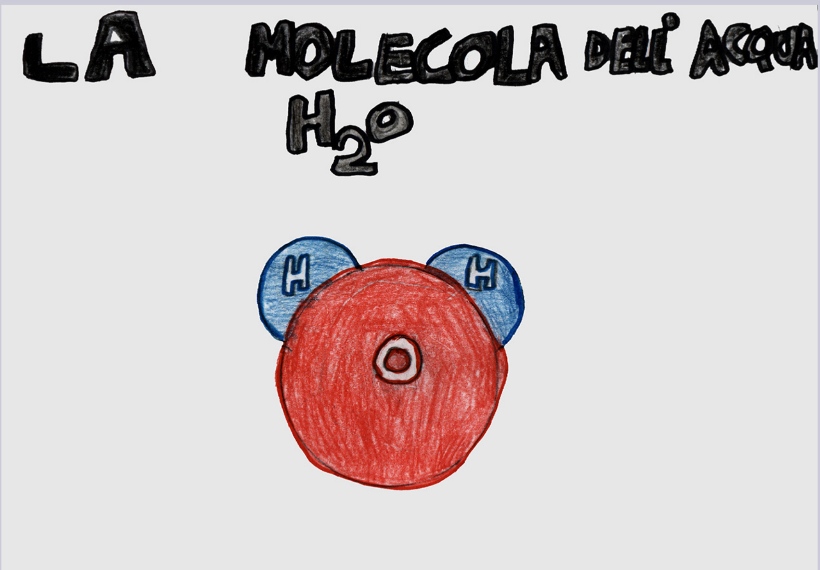
ACCADEMIA MEDICA DI ROMA

A HEALTH SCIENCE EDUCATION PROGRAMME IN PRIMARY SCHOOL THE SCIESA PROJECT

FOURTH YEAR
2016 – 2017



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INTRODUCTION

The fourth year of activity of the SCIESA project (SCIEnze della SAlute) was delivered in the 2016-2017 school year, as an initiative of the Accademia Medica di Roma, with the sponsorship of the Accademia Nazionale dei Lincei. The SCIESA project is an on-going experimental programme to teach health science over the five-year cycle of primary education. As in the previous three years, the project was delivered in two schools, in Via Asmara and Via Novara, both part of the Istituto Comprensivo Luigi Settembrini in Rome. The programme was taught to the same four classes already involved in the previous years' project, who were then in their fourth year of primary school. The planning and supervision of the project was run by the SCIESA working group, composed of Mario Stefanini, M.D., developmental biologist, fellow of the Accademia Nazionale dei Lincei, Antonio Cappelli, M.D., epidemiologist; Flavia Capozzi, M.D. child neuro-psychiatrist, all belonging to Sapienza University of Rome; Silvia Caravita, biologist, expert in scientific education at the IRPPS (CNR) Rome, and Gregorio Siracusa, M.D., anatomo-physiologist, at the University of Rome Tor Vergata.

The programme was delivered by the same teachers of the four classes, Paola Cherubini, Roberta Corvi, Grazia Cossu, Elena Feliziani, Maria Eleonora Medici, Annarita Pierini, Grazia Zimbalatti, under the guidance of the school headmaster and of Angelo Matrone and Claudia Regazzini, coordinators of Via Novara and Via Asmara schools, respectively. Approximately 80 pupils were involved in the experiment.

The project has been financed by the Fondazione Terzo Pilastro Italia e Mediterraneo during its first and third year (2013-2014 e 2015-2016) and by InterAcademy Partnership

(UNESCO) during its second and fourth year (2014-2015 and 2016-2017).

As with previous years, the present report – detailing the activities realised during the fourth year of the project – has been written in English and Italian, and can be accessed at the Accademia Medica di Roma web site, at the following link:
http://www.accademiamedicadiroma.it/index.php?option=com_content&view=article&id=573&Itemid=106 ,
as well as at the InterAcademyPartnership (IAP) for Health web site:
http://www.iamp-online.org/content/health-science-education-compulsory-primary-schools, (the SCIESA project has become an IAP project since 2014).

CHARACTERISTICS OF THE SCIESA PROJECT AND SUMMARY OF PREVIOUS ACTIVITIES

1. Motivation, objectives and methods of implementation of the SCIESA project (SCIEnze della SAlute)

1.1 Motivation

Developing a Science for Health education programme in a primary school was an idea stemming from an analysis of epidemiological data of the Italian population, which is strongly characterised by:

- an ageing population with consequential increase of chronic or degenerative diseases;
- the diffusion of a wide range of diseases typical of the "affluent society", defined by the WHO *Non Communicable Diseases* (*NCD*,), and known to be linked with incorrect and risky health lifestyles (e.g.

eating disorders, tobacco addiction, drug abuse, sedentary lifestyles, stress, etc.).

As a consequence of these phenomena, the overall demand for health care is increasing, with consequent greater costs for the National Health Service.

Among the prevention activities, special relevance is given to the *primary prevention* aimed at eliminating or at least in countering the root causes of those morbid events that one wants to fight.

Health education is considered as an adequate preventive approach to reduce the diffusion of the above mentioned pathologies. Initiatives in this direction are subject to criticism. Indeed, it can be observed that the general effectiveness of health education programmes in the primary school system is rather limited as:

- they are generally delivered as occasional or sporadic events;
- in most cases, the learners lack basic scientific trainings, even at an elementary level, indispensable for long-lasting and effective learning;
- the information which is transmitted is perceived as an undisputed truth, not based on scientific evidence.

These critical issues underpin the need of a new concept of *health education*, played as a systematic activity to “promote health”, focused on the appreciation of “healthy and correct lifestyles”. This new approach to a *science-based health education*, has to be based on the aware knowledge of own body, of its regulative mechanisms, and of the major health risk factors to be avoided.

In this direction, an effective health education programme in primary schools is of the outmost importance for a number of reasons.

Firstly, primary school pupils are the appropriate target for such educational activity because:

- the basic educational issues are established at an early age;
- the compulsory school allows an entire age segment to benefit from such activities;
- the bases for health *vs*. disease in adults are laid down in childhood;
- if efficiently conducted, these activities could raise awareness among the pupils' families as well.

Secondly, a targeted educational project may contribute to the long-term prevention of chronic pathologies that share risk factors, such as unhealthy diet, lack of physical activity, alcohol abuse, smoking, drugs consumption. Recent data from the *World Health Organisation* show that 70% of all deaths are caused by *non communicable diseases* (NCDs). In addition, the rapid rise in NCDs is predicted to hinder poverty reduction initiatives in low-income countries.

Finally, such approach may easily introduce the pupils to a teaching method based on their active participation in the learning process through inquiry (Inquiry Based Science Education, IBSE) – a method that is considered to favour the re-elaboration of acquired knowledge in a structured and long-lasting form – as well as through experiments and their recalling personal experiences. IBSE-based pilot projects are presently being implemented with success in many countries. Only a few of them, however, have explored the connections between science and health education, with interesting but limited impact and developments.

In essence, the core of the above mentioned educational activity is to transmit to the pupils, even if at an elementary level, the basic scientific understanding on the structure/functions of their own body and to contribute to their ability to positively face problems in life, by acquiring the so called *skills for life*, as defined by WHO.

1.2. Aims

With these premises in mind, the SCIESA project was conceived with the purpose to verify the feasibility of delivering to a target of primary school scholars a systematic *science based health educational programme* having the final aim of transmitting to these young learners an understanding on the conformation and functioning of the human body and of getting them to a personal, rational and scientific appreciation of lifestyles that can be considered as appropriate to help prevent the onset of certain infectious or degenerative pathological conditions. To this aim, the basic knowledge to be transmitted, appropriately framed to the learning abilities of primary school pupils, should primarily include the following:

- the general conformation and the main functions of the human body;
- the continuous exchanges that occur between the human body and the external environment~~;~~
- the relationships with others, and in general with the external environment;
- the major risk factors for health which can be met even at a young age, such as an unhealthy diet, lack of physical activity, alcohol abuse, smoking, drugs consumption;
- behaviours and lifestyles aimed at avoiding or contrasting those risk factors, thus preventing the onset of illness which can be established both at a young age or during adulthood.

For this feasibility study, the project was formulated conceived to be delivered to four classes over the entire five-year primary school duration, beginning at the first school year.

1.3. Method of intervention

The educational strategy adopted to achieve the above objectives is based on two basic principles: the use of an inductive method, and the active participation of learners during the delivery of the programme.

This strategy, aimed at enhancing the critical capacity of the scholars within an evidence-based educational programme, also implies:

- identifying and valorising everyday activities of the scholars (family life, school activities, physical exercise, play, conditions of well-being or sickness, etc.), to be used to create the foundations for a learning based on real, spontaneous or elicited, experiences;
- the direct scholars participation in the learning process through the systematic involvement of each individual in the group, and by encouraging interaction between group members;
- the continual training of the teachers involved in the delivery in the classroom of the proposed programme;
- the collaboration of scholars's families, by means of periodic information sessions (letters to parents, meetings, etc.) concerning the ongoing program;
- adopting an inductive methodology during the planning and implementation of the programme, to enhance reflexions on the experience itself, and to create solid foundations for effective learning, thus avoiding teaching based on the mere transmission of notions.

The syllabus for each year of the programme was essentially prepared according to the following plan:

a) Identification of "basic experiences"

Taking into consideration their age and social background, the pupils would be made to recall some of their own basic, everyday experiences, to be used as a part-of the programme.

b) Preparation of the teaching programme

The school year-long programmes were prepared by the SCIESA working group together with the teachers, and were articulated into various Modules to be used by the same teachers as a teaching guide. The Modules would be focused on a series of topics pre-selected in consideration of the general guidelines of the project, but also on the basis of the indications and experiences gained from the activities of the previous years. A "flexible" teaching programme was considered as more suitable for the effective delivery of an experimental programme with several innovative aspects.

Each module was to include:

- references of possible common daily experiences to be recalled by the pupils, in relation to the topics to be discussed;
- identification of specific learning objectives pertaining to the module;
- the analytical indication of the knowledge to be transferred;
- the methods, when possible inductive (*experience and evidence based*) to be applied when transferring a specified knowledge;
- a list of teaching support materials with indications on how these should be used.

c) Planning and production of the teaching support materials

The teaching support materials considered necessary for the delivery of each module (materials required for simple experiments, role plays, pictures/illustrations to be studied, etc.) were prepared or produced by the SCIESA working group, and were-presented to and discussed with the teachers.

d) Workshops with teachers

Given that the programme was to be delivered by the regular school teachers, various meetings between the teachers and the SCIESA working group were held before and during the delivery of the programme. The aims of the meetings were:

- to illustrate and discuss the programme, and to make any adjustments considered necessary;
- to give teachers the necessary indications, instruments and any other information (use of teaching support materials, etc.) necessary for the delivery of the module;
- to provide the teachers with a brief introduction to some notions of health science pertaining to the teaching modules (background training for the teachers).

The meetings would be conducted with a "teamwork" approach, before the start of the teaching activity and also during the class activity.

e) Presentation to the families of the scholars of the activity to be delivered

To encourage active collaboration with the scholars's families, a meeting with the families (in most cases, the parents) would be held before the start of the programme to present the project and its objectives. The teachers involved in the delivery of the project, the school supervisors and members of the SCIESA working group were to be present. During the school year, additional meetings would be programmed with the scholars's families, to receive feedback and comments regarding the on-going activities.

f) Implementation of the planned programme

To guarantee a certain “continuity” in the teaching activity (for a total of 40 hours in the school year) delivery of the programme was to be entrusted to the regular class teachers who, however, received continual monitoring and technical assistance from members of the SCIESA working group.

g) Assessment of results

Evaluation of the achieved learning outcomes was to be obtained according to a project which included:

- evaluation of individual learning obtained by the teachers by means of appraisal tests or *ad hoc* class activities;
- meta-analytic evaluation of the knowledge acquired by the scholars;
- meta-analytic evaluation regarding the scholars's capacity of inductive reasoning, their ability to explain their reasoning, and to draw logical and correct conclusions, based on periodic documentation of conversations in the classroom;
- evaluation of the level of appreciation and critical observations by the teachers involved in the programme, the school directors, and the scholars's families.

2. Articulation of the general teaching programme

As previously stated, the general teaching programme was conducted in a flexible manner, and was modified on critical analysis of the activities run in previous years.

The initial part of the programme (*learning to read the book of nature, for what concern the structural and functional organization of the human body*) was delivered during the first two years (years 1 and 2 of primary school), and was dedicated to the environment, environmental problems, and basic concepts of functional anatomy, approached as *"perceptible" anatomy"*, aimed to make scholars to gain awareness of specific experiences of everyday life, as well as of their own body through simple classroom experiments based on the direct observation the human body.

The Modules given during this early part of the programme were:

first year:

- Module 1. *The Environment and Us* (concept of environment and conditions of environmental well-being);
- Module 2. *The human body and movement* (general conformation of the human body and perceptible human anatomy of the musculoskeletal apparatus);
- Module 3. *Relationship and exchange between the human body and the environment* (what goes in and what comes out).

second year:

- Module 4. *The heart and blood vessels* (functional and perceptible anatomy of the cardiovascular apparatus);
- Module 5. *The brain* (the journey of signals).

The second part of the programme (*learning through an experimental approach the fundamentals of body functions*) has been delivered during the third and the current fourth year, by further developing previously treated topics.

third year:

- Module 6: *The senses* (functional and perceptible anatomy of our sense organs);
- Module 7. *A journey into the knowledge. The executive mental functions.* (the brain, is responsible for the central coordination of all complex activities of the organism).

fourth year:

- Module 8: "*The brain and its networks: external with the environment, and internal with the rest of the body*" (a revision and consolidation of the scholars's understanding of problems concerning the environment, and networks)
- Module 9. "*Travelling through a world that cannot be seen, from the organism to the cells and to the molecules*" (transmission of elementary, basic knowledge regarding the structure and function of the cell, the tissues, the molecules and the energy).

The topics covered during the fourth year are described in the present booklet.

<u>The third and final part of the program</u> (*awareness of health risk factors and learning how to counter them*) will be developed in the last year (fifth) of primary school.

3. Activities carried out in the previous phases

In the preliminary phase of the project the following activities were completed:

- elaboration of the general project for the Accademia Nazionale dei Lincei;
- presentation of the project for evaluation and discussion at a national (Accademia dei Lincei, Accademia Medica

di Roma) and international level (the executive committee of the *InterAcademy Partnership for Health*);

– presentation of the SCIESA project to the Fondazione Terzo Pilastro - Italia e Mediterraneo that co-financially supported the programme together with the Accademia Medica di Roma for the first and third years of activities),
– definition of an agreement protocol with the Regional Education Authorities of Lazio for the implementation of the experimental project in a primary school of Rome;
– definition of an agreement protocol with the Istituto Comprensivo Luigi Settembrini for initiating the activities in four first-year classes located in Rome (Via Asmara and Via Novara) and for their continuation for the entire five-year primary school period.

THE DIDACTIC PROGRAM FOR THE FOURTH CLASS

The educational program for the fourth grade (school year 2016-2017) was developed following the methodological approaches of the entire project already mentioned above.
The articulation of the two modules is shown in detail in the sections that follow.

MODULE 8
THE BRAIN AND ITS NETWORKS: EXTERNAL, WITH THE ENVIRONMENT AND INTERNAL, WITH THE BODY

1. EXPECTED LEARNING OUTCOMES

This module intends to recall previously acquired knowledge by the scholars by focusing again on the omni-comprehensive concept of the environment, and to underline the fundamental role of networks, of the exchange via these networks of different elements that constitute a single environment, or even between different environments.

On completion of the module, the scholars will:

- have a more consolidated understanding of the omni-comprehensive concept of *environment*, which is composed of different elements connected to each other;
- understand the characteristics that distinguish different environments;

- understand the nature and importance of relations that are established between different elements pertaining to the same environment, and between different environments (network relations);
- understand the nature and importance of the continual exchanges occurring between different elements in the same environment, and between different environments;
- understand that even the human being can be considered as an "environment" and, as such, one of the bases for its survival is the presence of internal networks which allow the continuity of relations and exchanges between the different elements from which it is formed (the organs and apparatuses), as well as the perception, elaboration and integration of signals coming from external networks.

2. SUBJECT MATTER

The subject content adopted to achieve the above objectives is detailed below (in **bold**, knowledge to be acquired mainly through an inductive approach; in *italics*, the experiences and experiments to be used.

THE CONCEPT OF ENVIRONMENT (RECALL)

The environment is what surrounds us with all of its characteristics, that is those elements that belong to it and contribute to its characteristics (territory, structures, living beings, objects, climatic conditions, emotional and relational conditions, etc.).

