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3 **What do children aged four to seven know about the digestive system and the**
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5 **respiratory system of the human being and of other animals?**
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10 **Introduction**
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12 The study of the life functions of the human being and of other closely related
13 animals is particularly interesting as early as the first grade of schooling. Nutrition is a
14 process which fulfils an indispensable life-maintaining function and studying it provides
15 useful knowledge which contributes to our understanding of how living beings function
16 in general and human beings in particular. Moreover, the subject of nutrition may be
17 connected with developing healthy eating habits. (Banet, 2001; Cakici, 2005). However,
18 learning about it is complicated (Caravita & Hallden, 1994), because it requires
19 integrating the roles of digestion, respiration, blood circulation, etc., which take place in
20 a set of different organs/systems, into the global nutrition process. More specifically,
21 children's concepts develop from a simple idea – living beings need to take certain
22 materials from their environment (food, water and air) in order to live – to other more
23 complex ones. Children should thus gradually begin to recognise that these materials
24 reach some specific internal organs, that they are transformed by those organs and that
25 they are then distributed to the different parts of the body through the blood so as to
26 obtain the matter and energy that are essential for the maintenance of life (Pujol, 2003).
27 Furthermore, children should come to understand that waste substances are produced
28 inside the body and that they need to be eliminated by means of specific organs.
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55 The Spanish Official Curriculum sets great store by nutrition in general, but it
56 goes more deeply into human nutrition in particular, starting as early as 6-7 years of
57 age. In Early Childhood Education (before 6 years of age), stress is placed on the
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3 external characteristics and the needs of the human being and other living beings around
4 them (feeding, respiration, etc.). In the Primary School curriculum, comprising children
5 aged six to twelve, the human being's feeding and respiratory functions are included in
6 the first stage as well as those of animals in general (ages 6-8); the organs which permit
7 such functions to be performed are included in the second stage (ages 8-10) and the
8 systems involved in nutrition and their interrelation are treated in the third stage (ages
9 10-12). Greater detail is given to these last aspects regarding the human being than
10 where other organisms are concerned.
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23 The importance attributed to breathing and feeding by the Curriculum as early as
24 the very first Years of education accounts for the need to know how children of these
25 ages interpret the inside of their bodies. It is particularly valuable for teachers to have
26 this knowledge before introducing these themes, since it helps them promote the
27 development of their pupils' ideas.
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35 There are different interpretations as to how young children acquire their ideas
36 about biology. Some authors, such as Carey (1985), give them a mainly psychological
37 origin, which refers to extrapolation from humans to other biological systems. Other
38 authors (Mintzes, 1984; Hatano & Inagaki, 1997) consider that children gradually build
39 up their biological knowledge during the first years, either through personal experiences
40 or based on knowledge conveyed in the family context. These experiences account for
41 the fact that even young children are aware of the existence of certain organs (Cuthbert,
42 2000; Reiss & Tunnicliffe, 2001a) and that they, in their turn, relate them to other
43 perceivable processes (stomach-eating, lungs-breathing...) (Cubero, 1998).
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56 The objective of some research conducted in this area has been to determine
57 what pupils' knowledge looks like and what possible learning obstacles there are in
58 connection with the functions of the organs/systems in the human body which take part
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3 in nutrition (Table 1). Most research projects have chiefly focused on studying the ideas
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5 of adolescents, while research aimed at young children is rather scarcer especially in
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7 Spain. This chart shows us that most of these studies are aimed at anatomical and/or
8
9 functional aspects of the digestive system and, to a lesser extent, at the respiratory
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11 system or the systems of the human body as a whole. On the other hand, these research
12
13 projects normally focus on human nutrition while those that deal with other animals,
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15 such as Reiss' study (2001b), which uses other species of vertebrates, are less frequent.
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17 Furthermore, the goal of these studies is to get to know the characteristics of the ideas
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19 that pupils of different ages have about this particular field. However, the longitudinal
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21 ones, which involve monitoring the individual ideas of subjects over a period of time,
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23 are less abundant.
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29 The research projects included in Table 1 also show that the youngest children
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31 have naive ideas with regard to the organs which make up the digestive and respiratory
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33 systems. Children associate the stomach with respiration. Moreover, they relate liquid
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35 elimination directly to organs belonging to the digestive system. Furthermore, the
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37 transformation of food is not recognised.
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TABLE 1

Characterising the pupils' knowledge has been done by means of different
methodologies (surveys, closed and open questions...). Drawings, however, seemed to
be an ideal methodology, especially to work with young children (Guichard, 1995;
Renie & Jarvis, 1995), because it allows us to detect their mental models (Buckley *et al.*, 1997) and to compare the conceptions of subjects from different countries with
different languages (Reiss *et al.*, 2002). Regardless of the data-collecting instruments
used for learning about pupils' ideas, these projects established levels, models and

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2
3 categories of different degrees of complexity. For instance, Reiss & Tunnicliffe (2001a),
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5 proposed seven levels for depicting the inside of the human body. The easiest levels
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7 were characterised by the inability to recognise the organs or by depicting them in an
8
9 unconnected way, and the most complex ones were characterised by the ability to
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11 recognise various interconnected systems. Teixeira (2000), suggested three models of
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13 perception of food intake and its destination. The most primitive model was
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15 characterised by food remaining in the abdominal area and the most advanced one was
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17 characterised by the ability to recognise the manner in which food is distributed inside
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19 the body. On the other hand, Carvalho *et al.* (2004) established three different categories
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21 with regard to three questions: how is the digestive tract anatomy depicted?; how are the
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23 changes taking place from the mouth to the intestine interpreted?; and how is the
24
25 distribution of food in the body understood? Specifically, the simplest categories
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27 involving the digestive tract anatomy were associated with the absence of a digestive
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29 structure or the ability to identify a “sac” which may or may not be connected to the
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31 mouth. The most complex categories were characterised by the ability to identify organs
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33 that are more or less correctly associated to a continuous digestive tube.
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41 Finally, it is worth pointing out that research has detected not only
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43 epistemological obstacles, associated with personal perceptions and experiences, but
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45 also didactic ones, promoted by teaching, which make accurate learning more difficult.
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47 Thus, deficient drawings, sketches and diagrams have been found in Portuguese
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49 Primary Education textbooks. They turn out to be too confusing and they do not make
50
51 interpreting the interrelations between the different systems which take part in human
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53 nutrition easy (Carvalho *et al.*, 2007). Similar deficiencies, as well as others related to
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55 physiological aspects of nutrition, have been found in Spanish texts (García Barros &
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60 Martínez Losada, 2005).

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What has been said thus far, has lead us to the conclusion that our research ought to focus on aspects which previous research projects have paid less attention to. To be precise, our study is aimed at young children and it focuses on how children perceive the organs/systems related not only to digestion, but to respiration as well. The study is not only aimed at the human being, but it includes other animals too. On the other hand, this research project does not only deal with the ideas of children belonging to different age groups, but it likewise monitors how the personal ideas of these children develop over time.

The first objective of this paper is to learn how children aged four to seven interpret where that which enters the body is meant to go, concerning both human beings and other animals, i.e.: Where does drink and food go?; Where does the air they breathe go? What specific organs are identified in each case? A second objective is aimed at finding an answer to the following question: How do the pupils' individual ideas develop in connection with the aforementioned aspects over a three-year period?

