

A ROD AND ITS JOB:

Gymnasium Lerbermatt – BC class 20abdh

1 The importance of our eyes:

If you can read this text, then you have eyes with structures such as rod cells. The eyes are one of the several sensory organs inside our body. Without them we would not be able to perceive the world in its whole beauty. In order for us to see all those wonderful things, a lot of complex processes need to progress. One of these processes happens in the rods, which are located inside our eyes and are crucial for our ability to see. You don't know what rods are? Continue reading and find out...

2.1 The location of a rod in our body:

Rods are found inside of our eyes. Every time we see an image, light must pass through our eyes. When it falls through the pupil, it has to get through the Retina. The Retina is a layer of nerve cells at the back of the eyeball. This layer consists of different types of nerve cells, such as ganglion cells, amacrine cells and bipolar cells. $\uparrow(1)$

When light reaches the retina, it permeates the nerve cells, which are located at the beginning, until it reaches the light-sensitive cells, the rods, which form one of the backmost layers of the retina. The rods constantly send nerve impulses via optic nerve to the brain, where an image is formed. $\uparrow(1)$

Firstly the rods send impulses to the intermediary bipolar and amacrine cells, which combine different information and signals. Thanks to this process, information is summarized and the most important features such as contrasts are highlighted. Finally, the information reaches the ganglion cells. These are responsible for sending the information further to the brain. $\uparrow(1)$

2.2 Rod structure:

A rod has an elongated form and consists of three parts: the outer segment, the inner segment and the presynaptic terminal. The cilium links the outer with the inner segment. The outer segment consists of about 2'000 discs, which are made of cell membrane, in which the pigments are located. The most important pigment is the rhodopsin. The retinal and opsin are the most important components of this pigment. These pigments help absorbing light. $\uparrow(2)$

The inner segment includes the cell body and all the cell organelles. The presynaptic terminal connects the rod with ganglion cells. $\uparrow(2)$