– *"Classroom environment" poster: Ask the scholars to list all those elements that contribute to the environment in which they are in (the classroom), and get them to write these elements on the poster under a series of main* *categories (structural elements such as walls, floor, ceiling, doors, windows; human beings and their various roles; animals; plants; furniture and other objects; climatic conditions, temperature, lighting, noise, cleanliness, orderliness, etc.; conditions of air and any possible odours; relationships; emotive characteristics such a joy, sadness, order, disorder,* etc.*).*

- *Assign to each pair of scholars the picture of an environment and ask them to describe it, identifying also the elements that constitute it.*

The environment in which we are in at any moment can be taken into consideration according to different dimensions (close environment and extended environment)

- *"Poster – diagram" of the progressively widening environments in which the classroom is located. Together with the scholars, prepare a "poster – diagram" using concentric circles to indicate close and extended environments in which the classroom is located (classroom, school, neighbourhood, city, region, nation, continent, etc.).*
- *Together with the scholars, identify all external factors pertaining to the environment in which they are in (the classroom) and which can influence the same environment (condition of the building, climate, air, external noise, light, water and electricity supply, waste disposal systems, etc.).*

Some circumscribed environments can be very small

Show the scholars a petri dish with a growth medium (environment where bacteria or microorganisms can live and multiply);

- *Using a shoe box or a jar, construct in the class a habitat and create the appropriate conditions for insects to live and grow.*

In our everyday lives, we pass from one environment to another many times during the day.

- *Show the scholars examples and discuss with them different environments (classroom, house, park, city, country, sea, mountain, etc.);*
- *Ask the scholars to briefly list the different environments that they have visited the previous day;*
- *Ask the scholars how many different environments they know, or have visited either on holiday or when visiting relatives;*
- *Activity: Raising and observing the growth of caterpillars (see teaching support materials). Discuss with the scholars this experience from an environmental point of view, trying to underline the importance that changes in the environment have for the colony of caterpillars (from a natural to an artificial environment), and the consequences these changes may have determined (modification of needs, signals, etc.).*

Each environment presents a specific set of relational or emotive characteristics.

- *Show the scholars a series of images of environments with different relational – emotive characteristics (pleasant-unpleasant, sad-happy, safe-dangerous environments, etc.);*
- *Divide the scholars into pairs and get them to imagine and draw an environment (their bedroom, house, classroom) that contains all those elements necessary to live comfortably during the day (participation in activities,*

requirements for their needs, for play, for their well-being, etc.);

- *Show these drawings to the class and using these, try to design together the "ideal environment", cutting out from the single drawings the appropriate or significant elements. List on the board the elements considered necessary for the ideal environment, dividing these by category (physical space, air, climate, objects, people, food, plants, noise, rules, type of activity, interpersonal relationships, etc.).*

A single environment changes continually

- *Experiment together in a simple fashion changes in the class environment (more or less light, silence, noise; colder or warmer; etc.);*
- *Identify together the possible changes in an environment regarding climate, cycle between night and day, odours, noises, the sensations that we perceive (tranquillity, fear, anger, etc.);*
- *Ask the scholars to identify and note down any changes that have happened in the class, in the school, between their classmates, or in themselves since the previous year.*

The characteristics of an environment can improve or can worsen

- *Ask the scholars to identify those physical and social elements that they believe critical in the "classroom" environment. Discuss which of these elements cannot be modified and why; and which of these can be modified;*
- *Plan and start to put in action a plan to improve the classroom environment and make the proposal to control this over a certain period.*

NETWORK RELATIONS

The concept of networks: a group of various elements, all connected to each other with the aim of exchange.

- *Start the session with the "Ball of Wool Game" (see teaching support materials);*
- *Show the scholars and comment on schematic images of networks (elements connected to each other to "allow" or "impede" exchange) and "non-networks" (elements not connected or connected only partially). The concepts of "connection" and "exchange" are fundamental;*
- *Examples of networks: a child that collects (stamps, football player cards, dolls, etc.) must "network" himself with other collectors to exchange items; telephone networks: many telephones connected to each other to establish contact between different persons; commercial network: many shops connected to each other to exchange orders, goods, information, etc.);*
- *The most evident example of a network is the Internet which connects millions of people, and allows the continuous exchange of information (this is why the Internet is also known as "the World-Wide Web").*

All living beings, be it animals or plants, are constantly *networked*, that is, in constant relationship with the environment (either physical, human, animal or plant) in which they are found.

- *Together, discuss images of relationships between people (the network at home, the network at school, in the playground, in a team game, etc.). Make the scholars reflect that in order to behave correctly in a certain network, a series of information regarding the type of interaction and rules pertaining to that specific network are required;*

- *Get the scholars to discuss how identical signals (e.g. a shout) may assume different significances in different relational network (in a playing field or at home);*
- *Show and discuss a series of images showing animals in a relational network and the different types of exchanges that exist: sound signals (the barking of a dog or the meowing of a cat asking for food, etc.); other types of signals (visual, olfactory, acoustic, tactile, etc.) that let them play with scholars or other animals, to be part of a flock of birds or a swarm or insects, to fly from one flower to another, to attack other animals, etc.);*
- *Show and discuss images of plants in network (sunflowers that orient their flower heads in function of light signals; other flowers that close at night; visual or olfactory signals – colour and odours – that flowers use to attract insects for pollination; tactile signals that allow ivy plants to hold onto trees or other structures to support its growth, etc.).*

Network relationships can be established by quite different means, and can be either positive or negative.

- *Together with the scholars, identify and list on the board the possible elements through which networks are established among humans (visual and auditory messages, physical contacts such as shaking hands or a pat on the shoulder, telephone calls or messages, olfactory messages, etc.);*
- *Again, as a group, identify and list on the board a series of positive networks (play groups, sporting activity, travel, etc.) or negative ones (arguing, quarrelling, fighting or waging wars, etc.).*

In human beings and higher animals, the brain has a central function in establishing and developing relational networks.

- *Refer to the previously acquired notions on the ability of the brain to interpret signals, to connect them, to compare them with information already memorised, to organise thoughts, to elaborate messages, etc (see, Module 5 "The Journey of Signals").*
-

EXCHANGE BETWEEN NETWORKS

An important type of relationships existing between elements within a single environment, or between elements belonging to different environments is that of continually occurring exchanges.

- *Together with the scholars, write down on the board a list of the type of exchanges that can take place between elements that constitute the classroom environment.*

These exchanges between elements from a single environment or from different environments may take many different forms (natural physical substances, artificial physical substances, messages, know-how, customs, opinions, tastes, songs, friendship, emotions, love, hate, etc.).

- *Ask the scholars to look through some illustrated magazines or the web for images representing examples of exchange of elements;*
- *Ask the scholars to write down examples of exchange that they have identified, and assign these to different categories: physical exchange (exchange of food, drink, objects, etc.) social, relational and emotional, etc.*

Exchange can occur by various means.

– *Together with scholars identify some of the various means by which exchanges can take place (vocal instructions, gestures, through visible or invisible connections such as roads, means of locomotion, power cables or phone lines, pipes, people moving, insects that fly, animals that move or are transported, etc.).*

The exchange that takes place within an environment and between different environments are indispensable not only to maintain relationships, but also for life itself.

– *Together with the scholars, prepare a list of common exchanges that are considered important to maintain relationships (verbal exchange, visual exchange, emotional signals, exchange of politeness, etc.);*
– *Again, with the scholars, prepare a list of exchanges that are considered vital for life (air, water, food, etc.).*

THE INTERNAL NETWORK OF THE HUMAN BODY

The human body can also be considered as an "environment", as it contains numerous elements (organs and apparatuses) which are constantly connected to each other and therefore can be considered as constituting a network (internal network).

– *With reference to previously acquired notions, formulate together with the scholars examples of relationships between different organs or apparatuses in the body (circulation of blood, circulation of oxygen, the cycle of nutrients, reflex phenomena, etc.).*

As well as carrying out the function of networking with the environment, the brain receives information (stimuli and sensations) also from receptors distributed throughout the body.

- *Recall previously acquired knowledge regarding the exchange of signals between the brain and receptors present in various parts of the body (see Module: "The Journey of Signals").*

The dynamics of the networks of the human body allow a series of exchanges that are indispensable for life.

- *Get the scholars to sit still in silence with their eyes closed for a few moments, and to concentrate on what they "feel" within their own bodies, and discuss about the feelings they registered;*
- *Ask the scholars to propose a series of signals that may come from their own bodies (stimuli: hunger, thirst, bodily needs; sensations: tiredness, well-being, sickness, pain, itchiness, dizziness, etc.);*
- *Ask the scholars what type of relationships are established by these signals (the relationship of ourselves with our own bodies) and if these sensations (what we feel inside our bodies) have any consequence/relationship with the external environment, or with others in the same environment;*
- *In addition to exchange of signals, ask the scholars if there are any other types of exchange that take place in our bodies and which are indispensable for life (oxygen, blood, nutrients, waste products, etc.).*

Many of the signals that come from inside our bodies can be considered as "alarms", and are useful to make us aware that something is wrong with our body.

- *Encourage the scholars to identify the significance of internal signals: pain (an organ that is suffering); itchiness (something that is irritating the skin); fever, a feeling of* *sickness, dizziness, nausea (I've got some illness); yawning (I'm bored or I'm tired); a feeling of hunger (I need to eat), goose bumps (I'm cold); sweating (it's hot).*

TEACHING SUPPORT MATERIALS

Experience from raising and observing caterpillars.

1. *Where to find caterpillars.* The best time to find caterpillars is in spring and summer. The best place to find them is on their host plants as they tend to live attached to their source of food: they can be found on the leaves of common plants in a garden or in a park. Gather also some leafy branches of the same plants that can be used later as food.

2. *How to raise them.* Caterpillars should be handled with care because they are very delicate. Some caterpillars have hairs that can irritate the skin, and therefore they should not be handled with bare hands. A 1 litre jar can be used to raise caterpillars (not too many in the same jar). The jar can be closed with a piece of gauze fixed with an elastic band. Place a moist tissue on the bottom of the jar to collect the excrement (to be changed every day) and place a leafy branch inside the jar. Caterpillars can be fed using leaves from the plant from where they had been collected: it is quite likely that this will be their host plant. Get sufficient leaves, as caterpillars tend to eat them very rapidly. Keep the jar in a light, airy place but out of direct sunlight. At a certain point the caterpillars will attach themselves to the branch or to the walls of the jar and will form a cocoon: this is the most delicate phase and they should not be disturbed. Try to avoid too much humidity and, if everything goes well, in a few weeks the cocoons will undergo metamorphosis into a butterfly or a nice yellow/brown insect. The duration of the process depends on the initial size of the caterpillars when gathered. Caterpillars of about 1 cm should complete metamorphosis in about three weeks, but this can also vary depending on the temperature of the environment.

The link https://www.wikihow.com/Raise-Caterpillars contains detailed information on how to raise caterpillars.

The concept of networks: The Ball of Wool Game (proposed by Feliziani)

Before starting recreation, each child can be given a small ball of wool (a different colours for each child). One end of the thread should be tied to the leg of each child's desk. Explain to the scholars that during play time they can play as usual, but moving around the room with care and winding their own ball of wool around the desk that they have chosen to play at. Explain that at the end of recreation we will see what has happened. Some scholars will have moved more than once, whereas others may have stayed in the same place.
Normally, a series of webs will have been created in various areas of the class which will give visible indications of where exchange has taken place. This may be a good starting point to commence the module on networks.

The brain receives information also from receptors distributed throughout the body.

Game *"The Map of Sensations*" (from the book Di Pietro M., Dacomo M., 2007, *Giochi e attività sulle emozioni.* Ed. Erickson, p. 53, modified): Useful in recognising the distinction between sensations at a physical level and those at an emotional level.
Materials
A large white sheet of paper, to be attached to the lower part of a wall.
Post-it stickers in two colours;
Prepare a list of physical and emotional conditions (photocopy the list);
Write these on the two-coloured Post-it stickers (according to the type physical/emotional).

Procedure
Using a marker pen, draw the outline of a child leaning against the sheet of paper;
The teacher will form two groups and will give to each group the two-coloured Post-it stickers. The teacher will read from the list in turn a physical and an emotional condition and ask the scholars to attach the corresponding Post-it to the outline. "In what part of the drawing would you attach your *Post-it*?";
In the discussion accompanying this activity, the teacher should not intervene to modify the choice of the child but ask him/her to justify their choice, and either making a counter proposal or asking any other child agrees;

In the discussion following completion of the diagram, the teacher should indicate the significance of the different colours and ask if the stickers with the same colour have anything in common, and if we can give a name to the two categories. Elicit from the scholars also if we can decrease or increase any of these (pleasant or unpleasant) sensations, and how.

MODULE 9
TRAVELLING THROUGH AN INVISIBLE WORLD
From the organism to the cells, and to the molecules

Identification, consolidation and sharing of common and everyday experiences of scholars.

Introduce the topic by inviting the scholars to recall some events of their lives, and – in connection with it – what they have learned during their work with the SCIESA Project. What happened that time when you hurt or cut yourself? What came out of the cut or graze? *(blood).* What have we learned about blood? What there is in blood? Discuss with the scholars to elicit their knowledge about blood, which is not only a liquid, but also contains cells, such as? *(red blood cells).* In the SCIESA project, have cells ever been mentioned? What ones? Discuss with the scholars to elicit that there are cells in the brain which are called *neurones*, and perhaps they will also remember that muscles contain other types of cells called *muscle cells*. Were you are able to see the red blood corpuscles in the blood that came out of your cut? Were you able to see neurones when you examined the brain? Where you able to see muscle cells in the pig heart that you were shown? Why not? Why are we not able to see cells? Discuss with the scholars until they reach the conclusion that cells cannot be seen because they are too small. How can we examine, or have a better view of something that is very small? Discuss with the scholars until you reach the conclusion that very small objects can be enlarged by using lenses or microscopes.

1. EXPECTED LEARNING OUTCOMES

On completion of this Module, the scholars will have acquired the following knowledge regarding the cell:

1. Every living organism is constituted by a certain quantity of matter which has a fundamental structural organisation based on *cells*.
2. Every living being is formed from either one cell (e.g. bacteria), or a group of cells which are functionally coordinated between them.
3. The cells that constitute all living beings are usually of a similar and very small dimension. The great differences in dimensions seen between living organisms (e.g., between an elephant and a human) is not due to the dimensions of the cells but rather to their number.
4. Due to their small dimensions, cells cannot be seen with the naked eye. To observe and study them, we have to use special devices such as the *microscope* which is used to magnify them.
5. The cells that form the animal species have all the same general organisation. In all these cells the following elements can be found:

   (a) the presence of a thin layer, called the *cell membrane* which envelops the entire cell and physically separates the contents of the cell from the external environment. It also regulates the exchange of materials between the cell and outside. So, we can understand that the cell receives its nutrients through the cell membrane;

   (b) the presence of a round structure known as the *nucleus* which is immersed in the *cytoplasm*, a matter that fills the space between the nucleus and the cell membrane. The nucleus contains all the information necessary for the cell to function, that is its *genetic patrimony*. Basically, this is rather like an instruction manual which the cell consults continuously to carry out most of its functions. This information determines the characteristics of each species, and each single individual. This genetic patrimony is transmitted from one generation to the next.

(c) the presence of intracellular mechanisms which allow the cells to grow and multiply, allowing the body to grow. Indeed, living beings grow by increasing the number of cells, which divide repeatedly. Cellular multiplication also allows living beings, that have a limited lifespan, to continue existing on earth due to their capacity to reproduce and give origin to new organisms.

(d) the presence inside the cells of energy stored within molecules, that the cells use to undertake vital operations that take place within them. As all processes, even those necessary to maintain the cell in life need a sort of constant "push", that is *energy,* for this to occur.

6. As all matter, the cell is formed of tiny little particles which are so small that they cannot be seen, even with a microscope. These particles are called *molecules* which in turn are made of even smaller particles known as *atoms*.

On completion of this module, the scholars will be able to associate every single living organism (simple, such as a bacterium or a yeast, or complex, such as a human being) with organised structures which are invisible to the naked eye (the cells), and a series of molecular processes which take place within the cell. They will also understand the cell is able to continue living by extracting from the surrounding environment energy and useful substances for its growth and multiplication.

2. SUBJECT MATTER

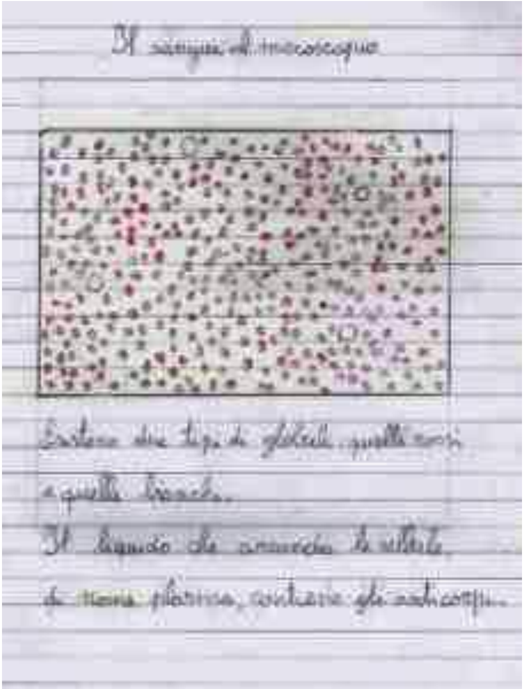
The subject matter of the module is hereby detailed (in **bold**, the concepts or notions to be developed using an inductive teaching methodology; in *italics*, the experiences to be performed).