Methodology

In all, 342 pupils from four different age groups (76 aged four, 74 aged five, 101 aged six and 91 aged seven), who are in the second and third year of Early Childhood Education and in Primary School Year 1 and Year 2 respectively, participated in this study. All of these predominantly middle class children belong to the same school in A Coruña (north-western Spain). There is hardly any teaching staff rotation at all and the teachers are highly experienced. More specifically, the staff teaching in the Years where this study was undertaken had more than 15 years experience at that particular Educational Stage. In these years/forms, pupils work on different aspects related to the functions carried out by the human being and other

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3 animals (they feed, they breathe and have children/baby animals...). They do not,
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5 however, study the different organs and systems involved in those processes (digestion,
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7 respiration...). The Spanish Education System deals with these aspects from Primary
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9 School Year 3 and on (8-9 years of age).
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13 The study of children's ideas about the digestive and the respiratory system or
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15 the organs related thereto was performed both concerning the human being and other
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17 vertebrate animals. Two different criteria were followed when choosing the animals: a)
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19 they should belong to the everyday sphere of life and be known to young children; b)
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21 they should be varied as far as their morphology (they have skin, feathers...) and their
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23 natural environment (sea, land, etc.) are concerned. Based on this, and after conducting
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25 a before-study of what the youngest children know about different animals, the
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27 following ones were selected: dog, duck and fish.
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32 Our research has focused on anatomical aspects related to the passage of
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34 different substances (food, drink and air) inside the body. We have ignored the
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36 physiological aspects, because they are beyond the scope of this paper. Besides, they are
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38 too complex and abstract for children of the age groups chosen for this study. This
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40 decision is based on the results that were obtained through a pilot study carried out with
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42 some children. Their answers to questions such as – What purpose does food serve?
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44 Why do we breathe? What happens to the food that we take in? – turned out to be very
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46 elementary and they nearly only referred to things like: “*we breathe to live*”; “*we eat to*
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48 *be strong*”; “*food enters our bodies, goes to our bellies... and that's how we become*
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50 *strong*”, etc. These first results essentially coincide with those found in other research
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52 projects (please refer to Table 1), which show that the youngest children, and even those
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54 not quite so young, do not know that food is transformed once it enters our bodies.
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3 With the aim of learning what young children know about the digestive system
4 and the respiratory system and what organs are associated to each one of them, the
5 following questions were posed to them in connection with the human being and the
6 animals chosen for this study: a) “Where does the food that you eat and the liquid that
7 you drink go?” and b) “Where does the air that you breathe in go?”. The children had to
8 express their ideas by means of drawings, individually. They were given silhouettes of
9 the four specimens for that purpose in the following order: first, the human being, then
10 the dog, duck and finally the fish. After that, the children were to identify what their
11 drawings depicted.
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24 The manner of asking the questions and the way the drawings should be done,
25 were adapted to the different ages of the participants. Thus, the children aged four to
26 five, who still do not know how to write, were asked the questions individually. Each
27 subject did the drawings required of them in the silhouettes and after that they identified
28 what they had drawn, verbally. The place chosen for these activities was a classroom
29 which the children were familiar with and which did not contain too many decorative
30 elements distracting the children. On the contrary, the children aged six to seven, who
31 knew how to read and write, were asked the questions collectively in the group that they
32 belonged to, in their own classrooms. Each child did the drawings required of them in
33 the silhouettes and subsequently identified the organs in writing. These data were
34 collected during Term 2 (January-February) of the academic year.
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50 The children’s drawings were classified into different categories, which were
51 progressively more complex, taking into account not only where substances come in
52 and go out, but the organs included as well. A before-analysis of a representative
53 number of drawings carried out for the different specimens was undertaken for this very
54 purpose.
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3 As regards the path which food and drink follow inside the body, none of the
4 children included the kidneys as excretion organ and they depict the solids (faeces) and
5 liquids (urine) as leaving the body directly from the digestive system. Therefore, the
6 following categories were established with regard to the digestive system: A_D (only the
7 entrance to the stomach); B_D (including the exits too); C_D (including the intestines as
8 well). A_D and B_D were subdivided in accordance with the type of entrance they have
9 (single or double) (see Figure 1). The term stomach has been used, although the
10 children themselves may employ others such as “tummy” to identify things in their
11 drawings.
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24 As for the respiratory system, the categories established were: A_R (ways in/out,
25 without any internal organs); B_R (including an organ, but not the lungs); C_R (including
26 the lungs as well as other organs) and D_R (including the lungs only). In categories B_R
27 and C_R, in their turn, subcategories were established depending on which organs had
28 been drawn (see Figure 2). This time, the before-analysis showed that some children
29 drew a different organ (gills) in the case of the fish, wherefore it became necessary to
30 establish a specific category, namely E_R, for that example (Figures 3).
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41 The drawings were analysed, independently, by two judges. Those cases where
42 an agreement could not be reached were discussed, though their disagreements did not
43 exceed 5% of the drawings they analysed.
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49 The longitudinal study, i.e. the study aimed at finding out how the personal ideas
50 of a specific group of children develop over time, was conducted with 32 subjects
51 during three consecutive years (from the age of five to the age of seven). These 32
52 children belonged to the initial group attending Early Childhood Education during the
53 first year of the study and then remaining in the school during the following two years,
54 i.e. also taking the first two years of Primary Education there. These children were
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3 asked the same questions, and in the very same way, as the rest of the participants,
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5 orally at the age of five and then in writing during the following years.
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10 Results

11 *Children's ideas about the digestive system*

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13 The children made the same digestive-system related depiction concerning all
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15 the examples of animals (including human) and they always managed to identify an
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17 organ. In all of the cases, the children drew a "bag" or "sack" which they called
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19 "stomach" or "tummy" Only a small number of children were able to identify the
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21 intestine as well.
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27 Most of the drawings made by the differently-aged children corresponded to
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29 categories B_{D1} or B_{D2} (Table 2). Category B_{D1} (two ways in to the stomach and two exits
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31 from that same organ) was the most frequent one in the groups of four- and five-year-
32
33 olds. In these groups, however, other more primitive categories were detected as well,
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35 namely A_{D1} o A_{D2} (with no exits at all). Category B_{D2} (only one entrance) was the most
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37 frequently found one in the groups of six- and seven-year-olds. In these last groups, a
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39 small percentage of drawings corresponded to the most advanced category, namely C_D,
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41 which includes the intestine. Figure 1 shows some representative drawings from each
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43 one of the categories.
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48 TABLE 2

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55 *How do children's ideas regarding the digestive system develop?*

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57 The study of the drawings of the digestive system, made by a subgroup of
58
59 students that involved repeated assessments (32 children from the age of five to the age
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1
2
3 of seven), shows that 23 of them evolved as they become older. Table 3 describes the
4 characteristics of that evolution. Most of them modified their type of answer only once
5 during the three-year period. Only three of them made different depictions every year.
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10 Virtually all of the children's last drawings corresponded to the B_{D2} (16 children) (One
11 entrance from the outside to the stomach and a double exit to the outside from this
12 organ) or C_D (7 children) categories (One entrance from the outside to the stomach;
13 there is a connection to the intestine; there is a double exit from this last organ). Ten of
14 the sixteen children who reached the B_{D2}-category initially made B_{D1}-type drawings
15 (their evolution consisted in being able to recognise that there is only one entrance) and
16 six children made more primitive initial drawings (A_{D1}/A_{D2}) (their evolution consisted in
17 being able to recognise that there are two exits). Five of the seven children who reached
18 the most advanced category, namely the C_D-one, initially made B_{D1}-type drawings (their
19 evolution consisted in including the intestine as well as being able to recognise that
20 there is but one entrance to the stomach) and two children initially made B_{D2}-type
21 drawings (their evolution consisted in including the intestine).
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38 The nine children who did not experience any sort of evolution at all always
39 made the same drawings, namely the type corresponding to categories B_{D2} (five
40 children) and B_{D1} (four children).
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46 TABLE 3

