Hands on Physics and Biology in House of Science

L. Gumaelius and K. E. Johansson[1]
Stockholm House of Science and [1]Stockholm University,
AlbaNova University Centre, SE-106 91 Stockholm, Sweden.
Lena@physto.se: kej@physto.se

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Abstract. *In House of Science physics and biology join forces to explore nature with microscopes, accelerators and particle detectors. The experiments range from the study of chromosomes, genetic effects and the use of DNA sequencing in criminology to the study of particles in the cosmic radiation and from radioactive substances in our environment.*
With a Sweeping Electron Microscope (SEM) a particle accelerator is used to explore biological matter demonstrating a new interdisciplinary project in physics and biology.
During the first four years of operation more than 2000 school classes and teacher groups, totalling close to 40000 visitors, made experiments in astronomy, biology and physics in the House of Science laboratories.

Keywords. Biology, DNA, Electron accelerators, House of Science, Physics

1. House of Science

Stockholm House of Science in Stockholm is a laboratory for Science, entirely devoted to schools [1,2]. The House is situated in an academic environment at Albanova University centre. Researchers, university students and teachers develop exciting and interesting experiments that can not normally be performed at school. The aim is to make modern science accessible to teachers, school classes and individual students and increase the students' interest in today's natural science. During its first four years in operation almost 2000 school classes and more than 40 000 students and several thousands of teachers visited the laboratory.

2. The world of particles

Many of the physics experiments start with a visual inspection of the continuous 40 x 40 cm area cloud chamber (Fig. 1).

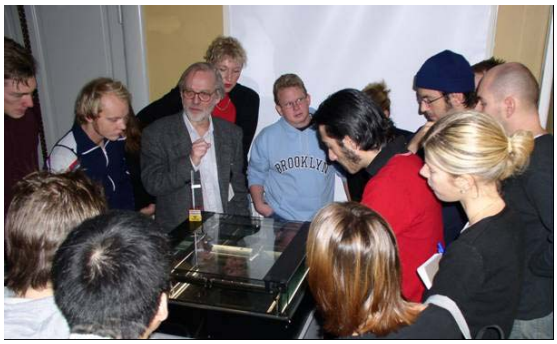

Figure 1. High school students studying particles in a Wilson cloud chamber.

Several types of otherwise invisible particles can be seen; electrons, muons from the cosmic radiation and alfa particles from the decay of radioactive substances in the surrounding. More detailed studies are performed with particle detectors and ionisation detectors to explore the world of particles, the cosmic radiation and the radiation in our environment.

2.1. Electrons and annihilation processes

The classical e/m experiment is a good way to get familiar with the electron, particle acceleration and the effect on charged particles of electric and magnetic fields. Annihilation of the electron and its antiparticle, the positron, was studied using a positron emitting specimen and the apparatus shown in fig. 2. In the annihilation two photons are simultaneously emitted back to back to preserve linear momentum, each with energy of 511 keV corresponding to the rest mass energy of the particles.
The particles are registered by detectors coupled in coincidence to eliminate background radiation. With the two sets of detectors, the location of the annihilation source, normally hidden under a cover, is determined. By detecting several such coincidences with a large number of detectors the precise location of the source can be pinpointed. This is the idea of the PET camera

(Positron Emission Tomography) used in medicine.

Fig. 2 A simple PET camera. Each pair of movable detectors is coupled in coincidence. During the demonstrations the source is covered.

Electron-positron annihilation at the highest energies available were studied using the web based education program Hands on CERN [3,4] based on real data from the DELPHI experiment [5] at the LEP collider at CERN. At high energies particle annihilations give rise to several types of particles - two photon final states are very rare.

2.2 Muons

Muons, seen as diffuse spots in the cloud chamber, are created in the upper atmosphere. According to classical physics it is surprising that muons with a lifetime of around 2 μs, created at altitudes of around 20 km, can make it down to the Earth. Einstein's special relativity and the description of the time dilation explains this as a prolonged muon lifetime with a factor of about 40. Fig. 1 shows students studying cosmic muons in the cloud chamber, contemplating mysteries that can be explained by special relativity.

2.3 Alpha particles

The highly ionising alpha particles are the most striking particles in the cloud chamber. What are they and where do they come from? This is the starting point of nuclear physics in House of Science. Radioactive substances, changes in the nucleus, the study of exponential decays and the exploration of radon in our surroundings are the main examples of where the observation of alpha particles in the cloud chamber can lead. House of Science is equipped with both stationary and mobile detectors making it possible to determine the radon content in different locations – in schools, cellars or the underground (Fig. 3).

Fig. 3 Preparing the measurement of Radon under ground.

3. The DNA molecule

The DNA molecule is a fascinating molecule that carries the information of life in almost every little living cell. Today the DNA information is used for many purposes, such as designing medicines or improving crops. However, some people are concerned about the consequences of improper use of gene manipulated organisms. Therefore it is important that students get a good understanding of DNA and its use, and get a chance to discuss the ethical aspects of using personal DNA.

3.1 Pyrosequencing

With a Pyrosequencing machine the DNA code can be established and used for identification of different species or individuals. This method is now used at House of Science to solve a fictive criminal case.

The visiting students work as criminal investigators_ resembling very much the investigators in real life or in CSI series on TV. The experiment is set in a crime scene where a hair has been found in the victim's bathroom cabinet. The different suspects are described and the case has to be solved within the next few hours.