1. Cells and tissues*

To study how living organisms are organised, it is not sufficient to observe with the naked eye. We have to use instruments that can magnify what we observe.

Let the scholars experiment using a magnifying glass, so that they can see small objects (a very small screw, etc.) magnified, and observe them in greater detail. Let them examine a blood smear (see Teaching Support Materials*:* Observing objects using a magnifying glass).

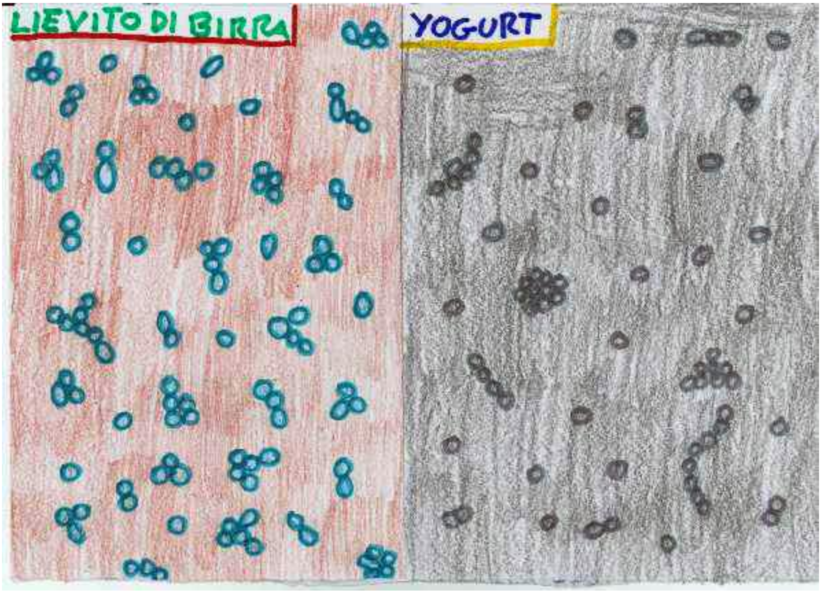
- *By noting that it is impossible to identify red blood cells using a magnifying glass, introduce the scholars to the <u>compound microscope</u> (which, for simplicity we will refer to as <u>microscope</u>) and its use. Tell the scholars that the microscope has a very powerful capacity to magnify objects, much greater than that of the magnifying glass, and get them to observe the same objects with the stereomicroscope. Let then the scholars to observe the blood smear under the microscope, so that they may appreciate that by using this instrument they can identify the red blood cells.* (see Teaching Support Materials: Observing objects using Microscope).



Unicellular organisms

Through the observation by a microscope of easily obtainable unicellular organisms, such as brewer's yeast or yoghurt lactobacteria, the concept that living organisms are made of cells can be easily introduced, and general information regarding the organisation of these small units can be attained.

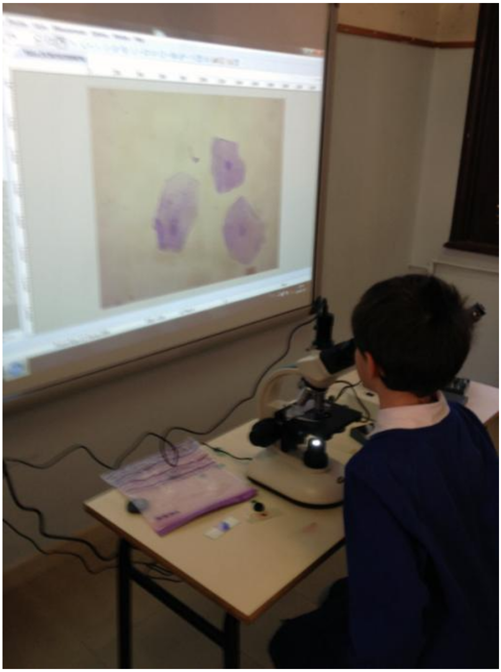
- *What do we notice when we look at a preparation of brewer's yeast under the microscope? (*see Teaching Support Materials: Observation of unicellular organisms*).*



Multicellular organisms

Even bigger living organisms are made of cells. The bigger the organisms, the larger their cell number. The cells present in bigger organisms are fairly similar to those that form the brewer's yeast we have examined under the microscope: they have an outer coating (the cellular membrane), a nucleus that looks like a small ball placed at the centre of the cell, and the cytoplasm, which fills the space between the cellular membrane and the nucleus (see Teaching Support Materials: Observation of pluricellular organisms).

- *In a stained smear of human oral mucosa, as in the epithelium of an onion we will be able to observe that the cells are well separated from the environment that surrounds them due to the presence of an outer membrane. We cannot see this membrane by a microscope such as the one we will be using because the cell membrane is very* *thin, but we can hypothesise its presence. The nucleus is distinctly visible.*



The nucleus appears as a small sphere within each cell. Indeed, the nucleus is an extremely complex organelle. Discuss with the scholars the complexity of the functions that the cells of our bodies carry out. What to do red blood cells do? (transport oxygen). And what do the cells that make up our muscles do? (they contract). And what about the nerve cells? (they transport signals to muscles to make them contract). But how do the cells in our bodies manage to do so many different functions? Get the scholars to reflect on this complex issue by interacting with them, and compare the cell nucleus to the hard disk of a computer. To play different video games on a computer, what do you have to do? (you have to change *programme for each different game). Is it reasonable to think that the cells also have different available programmes, and they choose which type of cell to become or how to function?* Using this possible analogy, explain that this is exactly what happens in the cells of a human being. When a child is still inside the mother's body and is so small that he could be studied by a microscope, the few cells present are almost all identical. Their nuclei, however, contain a variety of programmes that each cell can selectively activate to differentiate into a different type of cell (muscle, nervous, blood corpuscles, etc.) and to carry out different functions. The nucleus, therefore, is like an instructions manual for the building and functioning of the organism. This is the genetic patrimony, that cells consult and use continually during the development of the organism, and when carrying out most of their functions. This genetic patrimony is transmitted from one cell generation to another, and is constituted by fixed parts which characterise each species, and a variable part which allows each individual to appear differently. This variable information determines many characteristics of the individual, such as the colour of the eyes, hair and skin, temperament and so on. The genetic patrimony is also able to undergo slight reprogramming based on information that the cell receives from the environment.

Show the scholars how in multicellular organisms, cells interactions are well-organised (see Teaching Support Materials: Examination of a tissue under a microscope*)*.

2. Molecules

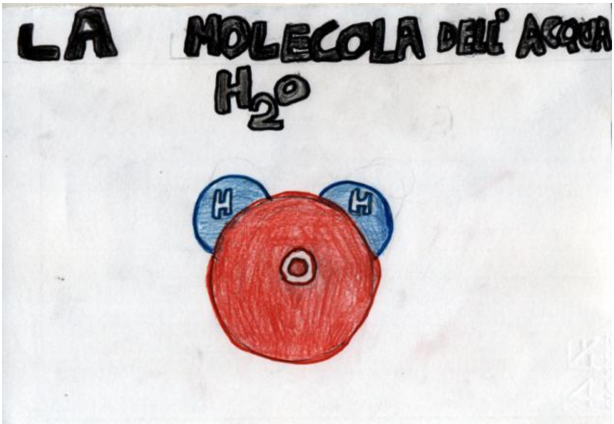
Molecules are so small that they are not even visible using a microscope, but their existence can be easily proven.

To demonstrate the existence of particles known as <u>*molecules*</u>*, which are not visible to the magnifying systems that the scholars know (magnifying lens and optical microscope), carry out the experiment of sugar in a solid state and in solution (see teaching support materials). The scholars should understand that the sugar which we saw in a solid-state is indeed made up of a large quantity of particles which are not visible singularly. Indeed, when we dissolve it in water, the sugar is still present, as shown by the fact that the water becomes sweet, but the particles that it is made of – the sugar molecules – are no longer visible as such.* (see Teaching Support Materials: Molecules are other entities smaller than cells).

Conclude by explaining to the scholars that the molecule is the smallest part of a substance that still maintains all of its characteristics (in this case, the sweetness of sugar). All matter is composed of an incredibly large number of molecules: these are all identical if they belong to the same substance, as in the case of sugar; have different sizes and forms if they come from different substances.

There are very many different molecules, of different sizes and shapes.

How can we see what a molecule looks like? Through complex physical chemistry experiments, we are able to understand what molecules look like, and by using models, we can represent how they are organised.



Show the scholars models of molecules, for example sugar (glucose), or water (see teaching support materials). Discuss with the scholars the complexity of these molecules, and try to get them to the conclusion that these same molecules are composed of other even smaller particles. Indeed, molecules in turn are made up of smaller structural units known as <u>atoms</u>*; these are held together by very strong bonds to make molecules.*

Do you think that a molecule of sugar and a molecule of salt are the same, or are they different from each other? (they cannot be the same because they have different tastes). *How can we understand in what way they differ from each other? If we look at the models of the molecules then we can try and get an answer.*

Let's compare a water to a sugar molecule (show the two models of molecules). How are they different? (in the number, type and arrangement of the spheres in each molecule). *What do these small spheres represent?* (atoms). *Explain to the scholars that the atoms are held together by very strong forces to form molecules. And so, what determines the different sizes of the molecules?* (The number of atoms that they contain).

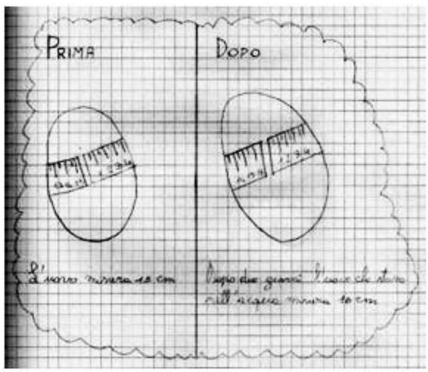
Show the scholars models of various molecules, in which the atoms are represented by different coloured spheres. For example, show the models of sugar (glucose), and of an amino acid (glycine), a fundamental component of proteins. In many cases these small molecules link up to other molecules to form gigantic molecules. (see Teaching Support Materials: Molecules can have different dimensions).

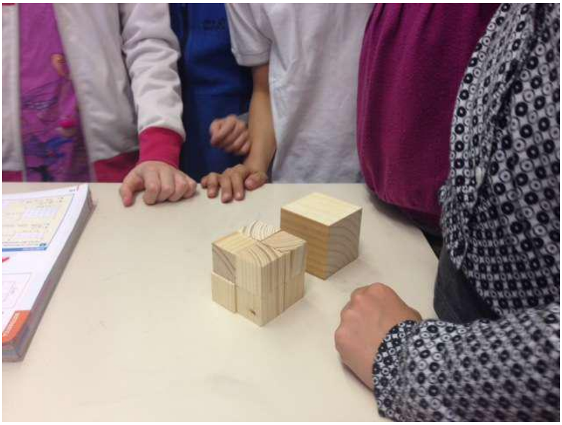
3. Molecules and cells

A cell communicates with the surrounding environment through the membrane which surrounds it (the cell membrane).

How do we take in the various substances we need for life? The scholars should reach the conclusion that this is done through the mouth, therefore only through a small portion of our external surface (if we are thirsty we cannot drink by putting our hand or foot in water!).

How can a cell take in what is necessary for life (for example, oxygen)? It would also need mouths. And where should these be? (on the surface). *Therefore, would there have to be lots of little mouths on the surface of the cells? How could we confirm their existence? We could try and do this by studying the behaviour of a chicken egg. This is an ideal analogy for its dimension and properties, and can be used to experiment the permeability of water through the egg envelope, which functions analogously to a cell membrane* (see Teaching Support Materials: The cell communicates with the environment through the membrane that surrounds it).





By comparing two wooden cubes of equal volume, a solid one and another divided into 8 small cubes, the pupils verify the fact that division provides additional surface. The experiment is illustrated in details in the Teaching Support Material.

The many little “mouths” on the surface of the cell are facilitated in their functioning by the presence of a series of tiny “hooks” which are capable of recognising and binding specific needed molecules present in the surrounding environment, and of helping in their transport through the membrane.

The cell membrane is selectively permeable to molecules

To exist, a cell needs its membrane. One fundamental aspect of this consists in the cell’s capacity to control the passage of substances (excluding some, and leaving others free to transit) between the external and internal environment (and vice versa). *To form an opinion regarding the regulatory capacity of the membrane, we can try and construct a large artificial cell visible to the naked eye: a small dialysis bag is formed by a material that permits the passage of small molecules, but* *impedes the passage of larger ones* (see Teaching Support Materials: The cell membrane is selectively permeable to molecules).

A living organism grows by increasing the number of its cells.

As a cell becomes larger, its food requirement also increases (the same as adults eat more than scholars). When the volume of a cell increases, its surface membrane also increases and therefore there will be greater numbers of “mouths” to satisfy its nutritional requirements. *But, is this sufficient for the cell to continue to nourish itself adequately?. Would it not be better for a growing cell to divide into two cells, each with the same dimensions as the original cell? Let's go and do some calculations.* (see Teaching Support Materials: For living organisms it is advantageous to increase their cell number rather than cell dimension.)

After completing this experiment, it can be useful to discuss with the scholars the previous issues along the following lines. Given that cells receive nourishment from the external environment through the cell membrane, cellular division would be the most advantageous mechanism as it allows the quantity of membrane of each cell to remain constant, and thus the possibility of an adequate supply of nutrients: indeed, cellular division also creates new membranes. The alternative hypothesis (when a living organism grows, cells do not divide but increase in volume) would be less advantageous as cells would start to have a progressively inadequate surface area respect to the volume, and this would cause an insufficient supply of nutrients. Therefore, we can conclude that the growth of a body is a process whereby its cells increase in number rather than in dimension.

4. Energy

In this world, nothing can be obtained without paying. The concept of energy.

Do you think you would be able to carry out all your daily activities without eating? And you think that cars would be able to run without petrol? Or would a lightbulb be able to shine if there was no electricity? And if there was no gas or flame on the stove, would we be able to cook an egg? Discuss with the scholars the following.

What do food, petrol, electricity, and heat have in common? (they all contain energy, carry energy*). Energy is present in various forms, but all these forms cannot be interchangeably used by the various users that we mentioned before (man, car, light bulb). Animals are able to use energy contained in food* (due to the digestion of food inside our bodies, the energy that is produced lets our muscles to carry out their activity, like running, or is used by the organism to grow, etc.); *petrol takes energy from the tank to the engine of a car* (which can then move faster or slower depending on how much petrol is used over a period of time)*; electricity transfers energy to the lightbulb which then lights up and illuminates the room; gas, by burning on the stove with a flame, releases thermal energy which can cook food, and even heat up the environment.*
(see Teaching Support Materials: Examples of energy)

Can energy be seen? (just like gases, energy cannot be seen). *How do we know it exists? Discuss with the scholars that we can see its presence through observing what happens when this is transferred from a sort of "tank" where it is stored, to a "device" where it is used.*

What happens when energy from a battery is transported along long metal wires (electrical energy) and into the filaments of a *lightbulb?* (the filaments overheat and emit light and heat which is their way of transforming energy. Indeed, when you get close to a lightbulb, you can also feel the flow of energy in the form of heat).

Elaborate with the scholars the concept that the changes indicated above (such as the lightbulb when switched on ; a stationary object which starts moving ; the transformation of an egg from the raw to the cooked state; the growth of a child in time) all take place in the presence of carriers of energy.

In the context of life-related phenomena, discuss with the scholars the central role played by energy which is contained in what we eat. Energy, as well as the material (molecules) that the organism needs to grow and to carry out its functions, derive from the transformation of the food that we eat. It is precisely due to the complexity these transformations, that this process is called metabolism*, an old word which means change or transformation*. This topic will be further developed in Module 10: The flow of energy from the sun to food: Food as a source of molecules and energy.

TEACHING SUPPORT MATERIALS

Background Information for the teacher

The microscope is composed as follows: an eyepiece, an objective lens, a specimen support platform, and a source of light. The *stereomicroscope* (SM) has two sources of light, one incident and one transmitted; incident light that illuminates from above is used to examine solid three-dimensional objects; transmitted light, which comes from below and through the object, is used to study objects which are transparent to light. The stereomicroscope (SM) also has a zoom objective.

Materials available for microscopic observation, and their uses

Interactive white board (IWB)
Camera CMEX-3
Stereomicroscope SMZ 143-N2GG
Cordless Microscope 2823 (this microscope has a rechargeable battery and can be used without electricity cables when the batteries are fully charged).

To use the stereomicroscope:

- place the camera in the central hole of the head of the stereomicroscope and connect it to the IWB
- switch on the IWB
- switch on the stereomicroscope with the incident light source
- verify that the images visible in the eyepiece are also projected onto the IWB

To use the microscope:

- place the camera in the central hole of the head of the microscope and connect it to the IWB
- switch on the IWB
- switch on the microscope
- verify that the images visible in the eyepiece are also projected onto the IWB

Please notice

Many experiments are detailed below, and to run all of these would probably require more time than is available. The teacher therefore will have the opportunity to select those experiments considered as being most appropriate. *We suggest that activities be selected according to the list of alternative experimental observations given below*.