47
48 ***Children's ideas about the respiratory system***
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50 As regards the respiratory system, the vast majority of the differently-aged
51 children (296 in all) made the same depiction in the human being as in the other
52 animals, although they did not always identify the internal organs, especially not the
53 youngest ones (Table 4). Besides, the organs identified by them were diverse: stomach,
54 heart and lungs. Only 46 children, which belonged to the groups of five- six- and seven-
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3 year-olds, drew different organs in the fish compared to the other three specimens
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5 (human being, dog and duck).
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8 TABLE 4
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10 The respiratory system was depicted in a more varied manner than the digestive
11 system. Table 5 shows the categories which the children's drawings fall into. In the
12 group of children who made the same depiction for all the specimens (Group 1), the A_R -
13 type categories, which are characterised by a single entrance/exit for air and by not
14 including the internal organs, were mainly detected in the drawings of children aged
15 four and five. However, at the age of five more than 35% of the children made drawings
16 corresponding to category B_{R1} (ways in/out connected to the stomach). On the other
17 hand, the C_R - or D_R -type categories, which are characterised by including the lungs,
18 were more frequent in the drawings of children aged six and seven. The most accurate
19 category, namely D_R (Only the lungs are recognised), was seen in the group of seven-
20 year-olds, in particular. The C_R -type categories, which include other organs in addition
21 to the lungs, were found in both groups. C_{R3} (ways in/out are connected to the heart and
22 that same organ is connected to the lungs) and C_{R2} (this one also connects the lungs to
23 the stomach) included the largest number of student responses. The most primitive ones,
24 such as B_{R1} , which amounted to about 20%, were likewise seen in these groups of older
25 children. Figure 2 shows some representative examples of drawings from each category.
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48 Those children's drawings of the respiratory system of the fish which separated
49 this specimen from the rest corresponded to one sole category, namely E_R (ways in/out
50 connected to the gills) (Figure 3). Like with the other three animals, those same children
51 made drawings that corresponded to C_R -or D_R -type categories (see group II in Table 5).
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53 The C_R -category was only found in the groups with the eldest children, C_{R3} being the
54 most frequent one.
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TABLE 5

FIGURE 2

FIGURE 3

How do children's ideas develop with regard to the respiratory system?

The study of the drawings of the respiratory system, made by the subgroup of 32 children aged five to seven, shows that 20 of them made the same drawings for all the specimens in each one of all the tests carried out all through the three-year period. The other twelve children made a different depiction of the fish at some point of the study. All of them drew gills when they are six and seven years old and but three of them drew gills when they were five. The study also shows that the drawings of 23 children actually changed over time, whereas the drawings the rest of them made (nine children) neither changed nor evolved to more accurate scientific categories (Table 6).

Of those 20 children who did not establish any differences between the four specimens (see Group I in Table 6), 14 evolved during this period, thereby reaching D_R or C_R -type categories. Generally speaking, the children modified their sort of answer only once throughout the three years; no more than five made different depictions every year.

Of those children who reached the most advanced category, namely D_R , which is characterised by the lungs being the only organs, six subjects initially made drawings that corresponded to the most primitive categories (A_{R1}/A_{R2}), where no internal organs at all were recognised. Only two children made previous drawings corresponding to the B_{R1} -category. In this case, their evolution consisted in substituting an accurate organ (the lungs) for an inaccurate one (the stomach). Those children who reached categories C_{R2}/C_{R3} , which include not only the lungs but other organs as well (stomach and/or heart), initially made either B_{R1}/B_{R2} -type (three children) or A_{R1}/A_{R2} -type drawings

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3 (three children). In all of these cases, the evolution consisted in including the lungs and
4
5 either keeping or including inaccurate organs.
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8 As for those six children who did not further their drawings into more accurate
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10 categories, only one of them made the same depiction (B_{R1}) during the three years.
11
12 Three children who initially made D_R -type drawings whose last drawings fell into the
13
14 C_{R2}/C_{R3} -type categories. This meant that they had incorporated more organs. The other
15
16 two children who initially made B_{R1} -type drawings produced A_{R2} -type drawings at the
17
18 end of the three-year period. This meant that they had eliminated the organ which they
19
20 had initially depicted (the stomach).
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24 TABLE 6

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26
27 The study of those twelve children who indicated a difference between the fish
28
29 and the other three specimens shows that, at some point during the period which has
30
31 been studied, nine children evolved as they became older with regard to these three
32
33 specimens (human being, dog and duck) and they did so by modifying their drawings
34
35 once (see Group II Table 6). Their evolution was characterised by changes which were
36
37 similar to the ones seen among the children who established no differences between the
38
39 fish and the rest of the specimens: five children reached the most advanced type of
40
41 depiction - D_R – starting from either A_{R1} (three children) or B_{R1} (two children) and four
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43 children reached type C starting from B_R . The changes in remaining three children were
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45 characterised by going from D_R to C_R .
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50 Discussion

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53 This study has shown that young children have a conception of the inside of the
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55 body, even without having studied this subject formally at school. This knowledge is
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57 possibly influenced by their empirical experiences, but also by everyday conversations
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59 with different people, the audiovisual media and even by the fact that some broader
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3 contents, which exceed the ones included in the official curriculum, related to this
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5 subject are introduced in their own classrooms. On the other hand, it appears that the
6
7 ideas which young children have about the inside of the human body are usually the
8
9 same as the ones they have for other animals which they are familiar with. So it is that
10
11 children generally make the same drawing, with the same organs, for all of the
12
13 specimens and only a few of them are able to identify the fish as being different by
14
15 drawing its gills. This suggests that children at these ages, perhaps, use their own body
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17 as a basic model of the functions of living beings until they acquire specific knowledge
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19 through formal or non-formal education.
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25 As a result of examining children's ideas about the destination of the food that
26
27 they take in and the air that they breathe, we found that pupils aged four to seven have a
28
29 more accurate view of the digestive system than of the respiratory system. In the
30
31 specific case of the digestive system, all of the children, even the four-year-olds,
32
33 identified the stomach as the place where both solid and liquid foods go. They always
34
35 depicted the stomach, which some of them also named tummy, as a sack connected to
36
37 the mouth by one or two canals. These results are similar to the ones found by other
38
39 researchers undertaking studies of children of similar ages (Giordan & Vecchi, 1988;
40
41 Cubero, 1998; Teixeira, 2000 1148; Carvalho *et al.*, 2004; León-Sánchez *et al.*, 2005).
42
43 As opposed to what happened in our study, however, children do not always depict the
44
45 place/places where food enters the body (Carvalho *et al.*, 2004). We likewise detected
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47 that all of the older children made somewhat more complex drawings of the digestive
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49 system. These drawings were characterised by the fact that they included the places
50
51 where food exits the body, which were always two in number and that they were always
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53 connected to the stomach or the intestine, in case this last organ was identified. This
54
55 suggests that school children aged six to seven have an idea about the digestive system
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3 as being a continuous one going from the mouth to the excretion orifices, although
4
5 students in the study never recognised the kidneys as excretion organs.
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8 The differences between the ideas that children of different ages have which
9
10 were found in the broader study, which was carried out including all of the participants,
11
12 is consistent with the analysis that was carried out with a small group of children over a
13
14 three-year period. During those three years, no great changes took place as regards the
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16 children's ideas about the digestive system, because none of the children went from the
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18 most primitive conception (where only the entrance/s for food and drink to the stomach
19
20 is recognised) to the most highly developed one (where one single entry leading to the
21
22 stomach and from there to the intestine, which in its turn is connected to two exits, is
23
24 recognised). However, it may be stated that those ideas did improve as the children
25
26 grew older. One of the improvements that were detected consisted in the ability to
27
28 recognise that the digestive system has an exit and that that exit is, furthermore, a
29
30 double one. Even though this idea does not establish a difference between the digestive
31
32 system and the excretion system, it did involve an improvement which may be
33
34 particularly influenced by the subject's experiences. For instance, young children know
35
36 that if they take in food which is spoiled they will later have diarrhoea, or if they drink
37
38 more than usual they will produce more urine. These experiences logically contribute to
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40 children establishing relationships between that which is taken in and that which is
41
42 eliminated. This could also justify the fact that only a small number of young children
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44 in the broader study did not recognise the exits of the digestive system.
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53 Another one of the improvements that were detected was that of substituting a
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55 single entrance for the double entrance – one for solids and one for liquids - from the
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57 mouth to the stomach. However, it should be remembered that the idea that there are
58
59 two entrances did persist in the groups containing older subjects. We put this
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1
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3 persistence down to the fact that children are not empirically experienced enough to
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5 counteract the establishment of the following causal relationship: if liquids and solids
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7 exit through different canals, it is logical to think that they also enter through different
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9 canals.
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13 Finally, including the intestine was an improvement which consisted in adding a
14
15 new organ without modifying, substantially, the initial model of the digestive system,
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17 which was characterised by a series of organs connected to one another from the mouth
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19 to the excretion orifices. Including the intestine is not very frequent, neither in the
20
21 longitudinal study nor in the global study. We believe that those who did include it did
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23 so fundamentally owing to the general knowledge which they had acquired by means of
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25 conversations, access to sketches, drawings of the inside of the body found in books,
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27 exhibitions, museums, etc. and so forth.
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32 As we have said, children aged seven manage to acquire a more complete idea
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34 about the anatomy of the digestive system, generally speaking. However, pupils, the
35
36 oldest ones too, have been found to have difficulty establishing relationships between
37
38 different organs even after studying the digestive system as such (Reiss & Tunnicliffe,
39
40 2001a). This could be influenced by the teaching method as well as by the classroom
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42 material. Specifically, textbook sketches and drawings do not always treat the
43
44 interconnections between those organs accurately (Carvalho & Alves, 2004). In our
45
46 opinion, the teaching process ought to take into consideration the adequate idea about
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48 the digestive system which most pupils seem to show (“a continuous tube” where the
49
50 substances that come in are different to the ones that go out), so as to contribute to the
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52 understanding that transformations do indeed take place inside it. This is important,
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54 especially because taking such transformations into account is not easy for pupils at all
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3 (Gellert, 1966; Contento, 1981; Brinkmann & Boschhuizen, 1989; Cubero, 1998;
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6 Teixeira, 2000; Rowlands, 2004).

