Discussion

We acknowledge that a more intensive methodology, for example one that combined drawings with subsequent interviews, would allow students more fully to demonstrate their understanding. For example, in some cases it was difficult for us to identify certain of the internal organs drawn. Interviewing would have allowed us to resolve at least some such uncertainties. At the same time, we were extremely keen not to cue students into those aspects of their drawings that were of particular interest to us. As drawings were done on a number of separate occasions, any interviews about the drawings would have had to have been undertaken after the last of the drawings had been obtained from each child. This would have been difficult given the number of students not present on every occasion.

We believe that the children learn about the organs as units and gradually piece them together so that eventually they form a mental model of a system, be it the skeleton , the digestive system or gaseous exchange. The fact that children aged five years who had just entered school had some understanding of what is inside animals reflects the public awareness and usage of terms related to the internal organisation of bodies, particularly blood, brains and bones and the heart. A particular concern of ours is the increasing loss of knowledge among UK pupils of organisms other than humans. In a related study (Tunnicliffe and Reiss, 1999b) we have shown that schools are significantly less likely to be cited by English pupils as sources of biological knowledge about the identity and taxonomic position of a range of animals than are other sources such as home, television and direct observation.

We found it noteworthy how few of the drawings reached level 6. And yet all that was required for level 6 was to produce a drawing with two of the major organ systems indicated (e.g. Figure 1). We strongly suspect that far too many students, however well they do on formal biology examinations, have only an atomistic knowledge of internal anatomy. Regrettably, English 'developments' in the biology curriculum and its assessment over the last ten years across the 5 to 16 age range have almost certainly reduced the chances of many students achieving a holistic understanding of much of what they study. Our belief is that too few of the students in this study, whatever their age, had any overall genuine understanding of internal anatomy, even their own.

Our work has clear implications both for ways in which schools might better encourage pupils to know about and understand the internal structures both of themselves and of other organisms, and for ways in which extra-school sources of scientific information, such as zoos, science centres and museums, might help. We are very interested to see whether studies in other countries would produce similar or different results and have initiated an international project collecting data about the knowledge of 7 and 15 years olds of the internal; arrangement of the human body.

Learning about animals and their internal organisation begins at home and reflects the public understanding of this area (Tunnicliffe & Reiss, 1999). We as biology educators need to find out what is this public understanding and to develop from that knowledge into biological knowledge as part of our pupils' education.

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