- *Observation of unicellular organisms*

Choose between yeast and infusoria (if yoghurt used, it might be difficult to obtain clear preparations)

- *Observation of multicellular organisms:*
  Choose between: cells taken from the internal wall of the cheek and onion epithelium
- *The cell membrane is selectively permeable to molecules*
  Choose between the potato experiment and the lettuce experiment
- *The dialysis tubing experiment will be conducted in class by a member of the SCIESA working group*
- *Examples of energy*
  Choose between the inclined plane and the wind-up spring mechanism toy experiment

Time allowing, additional experiments described in the present Teaching support materials *and not itemised in the above list may be done, also in consideration of their simplicity of execution.*

Observing objects using a magnifying glass

This is considered very appropriate for the scholars's learning due to their high level of involvement in the activity.

Required materials:

- small objects attached by adhesive tape to cardboard, e.g. a screw (supplied in the kit). The scholars can also be asked to source some small objects to be examined, e.g. a pin, an insect, etc.
- magnifying glasses with source of illumination (supplied in the kit).
- microscope slides with stained blood smear (supplied in the kit).

Let the scholars experiment using a magnifying glass, so that they can see small objects magnified, and observe them in greater detail. Get the scholars also to examine their own skin or bodies using the magnifying glass.
Ask the scholars if they are able to observe the red blood cells in a blood smear by using the magnifying glass (this is not possible).

Observation of cells and objects using the microscope

Required materials:

- the same small objects as before, including a blood smear.
- a microscope slide with the letter "**e**"
- wooden spatula
- toothpicks

- microscope slides
- cover slides
- physiological solution
- 6 cm Petri dish
- dropper bottle
- disposable gloves
- toluidine blue stain diluted to 2% in physiological solution, in a dropper bottle
- safranin stain in a dropper bottle.
- absorbent paper

Observation with the stereomicroscope

Place on the SM support (with incident light source) the sheet with the screw (or other small objects), and using the SM zoom function projected on the IWB, show how powerful the magnifying capacity of the microscope is when compared to a normal magnifying glass. Now place the blood smear onto the stereomicroscope. Turn off the incident light source and turn on the transmitted light source and the scholars will understand that the single cells are visible in the blood smear, differently from when they examined the same specimen using a magnifying glass.

Observation with the microscope

Continue to explain that to study cells, the magnification obtained by the stereomicroscope is still not sufficient, and it is necessary to use another type of microscope, which can magnify even more than the SM. One of these is the *microscope* . Move the camera onto the other microscope, turn it on and take the slide with the tiny letter "**e**" and focus the objective on the letter starting with a magnification level of 4x (the lowest level of magnification). We will note that the image that is obtained from this microscope is different from that with the stereomicroscope, because the new image is the reverse of the original (left/right, above/below). Progressively increase the degree of magnification. The scholars will probably be surprised by how much the letter **"e"** can be magnified.

Observation of unicellular organisms

Some living organisms are made of a single cell, e.g. ***yeast cells***. These can be prepared and observed by using the following procedure. The teacher should first show how the experiment is to be run, and then get the class to repeat it, after dividing the class into groups of five. Give each group a petri dish containing a small quantity of brewer's yeast which the scholars will dilute with abundant physiological solution. Using a dropper, they will take some of the solution and place one drop on the microscope slide. After putting on disposable gloves[1], *the teacher will add one drop of toluidine blue, or safranin*. The teacher will then place a slide cover on the preparation and excess liquid will be removed using absorbent paper. Then the slide will be placed on the microscope, and the image projected onto the IWB. By progressively increasing the magnification, the scholars will be able to observe the form and dimensions of the yeast cells, and will also be able to see the small organelle (the nucleus) inside.

Other unicellular organisms can also be observed easily. As an alternative, and time permitting ***lactobacteria of yoghurt*** can also be used. The procedure is simple and it is explained in the video available at the following link: https://www.youtube.com/watch?v=IAikQ7J8U8o.

Briefly, always in groups of five, each group will place a teaspoonful of yoghurt in a cup and will add two or three spoons of water to dilute it, mixing well the cell suspension. Using a small wooden stick (toothpick) dipped into this suspension, they will place a drop on the microscope slide. The teacher will place a coverslide over the preparation and will remove any excess liquid using absorbent paper. Then the slide is placed on the microscope and the image is projected onto the IWB. Observing carefully, first magnifying at x4, then at x10 and finally at x40, the scholars will be able to see single tiny (punctiform) bacteria or aggregates of bacteria in the yoghurt.

Other unicellular organisms are easily sourced and studied, such as *Infusoria*, protozoa that live in freshwater ponds.

Required materials

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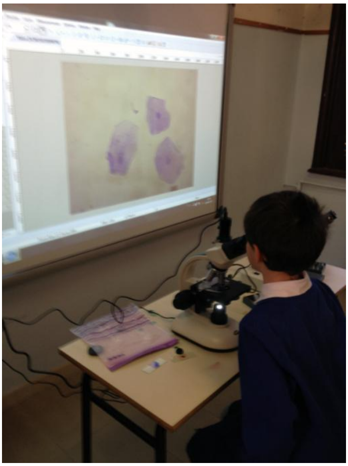
[1] Please note: Histological stains can be difficult to remove from the skin and clothes; in addition, the alcoholic Safranin solution is flammable and can irritate the skin and eyes.

- water from a pond
- petri dishes.

Briefly, divide the class into groups of five. Each group will collect a sample of water from a pond, or from a jar in which a handful of hay has been soaking for a while in water. The scholars will then place many drops of this water in the petri dish. The petri dish will then be placed under the stereomicroscope, and projected to the IWB by the teacher. The unicellular organisms present in the water from the pond (the *Infusoria* are a little larger than the unicellular organisms observed in the previous experiments, they can be seen to move and have different shapes. These are therefore more easily identifiable as organisms.

Observation of cells sourced from multicellular organisms

The observation of ***cells scraped from the inner wall of the cheek*** requires a simple procedure which is easily carried out after watching the video at the following link:
https://www.youtube.com/watch?v=i2x3MKSJez4.



Although this is neither risky or painful, to facilitate the execution of this experiment, the teacher will take the sample from him/herself.

Briefly, place a drop of physiological solution on a microscope slide; delicately run a wooden spatula along the inner wall of the cheek to scrape a few cells from it. The biological sample collected will be diluted by the drop of physiological solution already on the slide and a coverslide will be placed on the sample. Repeat the operation to prepare a second slide. On this slide, add a drop of toluidine blue to the cell suspension; after 20–30 seconds cover the specimen with the coverslide. Remove with absorbent paper any excess physiological solution or stain. Examine the specimens under the microscope connected to the IWB with progressively increasing magnifications. Observe first the unstained slide, then the stained one. By comparing the two slides (stained and unstained) the scholars will understand that the cells are transparent and the stain highlights the various cellular structures, e.g. by colouring with greater intensity the nucleus rather than the cytoplasm.

Onion epithelium is a very good example of plant tissue: the cells show a multifaceted and regular outline, and are arranged in close proximity - typical of epithelial cells – so that no intercellular spaces are observable. In plant tissue, cell borders are easily observable due to the presence of a cell wall (absent in animal tissue), which overlies the cellular membrane.
The procedure to observe the epithelium of an onion is easily reproduced by watching the video at the following link
https://www.youtube.com/watch?v=cmnhBJKfvNw.

The teacher should first explain and show how the experiment is to be run, and then get the scholars to repeat it, after dividing the class into groups of five.

Required materials:

- a medium-sized onion for every 20 scholars
- a small brush for each group of five scholars
- 6 cm Petri dish
- tap water
- 30% glycerol
- single-use gloves
- safranin stain in a dropper bottle

Procedure (see the link mentioned above)

1. The teacher will cut the onion into four segments, giving one to each group. The scholars will conduct the following part of the experiment wearing gloves.
2. By taking one petal and breaking it, the scholars can source the transparent thin layer (epidermis) present on the concave side.
3. The remaining part of the onion petal can be discarded.
4. Place the epidermal layer in a petri dish containing tap water.
5. Add to the second petri dish 3 to 4 drops of stain (safranin).
6. With the brush, transfer the epidermis from the water to the stain solution.
7. Wait until the epidermis gets stained (1 to 5 minutes): the ideal result should be neither too faint nor too dark.
8. Again, using the brush, transfer back the epidermis to the first petri dish containing the water, to remove any excess stain.
9. Place 2 to 3 drops of 30% glycerol on a clean slide.

10. Using the brush, transfer the epidermis to the slide. If it tends to fold over then try to flatten it using the brush. Cover it with a coverslide.
11. If necessary, press the coverslide delicately with a needle to remove any air bubbles.
12. Dry any excess liquid using absorbent paper.
13. Transfer the slide to the microscope. Observe the specimen. The scholars will be able to see a large number of polygonal cells in close proximity (easily visible as the stain will have coloured the cell walls, a thin cellulose layer that coats the cell membrane), the densely-coloured nucleus, and a faintly coloured cytoplasm.

Get the scholars to wash their hands.

Using the same process, the ***cell of Elodea (waterweed)*** can be easily observed under the optical microscope. This is an aquatic plant which is easily sourced from fountains, or in the school garden. In this case and without any staining agent, under the microscope we can see transparent cells which contain green chloroplasts which move in an orderly and circular fashion (the technical term is *cyclosis*) because these organelles do not occupy any fixed position in the cytoplasm and they are positioned near the cellular membrane to capture as much light as possible.

Observation of a human tissue under a microscope

Required materials:

Histological preparation of skin

Place on the microscope the histological preparation of skin and project onto the IWB at a low magnification level (x4). Tell the scholars they are observing skin tissue observed under a microscope, and therefore greatly *magnified from what they can see with the naked eye. Elicit from the scholars what role they think our skin tissue may have in protecting us from the external environment. What can you see? Is it made of only one or of many layers?* (there are two layers). *Do the two layers appear similar or different? And how are they different?* (at this level of magnification, the scholars may not be able to give the correct answer. They might respond that one layer is more densely coloured than the other). *But are you able to see the cells?* (no). *Why?* (because we have to magnify it even more) *Now increase the magnification (x10). Now can you see the cells? Are they all the same?* (no, the cells are different). *Are the cells organised the same way in the two different layers?* (No, in the upper layer, the cells are more numerous and are very close to each other to form a protective barrier (the epidermis); in the lower layer (the dermis), there are fewer cells and they are separated by various kinds of material that contribute to give consistency to the skin). *But are you able to recognise the various parts of the cells? Increase the magnification (x40) and once again observe the cells. What can you see?* (the scholars may now be able to recognise the basic elements of the cell - nucleus and cytoplasm - and may also note that there are different types of cells).

There are smaller elements than cells, which are called <u>molecules</u>

<u>Required materials:</u>

- sugar
- still mineral water, 500 ml
- plastic coffee cups
- models of molecules

Using a spoon, get the scholars to take a small quantity of sugar. Can we see it, touch it, taste it? What does it taste like? Now we place a small quantity of sugar in a little water and stir it. What happens? Can we still see the sugar? Why can't we see it? But if we can't see it, does that mean that it isn't there anymore? How can we check if it's still there? By taking a sip of the water we will taste that the water is sweet and therefore we can deduce that sugar is still present in the glass. In other words, the sugar is still present even if we cannot see it (at least by the naked eye).

Now let's place a drop of sweet water under a magnifying glass. Can we now see the sugar? (the scholars will still not be able to see anything). *If we put a drop of sweet water on a slide, and examine it under the microscope, will we be able to see something?* (no, even under the microscope we are not able to see the sugar in the sweetened water). *Why is this?*

Discuss with the scholars to reach the conclusion that the thing that gives the sweet taste to the water is something much smaller than the size of a cell, and we can't see this even with a microscope. These tiny entities which are able to create a sweet taste are called molecules.

The same experiment can be repeated with other substances that have specific tastes and can be dissolved in water, e.g. cooking salt.

Molecules can have different dimensions.

Required materials:
Three-dimensional models of molecules

- Show three-dimensional models of molecules, in which the atoms are represented by spheres of different colours (each colour representing a different type of atom). Preassembled models of water, sodium chloride (common salt), glucose (sugar), glycine (an amino acid) are provided. Explain to the scholars that the atoms are held together by very strong forces to form molecules. In many cases these small molecules link up to other molecules to form gigantic molecules.

The cell communicates with the surrounding environment through the membrane that surrounds it (the cell membrane).

The Egg Experiment.
Required materials:

- a dozen chicken eggs
- two transparent plastic cups
- a cup
- water
- vinegar
- salt
- a kitchen scale, or
- 20 cm of string

What can we do to see if water can pass through a cell membrane?
First, we have to find a cell big enough that can be observed without a microscope. What cell can we use? One possibility would be to use an egg, which for the purposes of this experiment can be coarsely equated to a single large cell and which can be useful to illustrate this phenomenon. If we touch an egg we notice that it has a hard outer shell. But if we break the

shell and empty the contents into a cup (being careful not to spill anything), we observe that there is a very thin and resistant membrane attached to the inner side of the shell. For the purposes of this experiment, this membrane behaves exactly like a cell membrane, in that it selectively allows transit of small molecules, like water, but not of large molecules, like proteins. Therefore, if we were able to remove the hard outer shell of the egg without damaging this membrane then we would be able to use the egg as if it were one large cell.

How can we remove the hard shell without damaging the underlying membrane? This can be done by placing the egg in a glass full of vinegar. We will see that a series of bubbles form around the shell, which is really carbon dioxide, which is generated by the chemical reaction between the acetic acid contained in the vinegar and the calcium carbonate in the hard shell. Gradually over a period of approx. 3 days, the hard shell will be dissolved. Now we can delicately wash the egg to remove any calcium residue of the shell and we will see that the egg is no longer hard but soft and surrounded by a membrane which, for what concerns the passage of water, behaves just like a cellular membrane. Now we have one "large single cell" to use for our experiments.

How can we see if water can pass through the membrane of this egg-"cell"? By simply immerging this shell-free egg into a glass full of tap water. After a couple of hours, we will see that the egg has increased in volume and we can check this by weighing the egg on a kitchen scale (brought from home) or by measuring the circumference of the egg before and after the experiment. This increase in volume is due to the passage of water from the glass through the membrane of the egg.

Can we understand what mechanism allows the water to pass through the cell membrane?

Let's suppose that it is the different quantities of molecules dissolved in the liquids inside and outside the cell (i.e., in the environment external to the cell), which makes water move through the cell membrane. To see if this hypothesis is true, we have to put the egg into different environments, containing different concentrations of molecules. We can do this by placing our egg cell in a glass containing only water, and in another one containing water and much salt (or sugar). The water without any salt will create a *hypotonic solution*, whereas the water containing a lot of salt will create a *hypertonic solution*. What is the difference? In the hypotonic solution (in our experiment, tap water) *there are no molecules dissolved in the water (few solutes) or at least there are very few, whereas in the hypertonic solution* there are *many molecules* dissolved in the water (*many solutes*). Let's now put one shell-free egg in the hypotonic solution, and another one in the hypertonic solution: after some hours, we will see that the egg immersed in the *hypotonic solution has increased in volume.* The water in the glass has indeed moved through the membrane and into the cell. *The egg immersed in the hypertonic solution has become smaller* because water contained inside the cell has moved to the outside solution. If now we invert the position of the eggs and put the one previously in the hypotonic solution (that had increased in volume) in the hypertonic solution, we will see that after some hours this becomes smaller. Oppositely, if we transfer the smaller egg, previously emerged in the hypertonic solution, to the container containing the hypotonic solution, we will see that this increases in volume after a few hours

Analysis of the experiment:

- water can move through cell membranes. Thus, the cell is able to drink!
- water moved through the membrane passing from an environment where there were less molecules of solutes (in our case, less salt) to where there were more.
- water therefore moves through the cell membrane from a hypotonic environment towards a hypertonic environment: this is as if the molecules present in a hypertonic solution "pull towards themselves" the water present in the hypotonic solution. This phenomenon is called *osmosis.*

The experiment is explained in detail at the following link:
https://www.youtube.com/watch?v=SSS3EtKAzYc

The Potato Experiment

This experiment, just like the following one, demonstrates how water is able to pass through the tissues of an organism by osmosis.

Required materials:

- one potato
- two cups
- a spoon
- a knife

Fill the two cups with tap water, and in one of them, add a lot of salt and stir well with a spoon to dissolve it. Cut the potato in half, and hollow out the inside of each half using the spoon. Place the two halves of the potato in the two cups so that the potato floats on the water. Carefully add some salt to the potato floating in the normal tap water (without salt), and some water in the potato which is floating on the salty water. Be careful not to make the half potatoes sink. After about 30 minutes you will note that the water contained in the potato floating on the salt water has disappeared, whereas the potato that contain salt now contains (salty) water.

Analysis of the experiment:

i) the potato has acted as a cell which allows the passage of water through its walls;

ii) the water moves through the wall from where there is less salt to whether is more. Thus, the water contained in the potato floating on the saline solution has disappeared, whereas water has entered into the salt-containing potato . As we said previously, this phenomenon is known as *osmosis*.