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8 As has been previously said, the children have a more inaccurate conception of
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10 the respiratory system than of the digestive system. So it is that particularly the
11
12 youngest ones did not identify any of the respiratory system organs, while the eldest
13
14 ones included the lungs and/or other organs (stomach, heart) outside the system as a part
15
16 of it. These results coincide with the ones found by other researchers (Brinkmann &
17
18 Boschhuizen, 1989; Cuthbert, 2000) and they can possibly be put down to the fact that
19
20 children do not have such evident empirical experiences here as they do of the digestive
21
22 system. In any case, the children did not appear to have any problems identifying the
23
24 number of organs of each type, even though they made this mistake. They knew, even
25
26 the youngest ones, that the lungs are two organs and that the stomach and the heart are
27
28 only one. However, the lungs were depicted in such a way that they looked similar to
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30 two bags resembling the stomach, while the heart was drawn looking like a heart of
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32 “two lovers” or a “Saint Valentine’s” one, thereby showing a clear cultural influence.
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39 The fact that the children, above all the youngest ones, did not recognise any of
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41 the respiratory system organs could be influenced by their inability to recognise air as
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43 matter (Stavy, 1988; Seré, 1989). Thus, children may think that air is capable of
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45 spreading inside the body. Moreover, there are no personal empirical facts inducing
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47 them to think that air transforms itself inside the body. In fact, there are no noticeable
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49 differences between inhaled and exhaled air. Therefore, the need for a specific organ
50
51 inside the body, as is the case with the digestive system, is not perceived. However,
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53 there were a large number of subjects who recognised the stomach as the only
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55 breathing-related organ, thus leading us to presume that some children “needed” air –
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57 just like food and drink – to reach the only cavity in the body they were able to identify
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3 (tummy/stomach). This conception persisted despite the fact that the children identified
4
5 the lungs as organs belonging to the respiratory system.
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8 On the other hand, regardless of the number of organs considered to be a part of
9
10 the respiratory system, the children tended to establish connections between those
11
12 organs and they always maintained a certain order of appearance. More specifically, the
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14 heart was drawn before the lungs, while the stomach was situated after them. There may
15
16 be a possible explanation for this order. However, simply analysing the children's
17
18 drawings did not permit us to make any interpretations. In order to do so, it would be
19
20 necessary to make interviews enabling us to study the children's thought more in depth.
21
22 As opposed to what happens with regard to the digestive system, the children did not
23
24 always depict the respiratory system the same way for the human being as for other
25
26 animals. A small group of subjects, all of them over five years of age, identified the gills
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28 as the fish's only respiratory organs and they drew them as some sort of lines looking
29
30 similar to a shark's gill clefts. Perhaps, this was influenced by their own experience
31
32 acquired at school, but outside it as well. Initially, this group of children could be
33
34 considered to have more accurate conceptions than the rest of their school mates, since
35
36 they also identified the lungs as the respiratory organs of the human being and of other
37
38 animals too. However, this consideration needs qualifying, because a substantial
39
40 number of these children included other organs outside the respiratory system in these
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42 specimens.
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50 The longitudinal study of the smaller group of children showed that the changes
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52 were more varied with regard to this system than the ones detected regarding the
53
54 digestive system. This was consistent with the greater variability of ideas identified
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56 concerning the respiratory system, because there was a greater number of organs to be
57
58 considered there. In fact, the number of categories established is virtually twice as big as
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3 those referring to digestive system. Furthermore, this time we found that most of the
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5 children did gradually acquire more accurate ideas during the three years of the study.
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8 Focusing now on the characteristics of the changes going towards more accurate
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10 conceptions, without taking the particular case of the fish into account, it could be
11
12 observed that some were more extensive than others. For instance, coming to identify
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14 the lungs as the only respiratory organs, when starting from an initial idea where no
15
16 organs at all were considered, constituted a desirable improvement which did not
17
18 encounter any sort of “interference” along the way. However, coming to that conviction
19
20 when starting from the idea that the stomach is a breathing-related organ, appears to be
21
22 rather more difficult, because it requires substituting a specific organ (the lungs) where
23
24 only air ends up, for the stomach, which is a polyvalent organ where everything that
25
26 enters the body ends up. This greater degree of difficulty may possibly explain why
27
28 various children, during this three-year period, added the lungs to the stomach, though
29
30 they initially considered it to be the only respiratory organ, rather than substituting one
31
32 organ for another.
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38 In connection with the regressions, we noticed that it is worth highlighting that
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40 most of them were characterised by adding other organs (stomach and/or heart) outside
41
42 the respiratory system to an accurate initial idea (i.e. that the lungs are the system’s only
43
44 organ). This suggests that children are more prone to relate “new” organs to the
45
46 respiratory system than to the digestive one, which makes it more difficult to teach them
47
48 about the former. Yet another regression consisting in the initial belief that the stomach
49
50 is the place which air reaches, only to be replaced by a vague vision of air inside the
51
52 body, was detected. Even though this change may be seen as a step backwards, it does
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54 constitute an idea which can eventually come to be productive, because it helps to
55
56 understand the fact that air needs to reach all parts of the body.
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3 Finally, we ought to point out that when the fish's gills were identified, they
4 were considered to be the sole and exclusive respiratory organ of this species. Those
5 children who did identify them did not include other organs outside them, even though
6 they did so where other animals were concerned. This may be due to the fact that the
7 gills were viewed more as an external organ where air or water circulates and the need
8 for an internal organ (heart, tummy/stomach) was therefore not perceived.
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17 **CONCLUSIONS AND TEACHING CONSIDERATIONS**