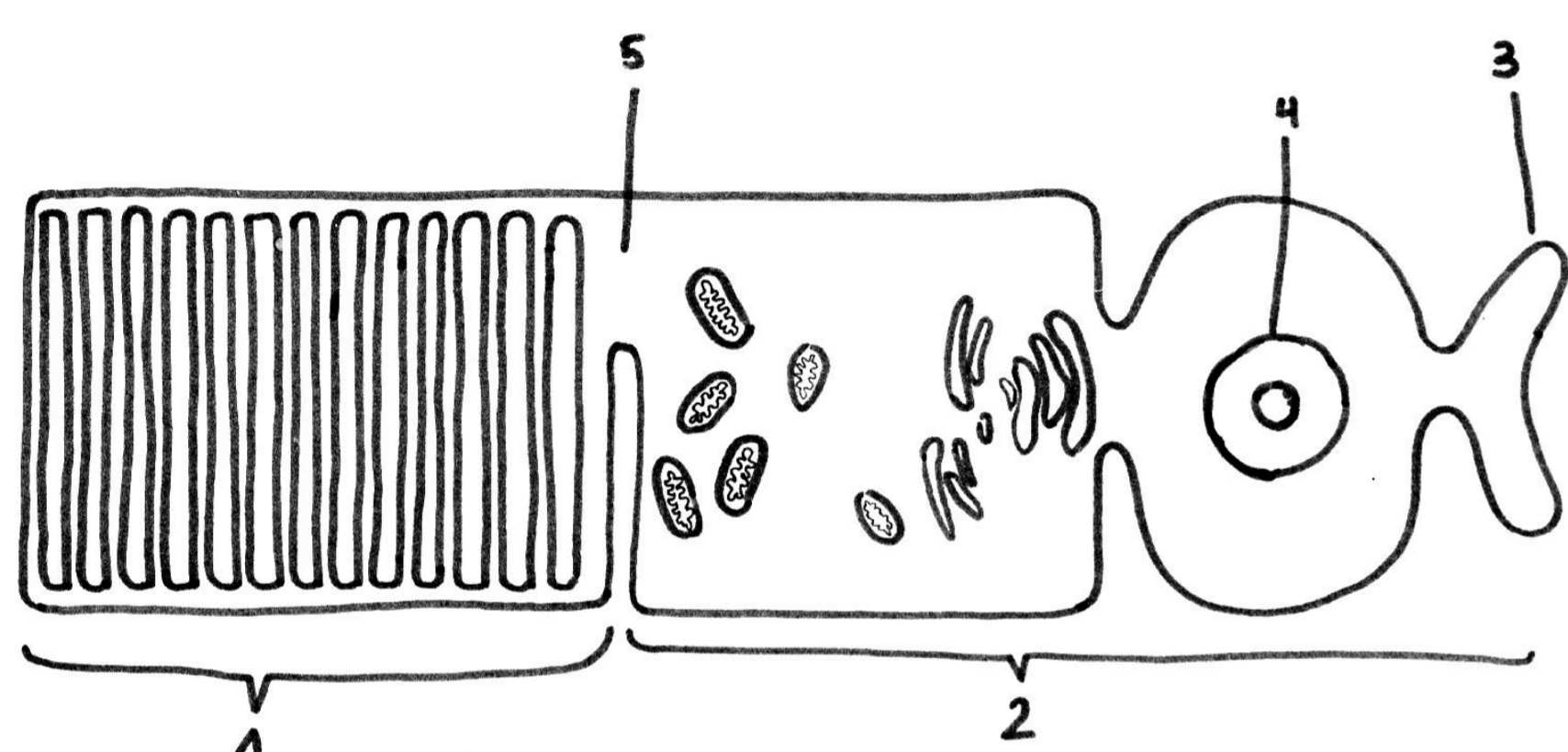


Fig. 1: The structure of a rod

1. Outer segment with discs
2. Inner segment with cell organelles
3. Presynaptic terminal
4. Nucleus
5. Cilium

2.3 Dark Current:

Contrary to other cells, rods are easily depolarized in the dark, meaning in an unstimulated state. Depolarization occurs when the membrane potential of a cell is reduced. The membrane potential is the difference in electric potential between the interior and the exterior of a biological cell. The interior of a rod is electrically more negatively charged in comparison to its surroundings. This difference in potential is the reason why Na^+ ions, which have positive electrical charges, are attracted to the rods and want to enter the cell. $\uparrow(1)$

The rods are easily depolarized because there are special channels inside the membrane of a rod, which are constantly held open by cyclic GMP, an enzyme. Due to this, there is a persisting stream of positively charged ions entering the cell. This stream is called the dark current. To ensure that the dark current is held upright, structures inside the rod pump out the positively charged ions. $\uparrow(1)$

As soon as light reaches a rod, the channels inside the cell membrane close and the dark current is reduced. A hyperpolarization occurs. This happens when the membrane potential is more negative than it was before. $\uparrow(1)$

The dark current enables us to see the difference between light and dark. There constantly are electric impulses reaching our brain when it's dark and as soon as it is light the impulse frequency is reduced. $\uparrow(1)$

2.4 Phototransduction cascade:

When light falls on a rod, a molecular chain reaction is triggered. The incoming signal of light is extremely reinforced inside of our rods. This process is called phototransduction cascade. First, the light is absorbed by the protein rhodopsin, which is found in our rods. The absorption of the energy of light causes an isomerization of retinal, which is a component of rhodopsin. Retinal changes from a bent 11-cis-shape to a stretched all-trans-shape. The rhodopsin molecule is now activated and disintegrates rapidly. $\uparrow(2)$

But before it decays, the molecule activates hundreds of transduction molecules. As a result, the signal of the light stimulus is fortified a hundred times. Furthermore, the transduction molecule activates the enzyme phosphodiesterase (PDE). Then, activated PDE splits thousands of cyclic guanosine monophosphate (cGMP) molecules, which keep the sodium channels open. Consequently, this causes the sodium channels to close and the dark current is reduced or interrupted. Because of this extreme amplification, a single rhodopsin molecule can close thousands of ion channels. $\uparrow(2)$