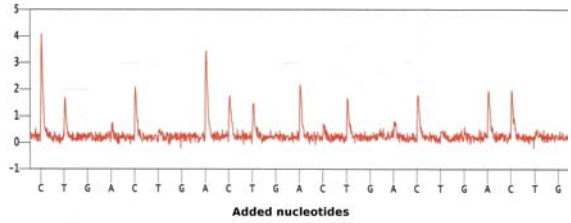

Figure 4. A pyrogram received from hair. The y-axis shows the strength of emitted light.

At the end of the experiment a typical pyrogram received by the students determine the first 10 nucleotides on this sequence. In figure 4 a diagram is presented where the sequence C, G, C, A, G, T, A, C, A, A, A, T, A, T, G, T, C has been determined. Comparison with sequences from the suspects shows that the analysed hair originates from the old housemaid. Despite that the technique is rather advanced the procedure consists of steps that are easily comprehended by the students [6].

3.2 Fruit flies

Fruit flies are excellent for genetic studies as it takes only nine days for a new generation of flies to be produced. The effect of the DNA information is manifested when studying the phenotype for different mutations in fruit flies. Breeding experiments are carried out with fruit flies having different eye colour. After nine days the result can be studied under a microscope and it can be determined by the students that the genes responsible of eye colour is located at the chromosomes of gender.

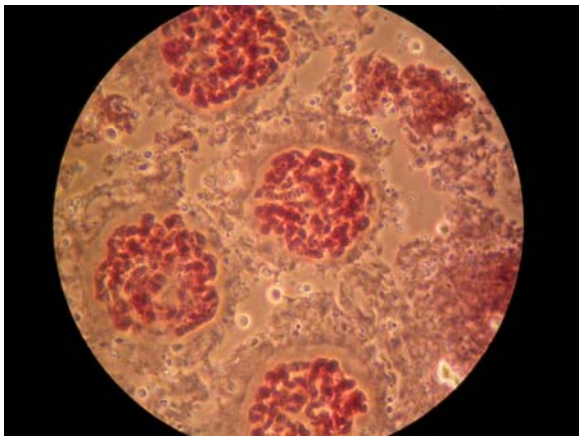

Figure 5. Chromosomes from the salivary gland in a fruit fly.

The larvae of the fruit fly are dissected to study the gigantic chromosomes in their salivary glands. As seen in figure 5 the typical darker bands with packed DNA and lighter bands with less packed DNA can easily be studied under a microscope.

4. Interdisciplinary projects

Interdisciplinary projects of biology and physics are implemented for the exploration of living material. Many discoveries of DNA were performed by chemists and physicists at the Cavendish laboratory and elsewhere [6]. In House of Science biology and physics experiments are performed very close to each other, sometimes using the same laboratory.

4.1 SEM (Sweeping Electron Microscope)

The development of sophisticated microscopes, and maybe particularly the use of a particle accelerator, are examples of how physics and biology join forces to explore biological structures. In the basement of House of Science an old SEM is used to depict biological structures. This microscope can provide a magnification of up to 50000 times while keeping a large depth of focus. Once loaded with samples the microscope can be operated by the students themselves. A typical experiment for students often starts with a look into the microscopic world and continues with the theory behind the technique of electron microscopy. Figure 6 shows a photo of a nettle leaf.

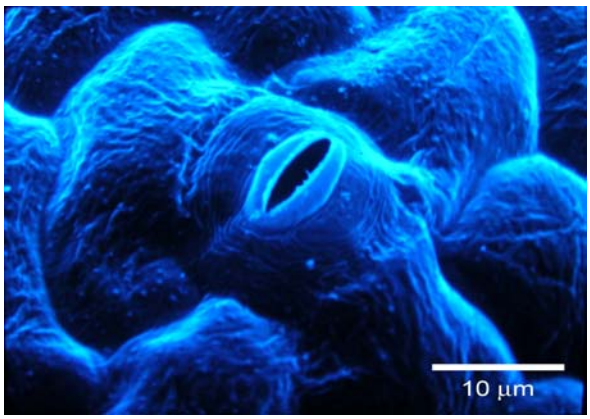

Figure 6. A stoma on the lower epidermis of a nettle leaf.

5. Summary

House of Science is a laboratory close to the university where hands on experiments can be performed by school classes. The experiments complement the basic laboratory experiments performed in school, and give the students a chance to experience the academic environment of a university. Different fields of science, particularly astronomy, biotechnology and physics are demonstrated and several interdisciplinary experiments are being implemented. The laboratory has become very popular in the Stockholm area with the yearly visit of around 700 school class and hundreds of teachers. The House of Science concept can be a model for other universities or academic environments.

6. References

[1] House of Science, a university laboratory for school, 2004 K. E. Johansson, Physics Education 34, 342.

[2] House of Science website: www.houseofscience.se

[3] Hands on CERN website: http://hands-on-cern.physto.se

[4] Hands on CERN – a well-used physics education project, K.E. Johansson, **Physics Education** 41 (2006) 250-254.

[5] DELPHI website: http://www.cern.ch/Delphi/Welcome.htm

[6] Principles of pyrosequencing, www.pyrosequencing.com/pages/technology.html

[7] Cavendish laboratory, http://www.phy.cam.ac.uk/