18
19 Ever since they were very young, the children in this study had a view of how to
20 depict the inside of their body and they recognised different digestion and respiratory
21 related organs. The older the children were, the more complex and/or accurate their
22 ideas. These depictions of their own body were the same as those used for other animals
23 which they were familiar with and but a few of them were able to distinguish the fish's
24 respiratory organs.
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34 The children's conceptions of the digestive system were more complete than those
35 of the respiratory system. Regarding the digestive one, they always recognised an organ
36 which is specific to it, but when it came to the respiratory system they did not always
37 identify organs, and "other" organs outside this system were often included. The organs
38 identified in both systems were connected to one another and they communicated with
39 the outside.
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48 Analysing the way these children's ideas evolved showed us that their conceptions
49 regarding the digestive system typically either advanced or remained unchanged.
50 Furthermore, quite an accurate idea of this system was reached by most children
51 (continuous tube with one or two main organs – stomach/intestine – which has two exits
52 leading to the outside). However, where the respiratory system was concerned, the
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3 evolution was more varied and not always was an accurate idea of this system achieved
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5 (the lungs as the only organs specific to the system).
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8 This paper shows that young children are able to reflect how they perceive the inside
9
10 of the body as well as the inside of other animals that they are familiar with by means of
11
12 drawings. This methodology is valuable but yet has limitations. Using one which
13
14 stresses the thought of the subjects more deeply, such as interviewing them, would
15
16 make it possible to answer different questions raised by this study – for what reason do
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18 children associate the heart with breathing and never with digestion?; what is the
19
20 function of the heart?; what view do children have about fishes' gills compared with the
21
22 lungs?, etc.
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26
27 This paper provides information about children's thought which may be useful for
28
29 those who teach about the inside of the human body and the way it functions. There are
30
31 positive aspects about children's thought which ought to be taken into account if the
32
33 pupils ideas are to progress. We are specifically referring to the fact that children in this
34
35 study did not appear to have any difficulty connecting the organs that they considered to
36
37 be associated to a certain system to one another. However, this connection did constitute
38
39 a problem for the older pupils, who knew about other organs in greater detail through
40
41 schooling. This paper likewise shows that children have a more accurate concept of the
42
43 digestive system than of the respiratory one. Even though the academic requirements
44
45 are low in Primary Education and even though the curriculum at this level limits itself to
46
47 the study of gaseous exchange, it is nonetheless necessary for the teacher to bear in
48
49 mind the fact that it is very hard for children to admit that air is, in fact, matter. It would
50
51 therefore be advisable for the teacher to include the type of experiences which make it
52
53 evident that air is material: to perceive that matter enters our body when we breathe; to
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55 observe that air takes up space (an upside-down glass vertically introduced into water is
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3 not filled, because it contains “matter”, i.e. air), and so forth. We believe that
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5 understanding that air is actually matter is vital if pupils are later expected to be able to
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7 grasp that air reaches some specific organs (lungs, gills...), that these organs are related
8
9 to a distribution system (the circulatory system) which is in charge of taking one of its
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11 components (oxygen) to the different parts of the body... and that, in short, all of these
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13 processes, when they are accurately integrated, contribute to the nutrition function,
14
15 which consists in obtaining the matter and the energy which living beings need.
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For Peer Review Only

Table 1 A review of the research projects undertaken regarding the ideas which children have about human and animal nutrition related aspects.

Authors	Ages and Instrument	Subject/Conclusion
(Nagy, 1953)	5-11 Multiple-choice test and drawings	Digestive system/Gaseous Exchange system of the human body - The children recognise the most specific organs related to digestion and respiration (stomach and lungs). - They associate each organ to an existential need (eating, breathing)
(Gellert, 1966)	4-16 Interview and drawings	Organs and systems of the human body Up to 10 years of age: - The children relate the stomach to respiration, which they limit to the gaseous exchange. - They are not aware that food is transformed (food is stored in the stomach and is subsequently expelled).
(Contento, 1981)	5-11 Interview	Digestive system of the human body - The children are not aware that food is transformed - They consider the stomach to be a “warehouse” for the food.
(Giordan & Vecchi, 1988)	4-adults Questionnaire with drawings	Digestive system of the human body Some anatomical inaccuracies are detected at all ages: - Differentiated transit for solids and liquids. - Inadequate connections between the organs of the digestive apparatus.
(Brinkmann & Boschhuizen, 1989)	4-11 Questionnaire with drawings	Digestive system/Gaseous Exchange system of the human body - The very youngest ones make simplistic anatomical depictions of the digestive system. Furthermore, they relate the stomach to respiration. - The eldest ones recognise food transformation.
(Cubero, 1998)	8-10 Interview and drawings	Digestive system of the human body Five different increasingly complex levels of understanding of the digestive process are identified: - The most primitive one identifies a “bag” where food is stored. - At the most highly evolved levels, the transit of food through different organs is identified. The most advanced of all recognises food transformation and the distribution of substances to the entire organism.
(Cuthbert, 2000)	7-11 Drawings	Various systems of the human body Some anatomical inaccuracies are detected: - The children do not include any connections or do not connect the stomach, the lungs and the heart adequately.
(Teixeira, 2000)	4, 6, 8, 10 Interview and drawings	Digestive system of the human body Three increasingly complex models are identified: - The simplest models identify the “tummy” as the place where food goes and it either stays there or is expelled to the outside. - The more complex models recognise that one part of the food is eliminated and that another part is distributed throughout the body by means of the blood. Few children take the transformation of food into account.
(Reiss & Tunnicliffe, 2001a; 2001b)	5-20 Drawings	Organs and systems of the human body and of various animals They identify seven increasingly complex levels of internal structure: - In the most primitive levels, the systems are not identified, they only identify some organs. The most well-known ones correspond to the digestive system and the gaseous exchange system. - In the most highly evolved levels, systems of interconnected organs are identified. In general, they show greater knowledge of the human body than about that of other animals.

(Reiss <i>et al.</i> , 2002)	7 and 15 years Drawings	Organs and systems of the human body They identify the previously defined seven increasingly complex levels in the drawings made by subjects from eleven different countries. - In general, similar average levels of knowledge are identified in children of different ages from different countries.
(Jaakkola & Slaughter, 2002)	4-10 Interview and drawings	Digestive system/Gaseous Exchange system of the human body - The children only identify the most representative organs (stomach, lungs). - From the age of eight, they relate certain organs to specific functions (stomach-digestion, heart-blood...).
(Carvalho <i>et al.</i> , 2004)	5-6, 8-9 Questionnaire with drawings	Digestive system of the human body Four types of anatomical depictions are identified: - The simplest ones only recognise the stomach/tummy, with no connection to the outside or to the mouth. - The most complex ones recognise other organs. Limited knowledge of the digestive process and of the distribution of substances to different parts of the body is detected.
(Rowlands, 2004)	10 Interview and drawings	Digestive system of the human body - The children recognise that food is distributed throughout the body to obtain energy, though they limit digestion to being a mechanical process.
(Cakici, 2005)	10-11 Interview and questionnaire	Digestive system of the human body - The children recognise that one part of the food is eliminated, but another part is distributed throughout the body by means of the blood. - They limit digestion to a "melting and dissolving" process.
(León-Sánchez <i>et al.</i> , 2005)	6-13 Semi-structured interview	Digestive system of the human body They identify two digestive system models: - The young ones only recognise the stomach. - The old ones recognise other organs as well as the need to distribute substances to different parts of the body.

Table 2. Categories related to the digestive system, which were identified in the children's drawings.

CATEGORIES		4 years N= 76	5 years N= 74	6 years N= 101	7 years N= 91
A _D	A _{D1}	8 10.5%	4 5.4%	-	-
	A _{D2}	5 6.6%	3 4.1%	-	-
B _D	B _{D1}	36 47.4%	35 47.3%	38 37.6%	33 36.3%
	B _{D2}	27 35.5%	32 43.2%	58 57.4%	43 47.3%
C _D		--	--	5 5.0%	15 16.5%

Table 3. Types of depictions of the digestive system, carried out by the children from five to seven years of age.