The experiment is explained in detail at the following link:
https://www.youtube.com/watch?v=SzOk5wwaJG8

The Lettuce Leaf Experiment

Required materials:

- two lettuce leaves
- three transparent plastic cups
- water
- salt
- a spoon

Fill two plastic cups with tap water, and in one of these add some salt and stir well with the spoon. Leave the third plastic cup without any water. Place a fresh lettuce leaf in each of the three glasses plastic cups. During the following days, it will be appreciated that the leaf placed in the plain tap water is still turgid, whereas the leaf placed in saline solution becomes limp, similar to the leaf placed in the plastic cup without any water, but to a lesser degree. As in the experiment of the potato, this phenomenon is due to the transfer of water caused by osmosis from a region of lower salt concentration to a region of greater concentration. The leaf immerged in the saline solution becomes limp because water has passed from the leaf to the salty water in the plastic cup, whereas the leaf in the plain tap water remains turgid because water has moved from the plastic cup to the leaf, substituting the water that progressively evaporates; the leaf in empty the plastic cup becomes limp because the water that evaporated was not replaced.

The experiment is explained in detail at the following link:
https://www.youtube.com/watch?v=IO0uZJuyeVA (starting from 4’30”).

Is it only water that can pass through the cell membrane, or other molecules do this also?

Experiment with a dialysis bag, as a model of a very big cell

Required materials:
2 glass containers, labelled *a, c*
2 dialysis bags with molecular weight cut-off 12.000
physiological solution (a solution of water and sodium chloride)
red stain (safranin) solution in physiological solution
myoglobin in physiological solution

- *Fill the 2 containers (***a***,* **c***) with saline solution; add a magnetic bar to each container.*
- *Fill the dialysis bag corresponding to container* ***a*** *with the* ***red stain*** *in saline solution. Immerse the bag in the container. Activate the magnetic stirrer at a low speed.*
- *Fill the dialysis bag corresponding to container* ***c*** *with* ***myoglobin*** *solution. Immerse the bag in the container. Activate the magnetic stirrer at a low speed.*
- *After some time you will see (***b***) that the colour has passed from the dialysis bag to the container, while* ***(d)*** *the myoglobin has remained trapped within the bag.*

Place on two microscope slides respectively one drop of the solution with myoglobin and one with the staining agent: microscopic examination in both cases will show no evidence of elements with any definite shape.

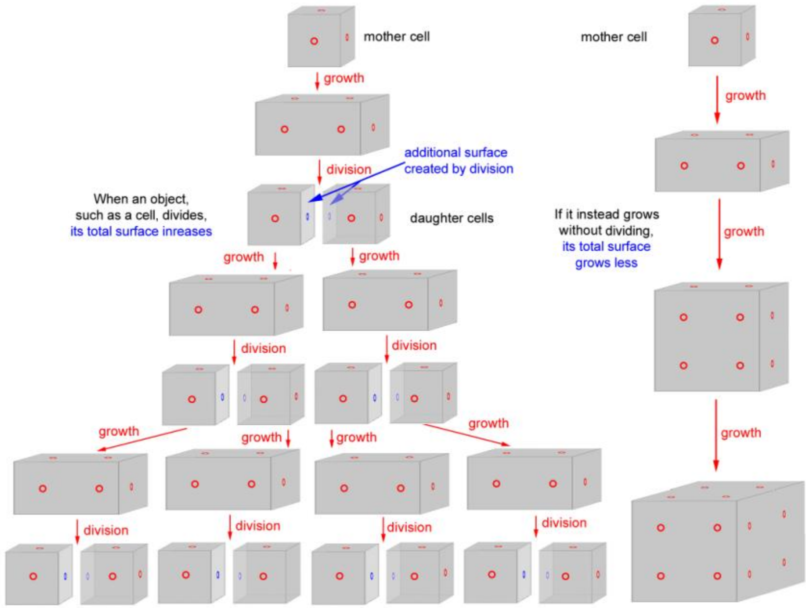
Analysis of the experiment. There is something that can be transferred from one compartment to the other, whereas some other remains trapped within the dialysis bag. This is something very small because it is not visible to the naked eye, nor under the microscope. What we are dealing with is a molecule. But why one of these molecules was able to exit from the bag, whilst the other was not?

To give an explanation to what has been observed, we can ask the scholars if we can consider that the wall of the bag is similar to a cellular membrane, as it contains a large number of tiny holes through which the molecules can pass? (The scholars will probably reply *yes*, rather like what they see when a teabag placed in a cup of water colours the entire cup). But why do the molecules of the stain pass through the membrane, while those of myoglobin do not? Discuss with the scholars until they reach the conclusion that molecules can be of different sizes and evidently the one that do not pass through are bigger than the holes in the membrane. Elicit from the scholars the following conclusions: i) that myoglobin molecules are much larger than the red staining agent that was used; ii) that the cell membrane behaves exactly like the dialysis bag and is selectively permeable to molecules.

The cube experiment showing that for a living organism it is advantageous to grow by increasing its cell number rather than its cells dimensions.

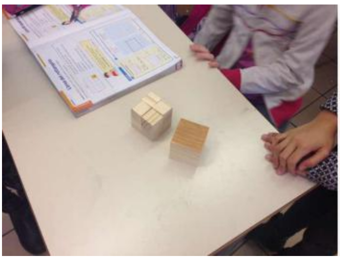
Required materials:

- 1 cube of wood, 6 cm, and 8 cubes of 3 cm each
- paper cuttings that perfectly cover the outer surface of the large cube and of the eight small cubes



Let us imagine that an individual grows because its cells divide giving origin to new cells of the same dimensions as the mother cells. Let us now go and see what happens at the level of each single cell (see figure above left). For simplicity, cells are represented as cubes, showing a “mouth” on each face, drawn as a small circle. After every division we see that *a new membrane is formed* (the new “mouths” are blue-coloured). As cells progressively increase in number, the dimension of this organism increases, but at the same time the number of “mouths” in each cell remains constant. Let us now see what would happen if, on the opposite, an organism was to increase its dimensions by simply increasing the volume of its cells. If we were to follow the growth of a single such cell, we would see that the number of “mouths” would indeed increase with growth, as compared to those present at growth start, but such increase would be much less than what would happen if the cells were to divide (see figure above right). If we compare the two methods of growth, in the case of increase in size of an organism through cellular division we see the presence of many cells identical to the mother cell, and each with the same number of “mouths” by which they can receive nourishment. Growth without cell division shows

that a lower number of “mouths” is formed and this eventually causes the cells to die because of inability to receive adequate nourishment. Indeed, growth without division does not allow the formation of enough membrane to support the increase in volume.
Let’s us now perform an experiment to see whether this conclusion is true.
In this experiment, the larger cube represents an organism formed from a single cell that has reached its final dimension without division. The eight small cubes instead represent another organism of the same final dimension but formed by cellular division. Ask the scholars to verify that the overall volume of both organisms is identical. (The scholars can position the small cubes together to see that they occupy the same volume as the large cube). Let us now ask the scholars to verify if there are differences in the surface area in both cases, by giving them them paper cut-outs, representing the external surfaces of the large cube and of the eight small cubes. By comparing the area occupied by the cut-outs of the eight smaller cubes with that of the larger cube it is easy to understand that the surface area of cells formed by cellular division is greater than that of a single cell of greater dimensions. Thus, they may now appreciate that cell division provides the cells of an organism with many more additional mouths available for their nourishment.



ENERGY

In this world, nothing comes free. The concept of energy

Background information for the teacher
All living organisms share a common energy currency: ATP
All transformation that we observe in the world - even the simplest such as the deformation of a spring, or the movement of a ball, or the increase in temperature of air near an illuminated lightbulb - are in relation to the

transfer of energy from one carrier to the other (e.g., from a spring-wound mechanism to a ball). In practical life, we need plenty of energy, which we buy using our money: to light our houses at night, we use electricity which we pay for in euros; to cook food and heat our homes, we use gas which we also pay for in euros; we go to the supermarket where we buy food and pay for it in euros. Therefore, we can see that the currency that we need for most of our external daily activities is the euro, which can be used to buy many of the things that we need. On the other hand, all the activities that take place within our bodies and which are indispensable for life (e.g. heartbeat, moving muscles to breathe or to walk, eliminating waste products through the kidneys, thinking and so on), are paid for within the cells primarily by using another type of currency which is known as ATP (adenosine triphosphate), due to its chemical composition. Breaking a molecule of ATP into two liberates the chemical energy which is stored in the bonds that link the two parts of the molecule together, and this energy is used to carry out a vast number of different biological processes. For example, signals can be transmitted along nerves due to the energy stored in ATP, which is transformed into electrical energy which travels along the nerves; muscle contraction depends on the transformation of the chemical energy contained in ATP into mechanical energy, and so on. It should be noted that only a portion of the energy liberated from the broken chemical bonds that is stored in ATP molecules is used for the required action (e.g. for walking); one part (approximately 50%) is dissipated in the form of heat which contributes to maintain the body temperature at 37°C, and which in turn is dissipated through the skin into the external environment.

In conclusion, **energy** is the physical quantity that measures the ability of a body or of a physical system to perform **work**, regardless of whether this work is or can actually be performed. To perform a work it is necessary to use a **force**. Energy can provide such force.

Examples of energy

A spring can store and transfer energy

Required materials:

- A spring wound toy car
- Ping-pong balls

Using the spring wound car, get the scholars to turn the key to wind up the mechanism. Once placed on the ground, the car will move straight until it reaches an obstacle. If we place a ping-pong ball in front of the toy car, then this will be hit and made to move. This process will continue until the car stops, because the spring has unwound and contains no more energy.

Discuss with the scholars the origin of this energy that allowed the series of events to take place (by turning the key to wind up the spring, the child transferred energy which was inside his/her muscles to the spring. The spring stored this energy, which for simplicity we will define as elastic energy: when the spring is released, it relaxes rather like an elastic. When the car is placed on the ground, the spring starts to unwind and makes the wheels of the car - which are connected to the spring - rotate, thus making the car move forward. In this way, elastic energy is transferred from the spring to the car wheels, which makes the car move (in ordinary language, the car acquires mechanical energy). When the car collides with a stationary obstacle such as the ball, we see a process of transfer of energy from the car to the ball. The events that we have just seen therefore are the consequences of a flow of energy which originated from muscular contraction, was transferred into the spring of the toy car, from there to the wheels of the car and then finally to the ping-pong ball. Both the toy car and the ball stop when they use up all their energy.

Possible questions: where did the energy come from that was in the muscles? The source of this energy is the food that human beings eat in order to live and to carry out all their daily activities. But where and how is energy found in food? (we will see this in Module 10, *From the sun to plants and animals: the flow of energy that allows us to live and grow and food as a source of energy and molecules*).

Transformation of gravitational energy into kinetic energy

Required materials:

- Wooden board
- Ping-pong balls
- Table to record the experiment

Recordings of the distances covered by the ping-pong ball as a function of its starting position on the inclined plane

	high	low
Average		

Obtain a wooden board about 60 cm long and a ping-pong ball. Create an inclined plane by leaning the board on a support of about 20 to 30 cm. Place the ball at the highest point and let it go

What do we observe? When it is released it is first stationary, and then it begins to roll down faster, but then it stops after some metres. Measure with a measuring tape the distance travelled by the ball.

Discuss: Why did the ball start to move when we released it on the inclined plane? (for the same reason if we leave something in mid-air, it drops to the ground because of the force of gravity. Because the ball cannot drop directly to the ground, it is forced to fall along the inclined plane).

Ask the following: But when the ball is stationary, held by us on the inclined plane, does it have this energy “inside”? (Yes, because as soon as you let it go it starts moving). This form of energy that is stored within an object is called *potential energy* and is liberated only when conditions change.

Let's place the ball now half way down the inclined plane and let it go.

What do we observe? (the ball starts to roll down the inclined plane like above, but it travels a shorter distance). Why? The reply is probably not intuitive. Discuss with the scholars: Does it take more energy to throw a ball 10 m or 5 m? The reply will be unanimous: “10 metres!”

Let the scholars reach the conclusion that if the ball travelled further when it was placed at the top of the inclined plane, evidently it had greater potential energy (due to the force of gravity) than when it was placed half way along the inclined plane. Ask the scholars to reflect on the fact that, as the ball descended along the inclined plane, potential energy was transformed into movement. The higher the starting point of the ball is, the greater the energy and the longer its journey.

Chemical energy

Required materials:

- Empty 500ml mineral water bottle
- Vinegar
- Sodium bicarbonate
- Balloons

Put 25 ml of vinegar into a bottle, and add 2 teaspoonfuls of sodium bicarbonate; close the bottle as soon as possible using a balloon. Over time, the balloon will start to inflate.

Let's analyse what happened: when we mix a solid (bicarbonate of soda) with a liquid (vinegar), gas (carbon dioxide) is formed. This experiment shows a typical chemical reaction, or in other words the result of the breaking of bonds that hold together the atoms of one or more molecules and the formation of new bonds between atoms, to form new compounds like the gas carbon dioxide. But how can we check that the gas is developed from the reaction between the bicarbonate and vinegar, and is not produced by either the vinegar, or the bicarbonate only? Ask the scholars to try and develop some type of control experiment. This consists in placing vinegar and bicarbonate of soda separately into different bottles closed with the balloon and waiting to see the results. In both cases, no gas will be formed. This control experiment will confirm that the two compounds need to react before gas is released. Even energy that is found inside food is stored in the form of bonds which bind together single atoms or molecules, and is called chemical energy. This is similar to energy stored in a spring that has been wound up, as it cannot be seen but it is always ready to be transferred to the surrounding environment (chemical energy also is potential energy, which means that it is stored energy that can be liberated, showing its presence in appropriate conditions in which it may generate “work”). The balloon was inflated by the energy associated with the gas liberated from the reaction between the vinegar and bicarbonate, just like it would by the energy associated with the air breathed by a child, pushed by the muscles of the respiratory system.

Chemical energy is found inside food and is liberated in our organism by a process of combustion, rather like other combustible substances that can burn and free stored energy into the surrounding environment in the form of visible flame and heat. Food behaves rather like combustible material and can “burn”, but the cells of living organisms would not be able to tolerate great quantities of uncontrolled heat as they would die. For this reason, there are some mechanisms inside our cells which are able to progressively release small doses of energy contained in food, and these doses are packaged and stored in molecules of ATP. We have to remember that in every process of combustion not only do we need the fuel but this process has to take place in the presence of oxygen. Therefore, in living organisms the metabolic processes – which are a type of combustion process which take place 24 hours a day – oxygen has to be introduced from the external environment by continual respiration, because our body cannot store this gas. In other words, without the presence of oxygen, any fire would be extinguished; and without respiration, organisms would die because its cells would not have sufficient energy to carry out any action. In the phenomenon of intracellular combustion, energy is released but without creating any flame; and at the same time waste material is produced mainly in the form of carbon dioxide (eliminated from the body with expiration) and water (eliminated mainly by the kidneys, and by sweating).

WORKSHOPS WITH TEACHERS

The teachers involved in the project were highly qualified and were able to adopt a pedagogical approach based on active learning rather than on simple transmission of knowledge. The experience and skills acquired by the teachers during the first three years of the SCIESA project made them aware of the expected learning outcomes and capable of implementing the inductive methodology which characterises the project.

The teachers actively participated in meetings of the SCIESA group and also contributed in the elaboration of the teaching modules. These meetings were mainly focused on contents (knowledge to be transmitted), and the practical approach to be adopted to achieve these goals (organisation of the subject matter, timeframe for delivery of concepts, teaching materials to be used).

On occasions, following specific requests by the teachers, this “working together” methodology was implemented by the presence in class of one or two members of the group of experts. This also helped to standardise ways of interacting with pupils when carrying out the practical activities and during class discussions. The contribution of teachers was also important in gathering documentation on the abilities shown by the scholars, such as to remember and properly connect experiences, to ask relevant and reasoned questions, to explain and justify statements, to use counter-factual arguments, to express personal views.

In the working group experience the teaching methodology adopted has produced excellent results, since the teachers have responded well to the group work approach, and have been able to give contributions concerning both contents and method.

One critical issue that came out, not easy to be solved, was the barely sufficient time the could be assigned to this type of activity. Indeed the teachers' teaching loads are substantial and very little space is left for innovative and complex type of activities such as that proposed by the SCIESA project.

EVALUATION OF COMPLETED WORK

PREMISE

The materials gathered can be subdivided into two categories:

1. documentation regarding the implementation of the models, used for *analysis of the processes*;

2. results from the proposed evaluation activities and used to assess the *level of achievement of the objectives*.

The *first category* includes the following:

- Log book;
- Conversations in class;
- Input from teachers;
- Opinions of parents.

This documentation, which brings together the views and opinions of all participants in the project, gives us information to evaluate the level of appreciation and feasibility of the modules, indications for the fine-tuning of the expected learning outcomes and subject matter of the modules, and finally, for the training of the teachers.

The *second category* includes the following:

- Analysis of scholars's written questions at the end of the school year;
- Analysis of the conceptual map for the Module Environment and Organisms and their relations;
- Individual written texts “I have learnt that …”

The analysis of these materials provides valuable information regarding the efficacy of the modules, particularly regarding if appropriate to the scholars's level of understanding, of values and their cognitive and meta-cognitive capacities to transfer this knowledge to their own lives.