TYPES OF DRAWINGS (5 → 7 years)		THE CHARACTERISTIC OF THE CHANGE	TOTAL n=32
They evolve (n=23)	$A_{D1}/A_{D2} \rightarrow B_{D2}$	No exits are identified → Exits are identified	6 18.8%
	$B_{D1} \rightarrow B_{D2}$	Two entries and two exits are identified → One single entry and two exits are identified	10 31.3%
	$B_{D1} \rightarrow C_D$	Two entries and two exits are identified → One entry and two exits are identified and it includes the intestine	5 ^(*) 15.6%
	$B_{D2} \rightarrow C_D$	One entry and two exits are identified → It also includes the intestine	2 6.3%
They do not evolve (n=9)	$B_{D1} \rightarrow B_{D1}$	No changes occur	4 12.5%
	$B_{D2} \rightarrow B_{D2}$		5 15.6%

(*) Three children change their drawings twice.

Table 4. General characteristics of the children's depictions with regard to the respiratory system.

TYPE OF DEPICTION		4 years N= 76	5 years N= 74	6 years N= 101	7 years N= 91	Total N= 342
With no internal organs in any of the specimens.		52 68.4%	25 33.8%	23 22.8%	10 11.0%	110 32.2%
With internal organs.	The same in all of the specimens.	24 31.6%	40 54.1%	60 59.4%	62 68,1%	186 54.4%
	The same in all of the specimens except for the fish.	--	9 12.2%	18 17.8%	19 20.9%	46 13.4%

Table 5. Categories related to the respiratory system identified in the drawings of the children

Categories		4 years		5 years		6 years		7 years	
		G. I n=76	G. II --	G. I n=65	G. II n=9	G. I n=83	G. II n=18	G. I n=72	G. II n=19
A _R	A _{R1}	40 52.6%	--	15 23.1%	--	9 10.8%	--	1 1.4%	--
	A _{R2}	12 15.8%	--	10 15.4%	--	14 16.9%	--	9 12.5%	--
B _R	B _{R1}	18 23.7%	--	23 35.4%	--	16 19.3%	--	14 19.4%	--
	B _{R2}	4 5.3%	--	3 4.6%	--	3 3.6%	--	--	--
C _R	C _{R1}	--	--	4 6.2%	--	7 8.4%	3 16.7%	--	2 10.5%
	C _{R2}	--	--	3 4.6%	--	11 13.3%	1 5.6%	14 19.4%	4 21.1%
	C _{R3}	2 2.6%	--	3 4.6%	--	13 15.7%	6 33.3%	10 13.9%	7 36.8%
D _R		--	--	4 6.2%	9 100%	10 12.0%	8 44.4%	24 33.3%	6 31.6%

G.I: Children who make the same depiction for all the specimens (n=296).

G.II: Children who make the same depiction for human/dog/duck. In the case of the fish, they only depict the gills (The E_R category) (n=46).

Table 6. Types of depictions of the respiratory system made by the children aged five to seven years of age

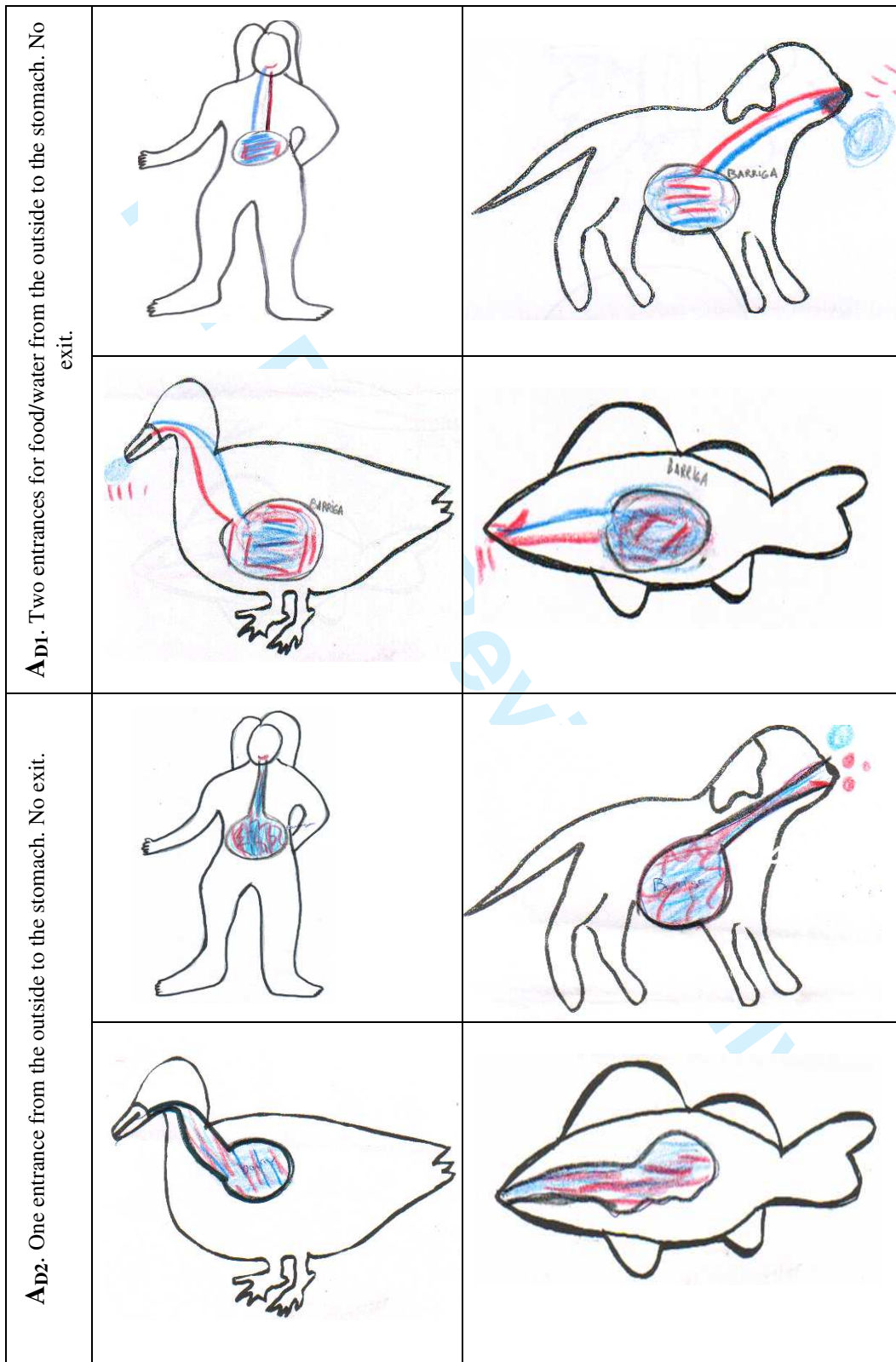
TYPES OF DRAWINGS (5 → 7 years)		CHARACTERISTIC OF THE CHANGE	TOTAL (n=32)	
			G. I n=20	G. II n=12
They evolve (n= 23)	$A_{R1}/A_{R2} \rightarrow C_{R2}$	Does not identify any internal organs. →	3* 15.0%	--
	$A_{R2} \rightarrow C_{R3}$	Identifies the lungs and other organs.		
	$B_{R1} \rightarrow C_{R1}$	Identifies the stomach or the heart → Identifies the lungs as well.	3 15.0%	4 33.3%
	$B_{R1}/B_{R2} \rightarrow C_{R2}$			
	$B_{R1} \rightarrow C_{R3}$			
	$A_{R1}/A_{R2} \rightarrow D_R$	Does not identify any internal organs. → Only identifies the lungs	6** 30.0%	3 25.0%
	$B_{R1} \rightarrow D_R$	Identifies the stomach → Only identifies the lungs	2 10.0%	2 16%7
They do not evolve (n=9)	$B_{R1} \rightarrow B_{R1}$	No changes occur	1 5.0%	--
	$B_{R1} \rightarrow A_{R2}$	Identifies the stomach → The air expands throughout the inside of the body	2 10.0%	
	$D_R \rightarrow C_{R2}$	Identifies the lungs → Identifies other organs too.	3 15.0%	3 25.0%
	$D_R \rightarrow C_{R3}$			

G. I: Children who make the same depiction for all the specimens.

G. II: Children who make the same depiction for human/Dog/Duck.

NB. The depiction changes in only happen once during the three-year period, except for the following cases: (*) two subjects and (**) three subjects.

Figure 1. Representative drawings of the digestive system for each category.



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<p>B_{D1} Two entrances from the outside to the stomach and two exits to outside</p>		
<p>B_{D2} One entrance from the outside to the stomach. A double exit to the outside from this organ.</p>		

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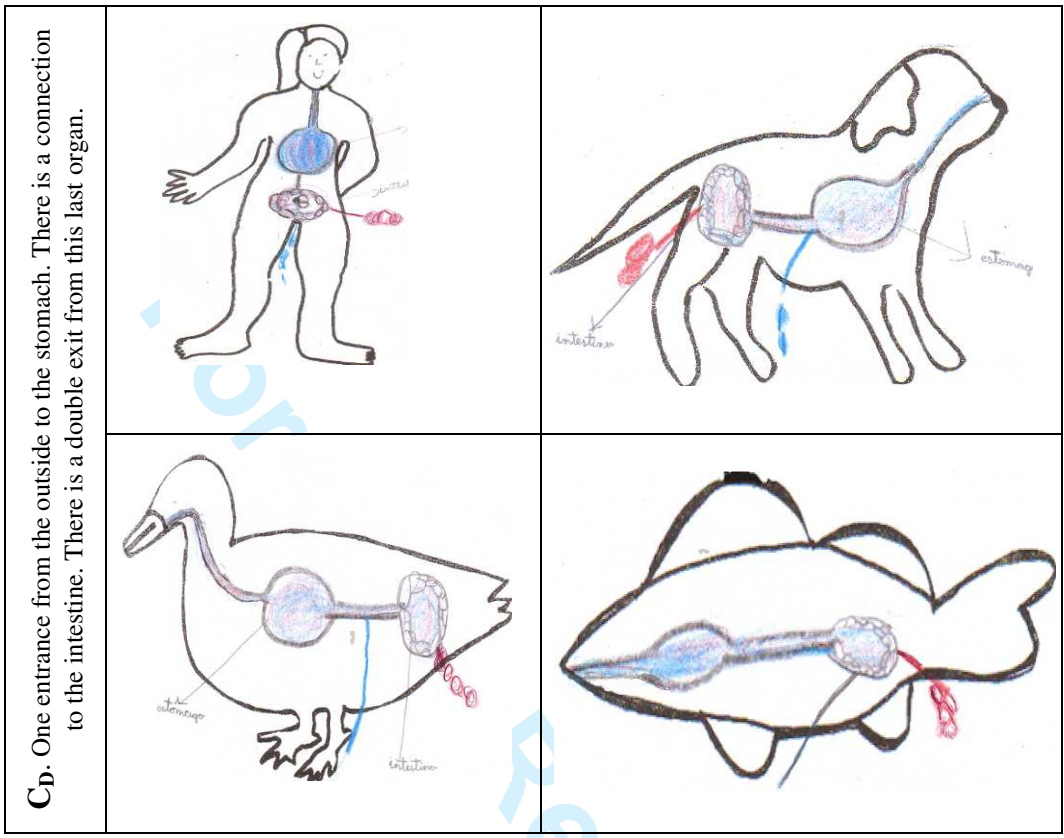

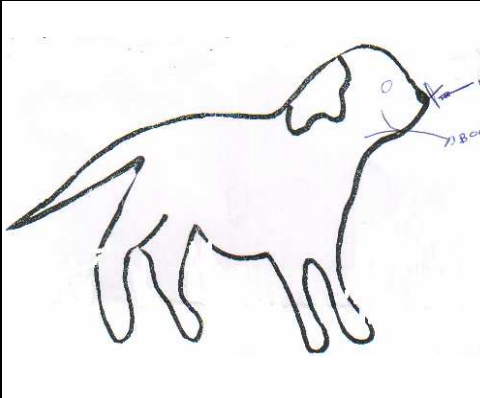
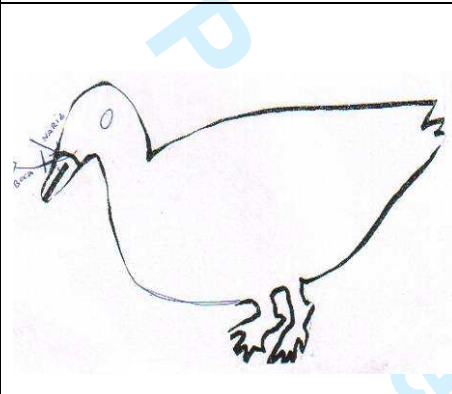
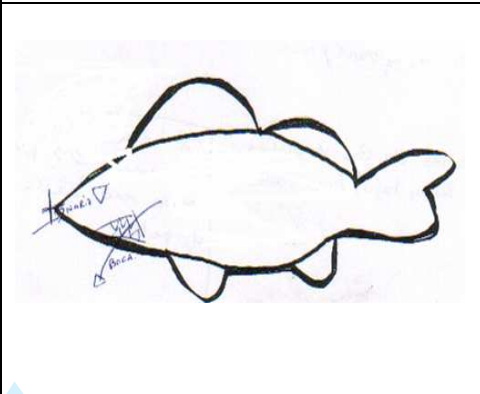
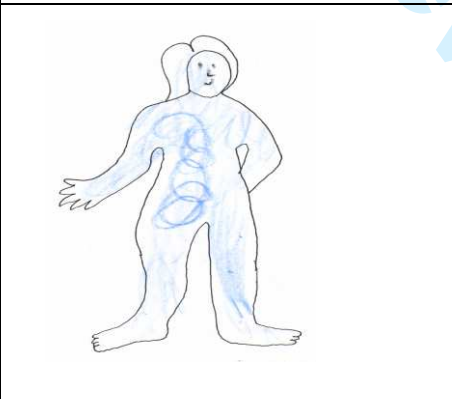