ANALYSIS OF THE PROCESS

1. From the log-books

As in previous years, the teachers recorded their views regarding the didactic Modules through the compilation of a “log-book”. For each activity, information regarding the implementation, efficacy and reaction of the scholars were recorded.

Concerning the Module “The Brain and its Networks”, the following information was noted:

the observation of a petri dish with a bacterial culture was not conducted by any class;

some other proposed activities were not conducted to varying degrees between the different classes. For the greater part, this regarded activities involving the use of images or discussions in class to elicit various points of view or to comment on the class activities;

similarly, there was some between-class variation regarding the efficacy of the proposed teaching activities. In general, activities involving describing or commenting images, group collaboration on the blackboard or on posters and consolidation of acquired know-how received lower levels of appreciation;

activities regarding practical experiences, play activities or those involving games or revisions received the highest levels of appreciation;

the activity of raising caterpillars also received a very high score. The activities regarding the body's internal network connectivity and preparing the “poster – diagram” on the environment were also well-received;

the teachers in some cases have modified the proposed didactic activities.

Regarding the Module “The Cell”, it is to be acknowledged that the contents of the first activity, involving observations of the “invisible reality”, which included getting the pupils to use with some confidence the microscope, was a challenging and difficult task for the scholars's level of experience. On top of this, some technical problems concerning connections between microscope and video projector did worsen the problem. Consequently, the pupils had difficulties in comprehension, which were partly anticipated by the teachers in the preparatory phase. The presence of SCIESA experts did alleviate to some degree the organisational and tutorial problems encountered. The activity using the dialysis tube proposed to highlight the exchange of solutes between aqueous solutions of different concentrations was not carried out.

As all classes had previously participated in a programme for schools organised by the Zoological Museum focusing on laboratory activity, the previous observation of microorganisms at the Museum was useful in overcoming the above critical points. This activity was very effective and highly appreciated by the scholars who showed great curiosity and sometimes surprise. Furthermore, the Interactive White Board facilitated the web search for images and videos to amplify the scholars’s direct experience on the microscope and generate discussion and questions.

One of the classes also visited an exhibition on DNA which was open in Rome during that period; this had a very positive fallout effect on the scholars's overall experience.

Aside from the general critical areas outlined above, the teachers found some of the activities pertaining to the Modules to be very effective. All classes found the activity with the chicken egg devoid of its hard shell (an easy operation) very interesting and useful in providing the fundamentals to understand the concept of the permeability of membranes.

As confirmed by the teachers, the experience with the cubes – proposed to highlight the relationship between volume and surface area for different-sized cells – was useful in achieving the cognitive learning objectives in classes IV B and C but was only partially successful for the other two classes.

The construction of models of molecules by Class IV B was useful because in the construction phase some scholars were able to understand that the atoms (the coloured balls) were connected to each other to form molecules of different dimensions.

The teachers also signalled the following critical areas:

"The concept of the nucleus which transmits information appeared very complex" (IV A);

"In general, the scholars were able to understand that different forms of energy create movement. It was less evident that an "isolated" body can also contain energy" (IV A);

"The scholars considered that there was no difference between force and energy: they are the same thing." (IV C);

"The scholars were not able to distinguish between the various forms of energy" (IV B).

2. Class discussions

Class discussions of about two hours duration took place twice each term, in the presence of both the teachers and the SCIESA experts, who made notes of the salient topics of discussion. Only in Class IV D were all work sessions pertaining to the project documented with written reports made by the teachers. The following is a summary of the observations from the written reports, organised by topic of conversation.

Memories of the activities of the previous year

As in previous years, at the start of the school year a short review of how much of the SCIESA learning objectives from the previous years the pupils recalled was conducted (in this case, with Teaching Modules 8 and 9). Active discussion at the class level was also encouraged.

From the analysis of the written reports, the results were similar to those seen in previous years: the scholars had a more vivid recollection of the practical activities (e.g., they often spoke of the experience with the egg without a shell, the activity of the potato, or the experience at the Zoological Museum). In particular, one child made the following remark: “I discovered things that I would never have imagined being able to see”. Frequently some of the scholars talked about different phases of an experience but demonstrated uncertainties when asked to explain the purpose of the activity or what it aimed to demonstrate. Furthermore, some scholars seemed unaware of the logical progression that connected the various activities pertaining to the Module, or only some scholars were able to verbalise their level of comprehension. The memories that they expressed were generally fragmentary. This occurred despite the classwork conducted under supervision of the teachers which included written and spoken re-elaboration of the activities, and sometimes consolidated through drawing activities.

It is interesting to note that the scholars recalled various activities from previous years (Module on Senses, the “bottle that breathes”, the candle that is extinguished if covered with a jar, the activity to represent neural networks). The scholars had vivid memories of the experience of the second year when they were able to see and touch the organs of real animals (heart, brain).

Observations on caterpillars

A jar containing some small leafy branches of a rose bush and a caterpillar is brought into class. The jar was left in the class to allow the scholars to observe the growth process of the caterpillar. This experience was well-received by the scholars. The teachers started interesting discussions with the scholars. The atmosphere in the classroom was very stimulating and animated, sometimes even a little chaotic. The scholars were very taken with this novelty. They made observations regarding how light and air can reach the jar, how to keep the jar supplied with water and food, the form of the excrement, the form of the caterpillar’s body and how this eventually transforms into a butterfly. The teacher divided the class into small research groups (each of three scholars) to examine the following: 1) How do caterpillars eat? 2) How do they breathe? 3) Where do they live? 4) How do they move? 5) How do they create the cocoon? 6) How do they reproduce? 7) How long do they live for? The same teacher then introduced the complex concept of “metamorphosis” which the scholars demonstrated to understand, explaining that this means “to change in appearance”. The hypothesis made was that the caterpillars will become butterflies.

This activity lasted for some time and was explained by means of a story in the form of a cartoon. Following this, the scholars of the same class raised two different types of caterpillar (one from a rose bush and another brought to class by a child) in different habitats: one on rose leaves and the other on lettuce leaves. It was observed that the caterpillar found on the rose leaves did not eat lettuce and the scholars concluded that each caterpillar has its own habitat. As this activity continued, the scholars understood that to survive, caterpillars need air, food, light, and an adequate temperature.

The caterpillar activity was conducted in all classes, but this did not always generate the same level of enthusiasm. The scholars in one class showed little curiosity and appeared uninterested in the activity.

The process of constructing a habitat

A class discussion was held with the scholars regarding the components of the ideal “class habitat”. In one class the scholars identified elements that were not only the most obvious concrete features (furnishing, objects, space, the quality of air, etc.), but also other elements such as people, a comfortable climate, a pleasant feeling, the activities conducted in class. One child noted the necessity of “rules”. The list of desired elements pertaining to the “class habitat” not only contained those related to improving functionality, but also elements such as colours, odours, play, music, temperature and even emotional and inter-relational elements.

In another class the teacher presented a series of images of different types of habitats, and the scholars identified the ideal habitat as a forest. Each child made some drawings of certain elements pertaining to habitats (tree, stream, flowers, birds, etc.). and these were assembled to make a forest.

Another class worked on the change of the habitat in relation to the seasons, and in particular to autumn. The teacher got the scholars to read some texts, and then projected on a screen some images and then ask the scholars to write down their thoughts. The scholars were asked the following: “What is nature?”. Some answers: grass, mushrooms, the sea, the plant kingdom. One child stated that nature is all that is not artificial. The teacher introduced the concept of ecosystem and the food chain. According to one child, ecosystems are environments that contain living and non-living elements, connected to each other through close and interdependent relations. Various scholars intervened demonstrating some knowledge of the concept of food chains, the difference between autotrophic and heterotrophic organisms, the diverse needs of different species of plants, adaptation to environmental factors. Later, the scholars also spoke of their experiences with domestic pets; this discussion was useful in highlighting the needs of living organisms and environmental factors which go beyond nourishment (affectionate relationships with people, cuddles, etc.).

Comprehension of the concept of networks

To clearly understanding the concept of networks and the nature of the exchanges that take place, a virtual classroom including all its components was created on the Interactive Whiteboard.

Encouraging the active participation of the scholars, the various characteristics of the virtual classroom were discussed, and the differences between this virtual classroom and a real one. Thus, the concept of network that characterises in different ways both virtual classroom and a real one was identified. With the help of the teacher, the scholars exchanged opinions to reach a definition of a network as a grouping of contacts with the final goal of exchanging information and of communication. The group discussed the possibility if similar networks also exist in nature. Different opinions were expressed regarding if similar networks exist in the plant kingdom. Some scholars maintained that plants cannot communicate with each other while others observed that there is continual exchange between plants and the rest of the environment. Plants exchange oxygen with the atmosphere and absorb mineral salts from the soil as well as energy from the sun.

The teacher invited the scholars to focus on the concept of exchange, and some of them were able to formulate examples to illustrate this concept. The scholars also discussed the possibility of a network being interrupted and some of the class tried to identify some examples from their everyday lives to illustrate this.

Knowledge acquired on cells and their functions

The scholars of Classes IV A and IV B of via Asmara went to the Zoological Museum where they participated in a workshop on the cell. They were asked to prepare a microscope slide (muddy water) and observe this first through a magnifying glass and then through a microscope. They were very enthusiastic when they were able to identify an amoeba. They also looked at leaves and flowers in the stereomicroscope, and later were able to observe some unicellular organisms as well.

In discussing this experience, the scholars showed some knowledge regarding the cell and its functions from previous class activities, but some doubts and perplexities came out as well.

When the teacher asked why it was useful for the cell to be so small, some scholars said that its small dimension allowed the cell to nourish itself more effectively and to access even very tiny spaces. This is the reason why cells tend to multiply rather than growing in dimension. Indeed, some scholars recalled the activity aimed to show how the surface area of a large cube was much less than the sum of the surface areas of a series of small cubes of the same volume. The connection between the relatively greater surface area and the greater possibility of exchange – and consequently, the absorption of nutrients – at the level of the cell membrane was, however, not immediately clear.

The scholars recalled the experience with the egg to demonstrate the existence and the function of the cellular membrane. Reference was also made to the experiment with the potato (process of osmosis).

Additional topics of the discussion elicited by the teachers regarded the following:

the significance of different forms of cells;

the relationship between cell division, consequent increasing of the number of cells and growth of the organism;

the functioning of the process of osmosis;

the lack of a relationship between the dimension of an organism and the dimensions of the cells from which it is generated;

the various functions that unicellular organisms can carry out.

Understanding what molecules are

By inviting the class to observe the “food pyramid”, and “what plants and animals are made of” posters, the teacher introduces the topic of molecules.

When elicited to imagine what the molecules are like, some scholars replied that “they are like small balls”. When asked to draw their impressions of what molecules are like, the scholars drew a molecule of water (a sort of Mickey Mouse head with two large ears) because they had already seen this image in schoolbooks and had previously built a model of the same molecule.

The representation of the imagination through drawing is a very difficult process. Perhaps some scholars did not have a clear image of the water molecule in their minds.

When continuing the discussion, the scholars demonstrated their understanding of the differences between the main classes of molecules used as nourishment by human beings.

Knowledge of nourishment and comprehension of the alimentary function

On the “Food Pyramid” poster, many foodstuffs were indicated accompanied by texts explaining their relative nutritional value. Three words were highlighted: Balance, moderation, and variety. The scholars explained the meaning of these words: “Don't eat either too much nor too little”, “Don't always eat the same food”.

The class that visited the Zoological Museum also participated in some activities regarding nutrition and the composition of various foodstuffs. The scholars had recollections of these activities, the names of some molecules, and their differences. In reply to questions regarding why foodstuffs provide energy, the scholars formulated various hypotheses: “So we can run, so we can grow”; “To make us strong because food reaches all parts of our bodies, the blood, the muscles and this is what gives us energy”; “My mother says: eat, otherwise you won't be able to pay attention in class.”; “If you don't eat, you won't even be able to stand.”

The scholars were asked if they believed that the human body steadily required a certain quantity of energy as some organs (heart, lungs, etc.) are always functioning. Also, in this case there were different answers: “It depends if during the night you move, because then you will be using up some energy. You use up energy because your heart is always beating.”; “Perhaps from the outside we don't notice, but inside everything is always moving, even if it doesn't use up a lot of energy. I kick a lot in my sleep. Inside me there are also other forces.”; “If you do artistic gymnastics, you grow more, but if you do it every day then you stop growing.”

The topic of growth was then introduced. The scholars were aware that this process is continuous and regarded the entire body. Some of the scholars talked about individual differences and variables (pathological, genetic, alimentary) which condition this process. The question regarding what can stop the growth process arose; the scholars attempted to formulate some hypotheses: “My brother's teacher does artistic gymnastics and he is very short, because he was sick and so he didn't grow very much”; “You don't have to grow in height, the important thing is age. Growth also depends on how you are born.”

Comprehension of the concept of energy

After the experiments run in class regarding the concept of energy, each child made a drawing and wrote some words about “energy”. In the discussion the followed, some scholars demonstrated to understand that different forms of energy can be used to produce movement, and movement is not possible without energy. The different forms of energy were labelled as follows: “pulmonary”, “mechanical”, “force of gravity”, “muscular”. Reading a textbook later, the terms geothermal and electrical energy were also introduced, as well as the forces that these forms of energy may generate. In response to the question whether it was the force or the energy that produces movement, the scholars seem rather confused: “The energy is contained within the force”; “the sails of the windmill accumulate the force of the wind in energy”; “the solar panels of a caravan give energy to turn on the lights, the fridge, and the air conditioner. Without energy there is no movement”.

The scholars are not able to answer why an eraser, when used to cancel writing, tends to get hot. The topic of energy is introduced once more, in particular “pulmonary” energy because the scholars had carried out the activity with the toy car pushed along by the air expelled from an inflated balloon. The scholars all agreed that the movement of the toy car was caused by the reaction of the air being expelled from the balloon, but they still did not understand the distinction between force and energy.

Emotions and relations with the entire organism

A class discussion was held regarding signals that the body sends, also in relation to the various emotions that we feel. Some of the scholars’s answers were significant: “Like when we run when someone knocks on the door. But who is it? It's the heart”; “The heart beats strongly when we do sports or when we are afraid”; The heart also beats strongly when we are happy”; “If the heartbeat is really strongly then you can have problems”; “The various parts of the body communicate with each other”; “The brain understands... but things happen that we don't even realise”; “I noticed when my mother is angry with me, even if she is kind with others”.

In brief, detailed examination of these class conversations give conclusions similar to previous years’: the scholars had better recollection of practical activities, and in many cases, they were able to explain the various phases of an experience, but were uncertain when explaining the objectives of such activities and the nature of the phenomenon to be demonstrated. Furthermore, they seem unaware of the logical progression connecting the various activities that were part of each Didactic teaching Module. In other words, they were unable to verbalise their level of comprehension. Memories that were expressed were generally fragmentary, despite the teacher-guided oral and written re-elaboration of the activities, and the use of drawings to illustrate the various activities.

3. Opinion of teachers

The teachers reported that the classes showed different levels of retention and interest for the previous year’s modules: Class IV A particularly appreciated the activities regarding the senses; Class IV D found the activities concerning the brain processes particularly interesting. Furthermore, the five new scholars in Class IV D did show great interest in what their fellow classmates had to say about the SCIESA project activities.

This element was referred to during the first meeting of the school year with the teachers, and can be considered as being a positive element: the initiative of printing the “booklets” (annual summaries of the SCIESA project activities) was well received by the scholars, who felt listened to and considered.

The scholars also demonstrated to appreciate the participation of “external people” (SCIESA experts) in class. In addition, the parents of the Via Asmara classes asked for copies of the “booklets”.

On presentation of the Module “Travelling through an invisible world”, some teachers expressed doubts regarding the scholars’ level of comprehension regarding the concept of energy, and the relationship between nutrition and energy. Regarding the scholars’ memories of the SCIESA activities, one teacher commented that the scholars had some difficulty in understanding the relationship between the class activities and the phenomena. It was agreed that this was a problem that should merit some reflection in the future.

4. Opinions of parents

There was greater participation by the Via Asmara school parents than Via Novara’s. Many parents reported that following the visit to the Zoological Museum, the scholars began using microscopes that they already had at home, but that had never been used.

It appeared evident that frequently scholars did not tell their parents about activities in class, even if these activities were interesting. It was true, however, that some scholars asked the parents to repeat the class activities at home. This probably happened because – as indicated by the teachers – the scholars showed greater interest in experimental part of the activities.

It was noted, however, that, when invited to express their opinions and give information that might help to contribute to the evaluation of the effectiveness of the SCIESA project activities, parents gave very little useful information apart from a few exceptions.

ANALYSIS OF PRODUCED WORK

level of achievement of the objectives

1 – Analysis of scholars's written questions at the end of the school year

As in previous years, towards the end of the school year the scholars in Via Asmara Class IV spontaneously asked to make a box to gather the questions on what they had learnt during the SCIESA project. The scholars built a box and labelled it “Scientific Questions...?” This was considered indicative of the scholars's attitude towards the acquisition of knowledge.

This type of activity was also implemented by teachers of the other classes. The Via Asmara classes were brought together in a joint session and shared questions and answers.