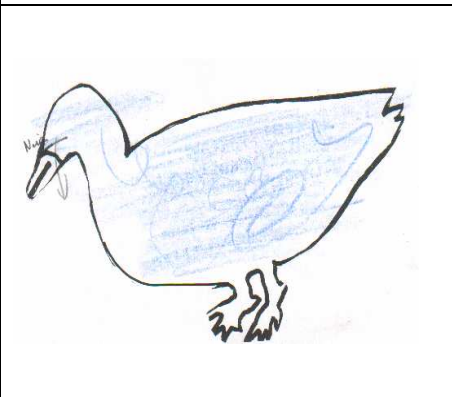
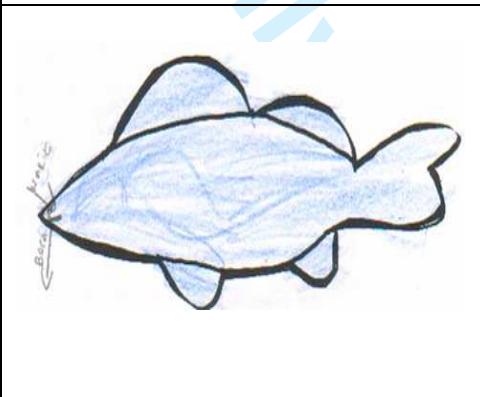
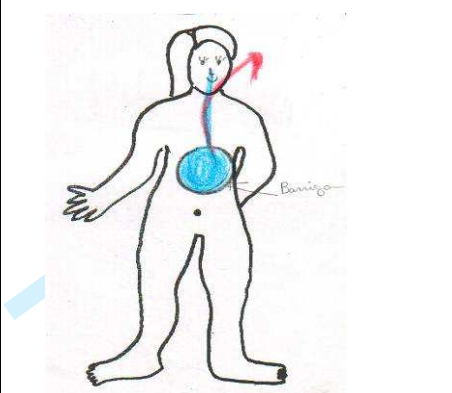
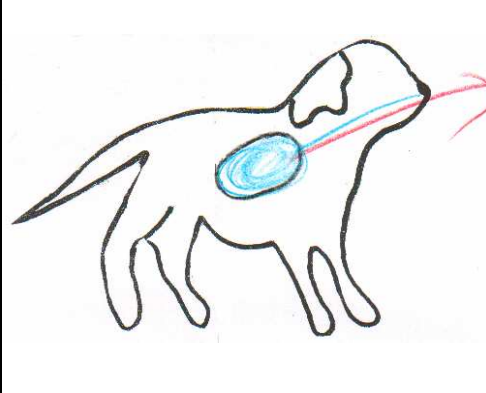
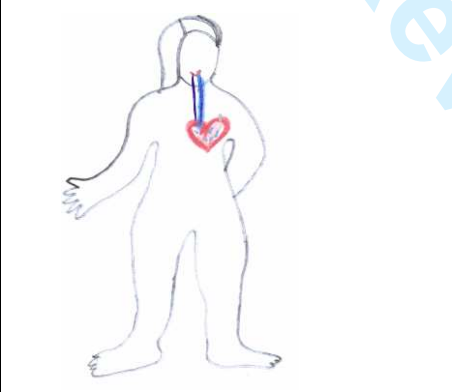
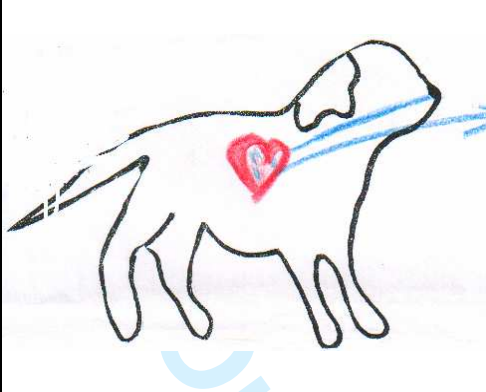
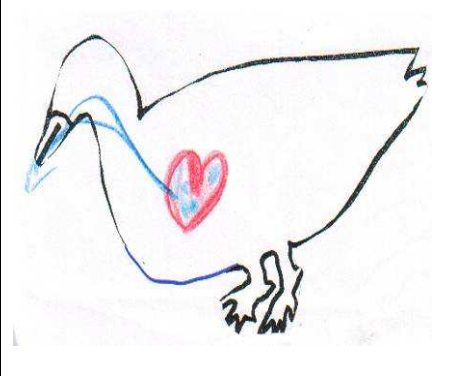
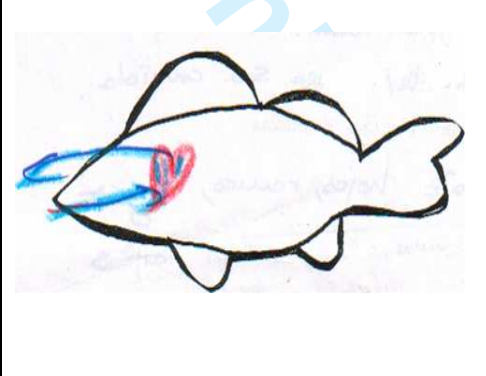


Figure 2. Representative drawings of the respiratory system for each category.

<p>AR1. One entrance for air from the outside. One exit to the outside.</p>		
		
<p>AR2. One entrance from the outside. It expands throughout the inside of the body. One exit to the outside, in the opposite direction.</p>		
		

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<p>B_{R1}. One entrance from the outside to the stomach. One exit to the outside, in the opposite direction.</p>		
<p>B_{R2}. One entrance from the outside to the heart. One exit to the outside, in the opposite direction.</p>		
		

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<p>CR1. One entrance from the outside to the lungs. There is a connection to the stomach. One exit to the outside, in the opposite direction.</p>		
<p>CR2. One entrance from the outside to the heart. There is a connection to the lungs and they are connected to stomach. One exit to the outside, in the opposite direction.</p>		

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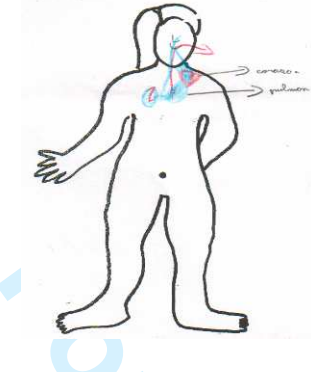
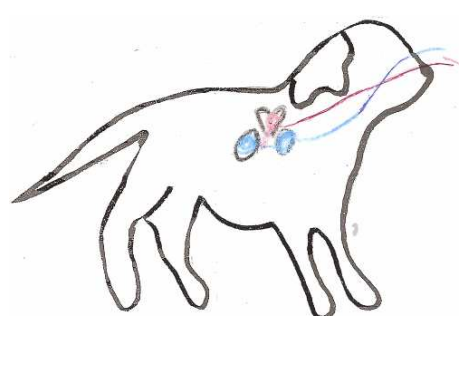
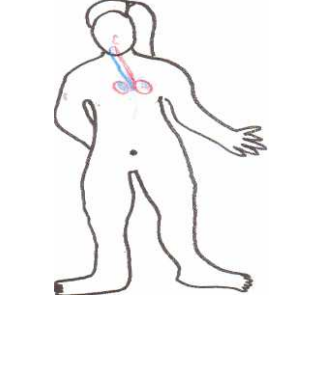
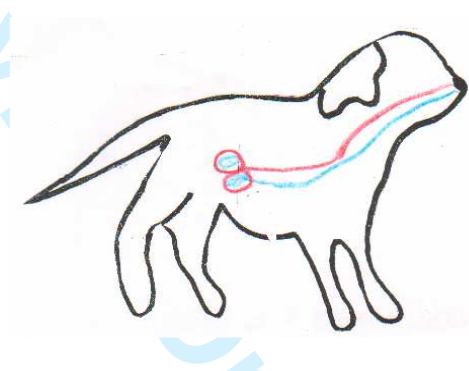
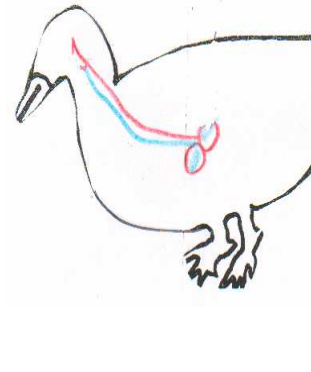
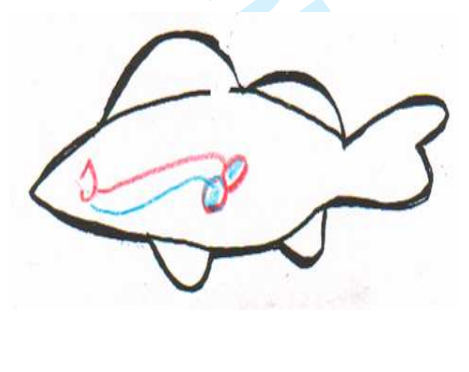
<p>CR3. One entrance from the outside to the heart. There is a connection to the lungs. One exit to the outside, in the opposite direction.</p>		
<p>DR. One entrance from the outside. There is a connection to the lungs. One exit to the outside, in the opposite direction.</p>		
		

Figure 3. Representative drawing of the fish respiratory system (E_R).