Examining the questions formulated by the scholars of the four classes showed that the total number of questions was greater than the number of scholars in the classes, that the questions were very pertinent and for the greater part showed a certain "authenticity", as they regarded plausible questions and reflections. The questions focused on the various topics dealt with within the modules (the cells, molecules, the environment) but also other events or phenomena familiar to the scholars in their daily lives. A certain characterisation in each class was noted, probably because the questions related to the most recent class discussions regarding the subject matter of the modules. Class IV C show great interest for illnesses, the agents that cause them, and how to combat them; Class IV B questions concerned DNA; Class IV D asked many questions regarding the relationship between organisms and the environment; Class IV A questions were more varied and had no pertinence to personal experience.

To highlight their ability of conceptualisation, the questions were divided into five main categories.

A – *Factual questions* interrogating on the state of things or facts, and usually formulated as follows: "what is…", "how much is…", "why does…" , "what is … made of" , "where is … found" , "is it more ...." , "how long ..…" , "what is the difference between … and ….''; (e.g.: Are both lungs the same? How many times does the heart beat in a minute? What is a cell? What is an atom? What does DNA look like? How big is an atom? Is blood a tissue? What is worse, chickenpox or measles? What is most dangerous, bacteria or viruses?).

B – *Functional questions* or those regarding processes or the functioning of things, on the dynamics behind events, on scientific procedures and usually formulated as follows: "what is..... for”, “why is it important for...”, “how is it that....”, “what happens if....”; (e.g.: What are proteins used for? How is DNA extracted? What causes meningitis? How do bacteria become stronger? How are molecules identified? Why do we need sleep? Do two different cells form new identical cells?).

C – *Hypothetical questions* interrogating alternative possible events, or the consequences of a hypothetical event, and usually formulated as follows: “what happens if ...”, “if.... then why....”, “can .... happen”; (e.g.: If I prick myself with a needle and blood comes out, how many millilitres will I lose? Why don't we eat mould if it is also medicinal? If the parents or family members are black (brown), can the scholars be born white, blonde, not suntanned? Can a cell change its role within the body? If you stay in a place without trees and without smog, is there oxygen? When one is not networked with the environment, what happens? Are there cells that don't divide?).

D – *Conceptual questions* Interrogating the significance of facts to consolidate know-how, and usually formulated as follows: “what does ... mean”, “how do you know if .....”; (e.g.: What does a balanced diet mean? How were antibiotics invented? How do you know if a certain antibiotic is the right one?).

E – *Explanatory questions* interrogating the causes of phenomena, and on the mechanisms that produce them, and usually formulated as follows: “why …”, “how does …”, “why does ... happen”; (e.g.: Why is it that when you prepare a soup for a new-born baby and you put some oil into it, why doesn't the oil mix? Why is it if you give blood and you don't eat you feel faint? How do cells divide? Why is it that when you chop an onion you start to cry? Why does the process of osmosis occur? Why do our bodies react in different ways and not always in the same way? Why are some bacteria good, like the bacteria in yoghurt? Why do we have homeopathic medicine? Why do antibiotics also destroy the good bacteria? What is the difference between force and energy? Why do cells tan or get darker? When something breaks inside your body, what happens to the cells?).

F – *Confirmation questions* interrogating the truth of information: (e.g.: Is it true that humans use only 20% of their brains?).

Leaving aside the questions from this last category (3), and another five non-classified questions, the following table contains the total of questions divided per class and the distribution by category for each class, calculated as a percentage of the total number of questions received.

The numbers of scholars in each class **(**N**)** differ considerably and this should be considered when comparing the results of each class.

	A **Factual**	B **Functional**	C **Hypothetical**	D **Conceptual**	E **Explanatory**
Total questions per category	60	16	12	8	39
IV A N = 7 Tot. 16	31.2%	18.7%	6.2%	6.2%	43.7%
IV B N = 13 Tot. 25	52.0%	20.0%	4.0%	0	24.0%
IV C N = 24 Tot. 54	33.3%	9.2%	9.2%	7.4	37.0%
IV D N = 25 Tot. 48	50.0%	5.5%	10.4%	5.5	10.4%

N = number of scholars

Although aware of a certain degree of subjectivity in assigning each question to a certain category, and the purely indicative character of the conclusions that can be drawn from such a small sample set, we still believe that some useful indications can perhaps be found from the above table.

Classes IV A and IV C produced a proportionally greater number of questions than the other classes. In these two classes the percentage of explanatory questions was higher than all the other categories. Overall, the factual question category was the most numerous, followed by the explanatory question category. Each class, however, showed a specific profile in the distribution between the various categories: factual questions were prevailing in Classes IV B and IV D.

If we consider the explanatory, hypothetical and conceptual categories as of a higher cognitive level than the others, and we calculate the relative percentages for each class, we can note that the questions proposed by Classes IV A (56.1) and IV C (53.6) were *to the point* for the quality of questions formulated by the scholars.

2 Analysis of the conceptual map for the Module *Environment and Organisms and their relations*

The classes had no experience in the construction of conceptual representations. For this reason, a simplified version was implemented by adopting a step-by-step procedure to identify firstly the sets, and secondly a network of words connected to each other indicating relations. The object of this activity was to test the scholars' capacity to explain with as many words as possible the concept of “environment” and “organism”, and to identify the type of relations that these words connect. The analysis of the produced maps is based on the count of words that the scholars added to the initial proposed set, on the pertinent relationships identified, and also on a qualitative evaluation of the type of word and relationship proposed.

This activity lasted for one hour and was conducted in class by the SCIESA experts. The activity was started by reminding the scholars that in previous years the activities were aimed at the elaboration of a series of products (a booklet and a series of posters) able to communicate to others what they had learnt during the SCIESA project. This request was made when the scholars were engaged in the elaboration of the “representative diagram” which is something more abstract that a simple story. A “representative diagram” of knowledge is a schematic diagram that can communicate information, even by simply looking at it. The objective of this diagram was to understand the significance of the concepts “ENVIRONMENT” and “ORGANISM”. For this reason, we brought a large poster into the class with a drawing in black pencil of two big circles next to each other, each containing other concentric circles. The large circles were labelled ENVIRONMENT and ORGANISM, respectively and then there were some Post-it labels with other words written on them: sun, air, water, people, things, animals, plants, viruses, bacteria, freedom. First of all, the scholars were asked why we had drawn two circles, then they were asked to place into the circles each of the words written on the Post-it labels (except the word “FREEDOM”, which was used later on). The scholars were then asked to propose other words which were then placed in the relevant circle. The scholars were reassured that there was no wrong answer, and the labels could be moved or taken away as they wished. After working jointly on the ENVIRONMENT circle, the group moved onto the ORGANISM circle, now using their own words. At this point the scholars were then asked if they could find any connection between the words within each Group, and between the two Groups. These connections were highlighted using different coloured marker pens. The scholars were told that not all these connections were of the same type, and they were free to name them, so they could then be identified. During this process all classes were asked the same questions to elicit their explanations for their placing of the various labels, and the connections that they proposed.

On completion of this phase, the words HEALTH was proposed, and the scholars were asked the following: Where should this label be placed? What is it connected to? What other words can be connected to this one?

This activity was of great interest to all classes, even if various explanations were required, as the type of activity was new for the scholars. In Class IV C the activity was also continued the following day as requested by the teacher, because some scholars were absent when the activity was presented to the group, and other scholars asked for further explanations. This revision session was the ideal opportunity for consolidation and to reinforce this type of representation of their understanding.

Analysis of the final diagrams (maps)

These diagrams contain only a part of the ideas proposed and discussed by the scholars during the activity. These reports give a detailed insight into their way of reasoning regarding the concepts acquired and how these should be represented, also on the capacity to question these when new words were added.

A summary of the written reports of each class during the elaboration of the diagrams *Organism and Environment* is given in the ***Attachment.***

We have used, as an indicator of quality of the diagrams, the total number of words present, the degree of interconnection (defined not as an absolute number of relations but as the relation between this and the number of words); the criteria chosen for the organisation of the words; the quality of the words and their relations. Evaluation of the number of scholars present in class during the activity must also be considered. Without any external control group, only a relative comparison between the classes was possible.

The following tables show a summary of some of the data.

ENVIRONMENT

Class	*Total no. of words*	*Number of words added*	*Connectivity relations per word*	*List of words*
IV A Present 5	15	6	1.33	Atom, City, Oxygen, Case, Smell, Emotions *placed at centre: Oxygen, Sun, Air*
IV B Present 10	13	3	0.84	Energy, Emotions, City *placed at centre*: Water, Plants, Person
IV C Present 19	20	12	1.05	Universe, Colours, Climate, Time, Stars, Planets, Air, Clouds, City, Dust and Soil, Food, Emotions *placed at centre*: People, Bacteria, Virus, Animals, City, Things, Air
IV D Present 20	16	6	1.68	Food, Earth, Emotions, Smells, Friendship, Sound/noise *placed at centre*: People, Animals, Bacteria, Viruses, Emotions

ORGANISM

Class	*Total no. of words*	*Connectivity relations per word*	*List of words*
IV A Present 5	11	1	Cells, Veins, Heart, Brain, Lungs, Blood, Water, Atoms, Viruses, Bacteria, Emotions *placed at centre*: Viruses, Bacteria, Atoms, Water
IV B Present 10	14	1.14	Skin, Veins, Blood, Circulation, Heart, Brain and neurones, Muscles, Skeleton, Lungs, Senses, Cells, DNA, ATP, Emotions *placed at centre*: Heart, Lungs, Brain, Cells, Blood
IV C present 20	14	1.5	Brain, Eyes + 4 senses, Heart, Lungs, Intestines, Muscles, Bones, Cells, DNA and RNA, Bacteria, Viruses, Veins and arteries, Antibodies *placed at centre*: Heart, Lungs, Cells, Brain
IV D present 19	7	0 *	Cells, Tissues, Organs, Apparatuses, DNA, Atoms, Red/white blood cells and platelets *placed at centre*: DNA, Atoms

The map has been organising a hierarchical order from DNA to Organs, and then by group.

<u>Map of the Environment</u>

The following considerations should be interpreted with caution, due to the small dimension of the sample.

Considering the relationships between the number of words added and the number of scholars present in the class, Class IV A appeared to be the most productive and showed a high index of connectivity.

In all classes words stemming out of the subject matter of the Modules during the year were mainly proposed. The presence of the word EMOTIONS and the reasons given by the scholars for its inclusion are very interesting.

In Classes IV A and IV B the criteria selected were to place the SUN at the centre of the environment, following an "astronomical" order, integrated with the criteria "importance" for life, such as AIR/OXYGEN, which were added step-by-step as they considered the other words. Nevertheless, WATER in Class IV A was placed next to PLANTS, a word placed in a more peripheral position than the word SUN, together with the words ANIMALS and PEOPLE. Classes IV C and IV D discussed at length the choice of proposed words: "astronomical", from the EARTH to the UNIVERSE; "ecological", from terrestrial environments to aerial environments; "importance" (with respect to life or human beings). There was a tendency to place those words belonging to the EARTH at the centre, but there was still some difference in opinion on how to consider the relative importance of certain words (regarding life, regarding humans in general) and of the repetition of words in the real and conceptual environments.

<u>Map of the Organism</u>

Again, Class IV A was the most productive, while Class IV C showed the highest index of interconnectivity.

All classes were reminded of the main organs of the human body, and of various microscopic and molecular aspects dealt with during the year (CELLS, BACTERIA, DNA, ATP, ATOMS, MOLECULES).

Different criteria for the organisations of the words in the map were shown between the classes: Classes IV B and IV C proceeded from the centre to the periphery following the order of importance to keep the organism in life; Class IV D followed the inclusivity criterium, from the micro (ATOMS, DNA) to macro (APPARATUSES); the same criteria were partly adopted by Class IV A as well, which however, when constructing the map of the environment, had already placed WATER at the centre of the organism.

<u>Quality of the relations</u>

The relations that connected the words identified by the scholars within each of the two diagrams belong mostly to the type “it is part of…” in the sense of “it is a component of” and “it is contained within”. There were other relationships such as: “it needs…” or “it is necessary for …”, “it is because of …” or “produced by…”. In the case of the organism, the brain was connected to the organs, as it is physiologically connected to these.

Many relations were identified, all valid, also between the organism as a whole and elements of the environment (e.g., with AIR, WATER, FOOD, BACTERIA, FREEDOM) or between elements of one group and elements of another group (e.g., DNA with PLANTS, with ANIMALS, with PERSONS; BLOOD with WATER; RED CORPUSCLES with AIR, with ANIMALS). EMOTIONS appear both as components of the organism, and as components of the environment because they are produced from the relationships that people have with the environment.

In conclusion, it can be highlighted that all classes have shown a vision of the environment and the organism as groups of different components ranging from the micro to the macro level, all interrelated and in relation with each other. It is to be remarked here that in their way of reasoning, HEALTH eventually belongs to both groups, as the result of relationships between the organism and the environment.

3 – Analysis of the written individual texts "I have learnt that …"

In December 2017 it was agreed to propose to the scholars, now familiar with the task of "writing",–to write a short individual composition based on what they had learnt in the previous year, and developing one or more of the arguments dealt with within one of the SCIESA project modules. Although at an elementary level, this written task calls into play the scholars's metacognitive skills and reveals the first level of comprehension of the activities carried out previously.

To facilitate this task, each of the arguments dealt with within each Module was briefly listed on a sheet, as a possible list of arguments that could be freely developed in written form.

Regarding Module No. 8 ("The brain and its networks: external with its environment, internal with the body") the following arguments were proposed:

- the environments where we and the others live our everyday lives;
- environments that create positive and negative emotions;

- environments are different or changing, giving thus origin to emotional changes;
- can the characteristics of an environment be improved?
- can an environment be considered as a network of relations between various components?
- do any forms of exchange take place within an environment?
- can the body be considered as an environment in which different components are connected to each other through a network?
- do we receive signals from inside our bodies regarding its good or bad functioning?

Regarding Module No. 9 "(From big to small. The microscope lets us see how we are made") the following arguments were proposed:

- through a microscope we can see organisms made of a single cell;
- the microscope lets us see the cells that make up the tissues of animals and plants;
- through a microscope we can see different types of cells;
- with the microscope, we can see that cells have a form and an internal structure;
- cells need energy to grow and this is why cells feed;
- through this process cells can multiply and the organism can grow;
- we cannot see molecules through a microscope;
- molecules are also different from each other;
- molecules are made of even smaller parts;

- you did some experiments, research, and discussions with the teachers and your classmates; what do you think you have learnt from this activity?

This task was presented differently to the four classes. In Class V C, the teacher read out the list and then started a short discussion to elicit questions, and then using these, created a sort of “outline”. The scholars were then left to answer to those questions that they considered most pertinent.
In Class V D, the teacher projected onto the IWB a slide with the list of topics, and left the scholars free to write whatever they chose.
In the joint Class V A and B, the teacher distributed the list to the scholars.

The written works elaborated by the pupils testify their efforts to explain their understanding and elaboration of the debated issues. The following was noted from Module 8: scholars’ fear of being alone at home, fear of the dark, generally liked activities (e.g., football, dance, video games), upcoming holidays, negative emotions when being told off by teacher, disgust when finding ants in the bathroom at night.

These written works demonstrated that the Modules had transferred knowledge regarding processes and elements, and also the scholars’ capacity to establish relationships between these. Another important difference noted was the different abilities of the scholars regarding their linguistic expression and morpho-syntactical capacities. The written works of the scholars in the two via Asmara classes (IV A and IV B), that were merged in a single class in school year 2017-18, were generally briefer, less correct and with a simpler organisation at a formal level. In most cases there were no notable differences in levels of conceptual comprehension in the classes pertaining to the two different centres.

Regarding Module 8, the capacity to understand the concept of *environment* and to identify relations between environmental characteristics and emotional states was also noted. Typical sentences are the following: *"Since the first year of school, we have learnt that the environment includes our bodies and our emotions"; "Normally to feel good I pretend that nothing has happened and think about the new Pokémon game"; "The characteristics of an environment vary depending on the place. For example, when are at the dentist and we get bored, or when were playing during the break and time passes very quickly." The scholars also pay attention to some functional aspects, e.g.,* "*How the school desks are arranged to encourage communication between scholars*". They also show a capacity to separately identify physical and social elements (things, people, friends, schoolmates), to recognise environmental diversities (sensitivity of the scholars to light, colour, crowding in restricted spaces).

In almost all of the writings in one of the classes, the environment was also represented as a network of emotions, of relationships between people, of physical or emotional exchange and the sharing of food. Some examples are the following: "*in this last year in class we have learnt many new things such as networks. This was one of my favourite topics and to understand more about this we talked a lot and we did a lot of activities"; "It's like swapping or exchanging things, but this exchange is not only of things but also of emotions; we exchange emotions, harmony and we help each other"; "exchange happen within a network just like when we exchange messages with a mobile phone"*. "*For example, we can imagine our bodies to be like an environment and our* *organs are part of this environment, just like people that exchange information between themselves to discuss if things are working well or badly. In our bodies, these channels of communication reach our brain which then transforms these into emotions, experiences, research, and reasoning".*

The scholars demonstrated understanding that information that signals alarm, symptoms, the good or poor functioning of the entire organism, is transmitted within the body. *("Our bodies receive signals regarding its good and bad functioning, like when we have a sore neck because our nerve has been pinched, or when we get ill because "bad" bacteria have got into our organism"*).

We can state that in almost all the written texts the scholars commented that it was possible to intervene on those elements that render an environment unpleasant. The following sentences show some examples: *"the characteristics of an environment can be improved not only physically, but also mentally. For example, if a classmate is sad then he or she can be cheered up by making the environment little bit more fun"; "We can help the environment not only by being careful not to pollute it, but also by helping someone if they are sad. In that way we are helping someone who is part of a network. And if that person is happier, then the whole network is improved, and therefore the whole environment gets better".*

The scholars interpreted "well-being" as eating healthily and in the right amounts, participating in sporting activities, and paying attention to hygiene. Someone amplify this concept by writing: *"the habits that we should adopt for our well-being are: to stay together, to not fight or argue, do not say bad words, to pay attention to the teacher when he or she is talking to us and helping us".*

One child showed to have learnt to associate the well-being of the body with the microscopic level of organisation of the body. e.g. *"the cells become unwell when we eat too much sugar, too much chocolate and too much of other harmful foods"*.

Regarding Module No. 9, many scholars tended to paraphrase the title of the module. Very often, however, new contents were expressed, confirming the acquisition of new knowledge: the cells are *"a small unit of life"; "to see a cell in detail, we need to use a staining agent"; "the cells are different from each other"; "cells form animal or plant tissue: there are also multicellular organisms".*

In general it was specified that the cells are nourished "*to receive energy*". The way in which they obtain nourishment is expressed in various ways: *"they feed on blood", " they are nourished by the blood", "they are nourished through the blood".* Someone also added that the cells need air or oxygen to survive.

Some notions appeared to be rather confused in the scholars's written texts. In particular, the fundamental concepts regarding the function of the cell membrane for the passage of substances, the relationship between the size of an organism and the dimension of the individual cells, the relationship between the size of a cell and its surface area for the exchange of substances were often confused or not fully understood. Only some scholars referred to the mechanism of the permeability of membranes and stated, when talking about the dimension of cells, that *"it is better to have more cells than just one.* The concept that *"many cells are found in our bodies and they are very small, because in this way there is a greater* *quantity of cellular membrane than there would be with one big cell. This is very important because this means that those important nutritional substances have larger access to the cell."*

The analogy of the membrane of an egg and that of a cell proved to be difficult to understand: *"We have seen a very big cell – the egg – which is visible to the human eye"; "We used an egg to see how cells are made and function; we put it in vinegar and the shell was dissolved, leaving just a thin membrane. When we took it out of the liquid, the egg without the shell became bouncy".*

It was generally understood that cells reproduce, and scholars stated the following: "*Every time a cell dies, another one is born to keep us alive"; "Cells multiply in order to take the place of those that die"; "They multiply and so they can grow and move"; "Cells multiply through cell division to create new cells, or sometimes to join together to create another one".*

Almost all the written works in one of the classes showed signs of misunderstanding between unicellular organisms and bacteria.

Finally, the scholars also wrote that: "*the cells are made of molecules ("tiny little organisms") and these in turn are made up of even smaller things called atoms"*; "*molecules are found everywhere, even inside things"; "you cannot see molecules through a microscope*"*; "to understand about molecules, we played a game"*, *"I learnt that everything is always made up of something else, like the cells are made up of molecules, and molecules are made up of atoms".*

LOGBOOK

As previously noticed, the evaluation of teaching Modules carried out in class has been performed by the teachers. They have been asked to write down, during the course of each section of the Modules, an evaluation of the didactic efficacy shown by the experimental items proposed (experiments or experience). To this end, the teachers were provided with a “logbook” in which they were to record, for each experimental item, whether it was fully realized in class (yes, no, partially), the degree of efficacy (rated on a 1 to 10 scale), and possible additional notes.

An example of the logbook that was used for the Sight section of Module 9 “Travelling through an invisible world , is given below.

Experiments and experiences	Realization			Efficacy (1-10)	Additional notes
	yes	part.	no		
Observing and describing objects and areas of the body surface using a magnifying glass (the glass magnifies images, allowing to distinctly observe small details).					
Attempting to observe single red blood cells in a glass smear (single red blood cells cannot be identified). Magnifying glasses do not allow to see small objects or details).					
Showing to the pupils the microscope and the stereo-microscope explaining their functions (the huge magnification allows fine details, not visible by naked eyes, to be observed .					
Microscopic observation of a blood smear (single red blood cells can now be identified).).					
GENERAL OBSERVATIONS					

ATTACHMENT

Summary of the written class reports made during the preparation of the Organism and Environment conceptual maps

1) Why do you think we have drawn these circles? First of all we will deal with the ENVIRONMENT circle, and then the ORGANISM circle (on this occasion this term is used as a synonym for the human body). The scholars are asked to chose a word to be placed inside the circle from the series of words written on Post-it notes.

In Class **IV A** the circles were considered like a solar system, the word SUN was placed at the centre of the ENVIRONMENT circle, and in a more peripheral position the words PEOPLE and PLANTS. The word AIR was placed in the centre of the ENVIRONMENT circle, whereas ANIMALS and THINGS were placed next to the word PEOPLE. For Cristian, the SUN should not be placed at the centre but more “laterally, because the sun sets”. Passing on to the ORGANISM circle, the same procedure was repeated. And BACTERIA? Bryan: a central position in the ORGANISM circle. Cristian: Yes, because bacteria are everywhere. Silvia: Yes, but are they found in the environment? The scholars say no. WATER? Airon: it is found in the ORGANISM and in the ENVIRONMENT, in the last circle next to PLANTS. Where should we place the word ATOMS (an added word)? Both in the last circle of ENVIRONMENT, and also in ORGANISM. What are atoms? Ivan: Organisms that make up things. In the ORGANISM diagram the words BACTERIA and VIRUSES were placed at the centre; the words HEART, BRAIN, LUNGS, VEINS, BLOOD were placed in the external circle. Where should we put the word CELL? In the most external circle of ORGANISM.

Also in **Class IV B** there was much discussion on the choice of criteria for the diagrams; here again the scholars started with the criterion ENVIRONMENT. Giulia: those things that are most connected should be put in the smaller circle at the centre. Valerio: we should put the smaller things in the circle at the centre. Michele: in the bigger circle, and then in the more external circles according to their importance. No unanimous decision was made.

SUN was placed at the centre. No agreement was made on the criterion PEOPLE, which was later placed in an intermediate position together with ANIMALS. PLANTS was placed at the centre because these allow us to survive, and also oxygen. The words WATER and later AIR were then placed at the centre. THINGS was placed last. There was no agreement on the criterion VIRUSES. FREEDOM: the scholars made no proposal on where to place this word. Valerio: One cannot be free to choose to jump into a volcano. Francesca said that not everyone is free, and in the world slavery also exists.

In the ORGANISM diagram the words BLOOD, HEART, BRAIN, BONES, SKELETON, “the essential organs” were placed in the centre. *Teacher*: Can you name an organ that isn’t essential? Francesca: the tonsils, muscles. Other scholars: but without muscles you can’t move. Francesca: I know, but you’re still alive. Ilaria: yes, but that’s not a good life. Francesca: The cells should be at the centre because they’re essential. Ilaria: the SENSES, the SKIN. Where? At the centre or perhaps in the intermediate circle.

Two possibilities were offered to Class **IV C** for the environment – organism diagram, but they chose the first one: the EARTH is round and on the living organisms like PEOPLE and ANIMALS live on it. The centre of the ENVIRONMENT is the earth, and the other circles should be the sky and the universe. The ENVIRONMENT should be divided up into the AQUATIC ENVIRONMENT, LAND, and sky and the last circle should contain the word SEA. Giorgio then proposes another criterion which regards more the organism diagram. The most important things should be in the centre so that there are more protected.

Later, the following criteria are placed: in the outermost circle together with the words AIR, PEOPLE and PLANTS are placed in the centre. THINGS is placed next to PEOPLE. WATER is placed in the intermediate circle. BACTERIA? Between PLANTS and PEOPLE. No, in the intermediate circle between EARTH and WATER. But animals are also found in the sky, and the scholars realise that the criterion that they have chosen does not work! They propose another criterion for the centre circle, the things that can be found on land, and around these the things that are found in the sea and then in the most external circle, the things that are found in the sky. From the ENVIRONMENTS diagram we have the words FREEDOM, EMOTIONS. Why are these words here? The environment can be seen from different points of view, such as when a child lives in an environment where there is peace or in one where there is war.

A hierarchical organisational order is used also for ORGANISM, with the most important organs, BRAIN and HEART placed at the centre and MUSCLES, INTESTINES, VEINS, ARTERIES, BLOOD, BONES, THE

FIVE SENSES placed in a more peripheral position. CELLS are connected with DNA and with BLOOD, since blood contains cells. At this point the adopted criteria (hierarchically based on organs) do not seem to work any longer: I would put DNA above because it gives you all the useful information, and so I would move the words CELLS and DNA above all the other words. And why? The cells go above because they are found in every word that we have written ... I would move CELLS and DNA to the centre because all organs are made up of cells, and all cells contain DNA. According to Chiara, another criterion should be used to place the words within the diagram: We have to keep in mind the positioning of the organs within our body. A highly animated discussion takes place.

For the ENVIRONMENT diagram, Class **IV D** scholars were reminded of the diagram that they had made previously with concentric circles, in which they had taken into consideration the various environments where they live: "seaside, school, city". The same logic was followed from "CELL, TISSUE, ORGAN, to APPARATUSES". For the criterion SUN, no immediate decision was made because the more external circle "is large and can contain other things", or the second proposal "because the criterion GALAXY should be in the more external circle", "and so we should put it at the centre!". PERSONS: "SUN more externally, and PEOPLE at the centre", "on the edge, between the small and the medium-sized circle". The class continuously shifts the criteria from an astronomical classification to spatial proximity, and to an anthropocentric perspective. BACTERIA were placed in the ORGANISM diagram. WATER and THINGS in the intermediate circle, ANIMALS and VIRUSES at the centre, AIR: intermediate or external. A decision was made for the criterion SUN: a circle more external to that of AIR (" because this contains the sun"). The criterion EARTH was added between the intermediate and the external circles. For the ORGANISM diagram, the criterion CELL was placed in the intermediate circle, DNA in the centre (thus, following a reasoning from the micro to the macro level). *Teacher* - and what are red blood cells then? Are they cells? Pietro - ATOMS should be at the centre. Nicoletta - TISSUES should be in the intermediate or external circle. Giacomo: I would put ORGANS in the external circle. Dalia: and what about the SKELETON and the DIGESTIVE SYSTEM?

2) <u>Can we find any other words to write on the Post-it notes to be placed on the poster?</u>

Class **IV A** added the following words: OXYGEN, FOOD, SMELLS, CITY, EMOTIONS, SCHOOL, REGION, ITALIAN PENINSULA, EUROPE, UNIVERSE, ATOMS, CELL.

Class **IV B** added the following words: LIFE, RESPECT, CITY, ENERGY, CELL, BLOOD, HEARTS, BRAIN, MOLECULE, ATOM.

Class **IV C** added the following words: PLANETS, CLOUDS, FOOD, DUST, WIND, TIME, COLOURS, CITY, CLIMATE, UNIVERSE, OXYGEN, BLOOD, HEART, BONES, CELL, DNA, MUSCLES, VEINS, ARTERIES.

Class **IV D** added the following words: EARTH, CITY, SMELLS, COUNTRYSIDE, NOISE (in the intermediate circle), EMOTIONS (in the centre because PEOPLE have emotions), FRIENDSHIP, FOOD (intermediate circle), CELLS, TISSUES, ORGANS, APPARATUSES.

3) <u>can we find other connections, relationships between these words? What are the interactions or exchanges that occur between these criteria? Can we find any connection between "THINGS" in the ORGANISM group and "THINGS" in the ENVIRONMENT group?</u>

Let's trace with the red coloured felt-tip pen the lines to indicate these connections between the "THINGS" in the ORGANISM category and those in the ENVIRONMENT category, and a black line to indicate the connections within each category.

Class **IV A** made the following connections: ORGANISM–AIR; FREEDOM-ANIMALS and PEOPLE, etc.. Can you see that all of these connections are making something. Bryan: a chain […] a sort of network. And where shall we place EMOTIONS? Scholars: on both sides, in the ORGANISM category we have the heart and the brain, and in the ENVIRONMENT category this is what links people with animals. These lines are useful to establish relationships between these keywords.

Class **IV B** made the following connections: PEOPLE – CITY, PEOPLE – WATER with AIR, with ENERGY always present. ANIMALS – VIRUS ("they have them but they don't need them"). SENSES – BRAIN, BRAIN with SKIN, MUSCLES, SKELETON, ANIMALS – CELLS. WATER – BLOOD, CELLS – DNA – MOLECULES – ATOMS. Silvia: everything is connected to energy. Why is that? Scholars: the cells all contain ATP.

Class **IV C** for the ENVIRONMENT category made the following connections: PLANTS – ANIMALS (because some animals are herbivorous), WATER – PEOPLE and ANIMALS, STARS – PLANETS with TIME and SUN. In the ORGANISM category, connections were made between CELLS – BLOOD, VEINS – ARTERIES, BRAIN with various organs (with all of them!). Continuing the discussion, the scholars then connected all of the organs in the physiological apparatuses (e.g.: the digestive system because this was easy to reconstruct from personal experience). The scholars were then asked if it were possible to organise the diagram on a hierarchical organisational model: molecule, cell, tissues, organs, apparatuses. Silvia: and where do we put the word FREEDOM? Scholars: everywhere. Some of the scholars: next to the word PEOPLE. Other scholars: sometimes it's there and sometimes isn't; it depends on the part of the world we consider. There are various questions on the word TEMPO [in Italian the word "TEMPO" can mean either WEATHER or TIME], also to clarify the distinction between climates/time. Why did we include the word TEMPO between the two circles? Because we change over time, and so does the environment. …. We change through our experience Ideas also change over time and so TIME is everywhere.

In Class **IV D** the SUN – EARTH, PEOPLE are connected to NOISE, SOUND and with THINGS; ANIMALS – ODOURS. Viola: PEOPLE, PLANTS, ANIMALS and WATER should be connected. Silvia draws the connection between the parts of the ORGANISM, CELLS and APPARATUSES and asks "what is the NERVOUS SYSTEM connected to?" Scholars: with everything. The CIRCULATORY SYSTEM is connected to the DIGESTIVE SYSTEM. Everything is connected to each other in the body. Silvia: are RED BLOOD CELLS connected to the ENVIRONMENT? Scholars: yes, to PEOPLE, to ANIMALS, to AIR and also to WATER. The RED BLOOD CELLS to OXYGEN. Scholars the CELL is connected to PEOPLE and ANIMALS …… but also to PLANTS. The various APPARATUSES to PEOPLE, and PEOPLE are HUMAN BEINGS. Silvia: is the ENVIRONMENT is connected to the ORGANISM, what is the connection between the ORGANISM and ENVIRONMENT? Scholars: the ORGANISM is also an ENVIRONMENT. Emanuele: PEOPLE, PLANTS AND ANIMAL all live together. Silvia connects them and then asks "what is coming out in this map?" Scholars: a NETWORK, that should also include FRIENDSHIP and EMOTIONS, PEOPLE and ANIMALS. Veronica: ANIMALS with BACTERIA and VIRUSES. Scholars: FREEDOM with PEOPLE (previously, it had been connected to

ENVIRONMENT: “it is part of the environment, in the intermediate circle were the word EARTH is”). Nicoletta: everything has connections. Ilaria: the ORGANISM is connected to the ENVIRONMENT. Between these two there are many things that can be joined or moved. The ENVIRONMENT contains many things, just like the ORGANISM.

4) <u>Now we propose another word: HEALTH. Where should we place this word? What is it connected to? What other words can be connected to this one?</u>

Class **IV A** Scholars: HEALTH is connected to ENVIRONMENT, PEOPLE, ANIMALS, CITY, but also to ORGANISM.

Class **IV B** And the word HEALTH? Francesca: HEALTH belongs to the ORGANISM, but also to the ENVIRONMENT. Both the ORGANISM and the ENVIRONMENT need to be healthy.

Class **IV C** the word HEALTH should be placed between the two circles (HEALTH and ORGANISM). The ENVIRONMENT is important for our HEALTH. HEALTH is connected to both, because we don’t live well in a dirty environment. But what does environment mean for you? And what about PEOPLE or FRIENDSHIP?

Class **IV D** Silvia: and what if I say the word HEALTH? What does that make you think of? Is the HEALTH of the environment connected to the health of the organism? Carlotta: HEALTH is connected to both the environment and the organism. Pietro: the organism depends on the environment and vice versa. The words HEALTH is connected graphically with PEOPLE, with the ORGANISMS that combat VIRUSES, with WHITE BLOOD CELLS, with FOOD. Andrea: the ENVIRONMENT also affects our HEALTH.