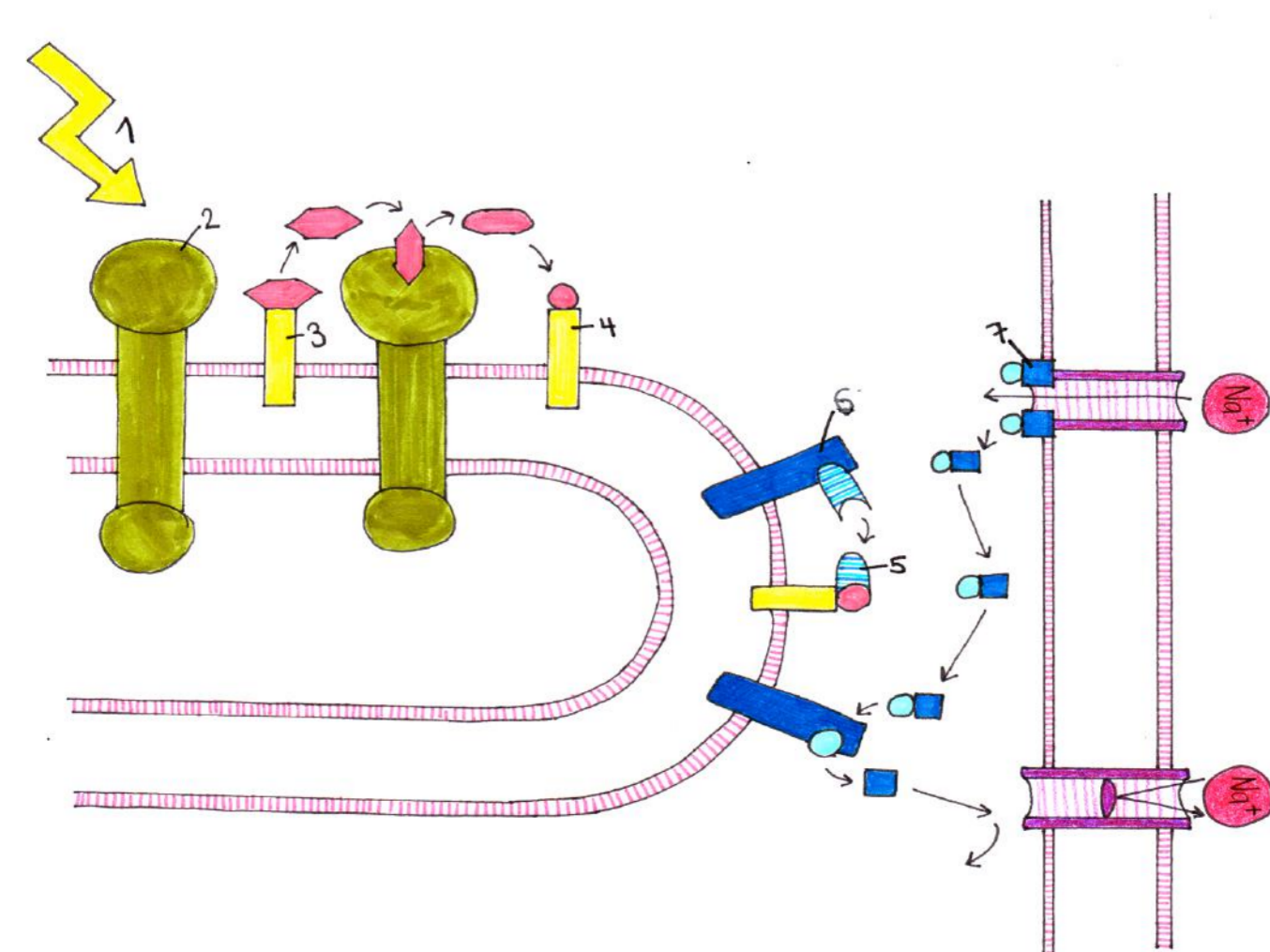


Fig. 2: chemical processes inside a disc

2.5 Regeneration of rhodopsin:

Activated rhodopsin rapidly decays in to its components. Consequently, our eye must resynthesize it. The regeneration affects our process of seeing. If a lot of light falls into our eye, numerous rhodopsin molecules decay. In this case we can see a negative afterimage because there's not enough synthesized rhodopsin available. This leads to a reduction of the light sensitivity of the rods. $\uparrow(2)$

3. Method:

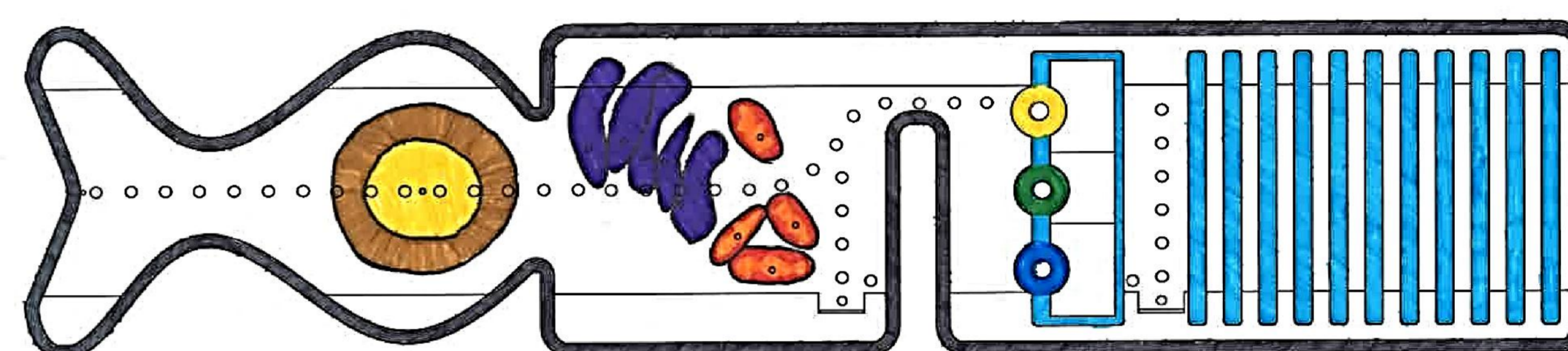


Fig. 3 Construction sketch of our model

Firstly, a construction sketch was made and the material, from which the model would be made of, was chosen. It was decided that the model would be 3D printed. This meant that a model of a rod needed to be drawn in a computer program. Since the model was too big to be printed in one piece, one divided it in to several pieces, which would be glued together afterwards.

The cell organelles were made from modelling material. Once they had dried, one painted them and later, they were stuck onto the rod.

Furthermore, a software was developed which lets LED lights light up in the order of the process occurring inside of the rod. The software was made with the program Arduino.

The incoming light through the rod is illustrated by white led lights. When our model is triggered by light a sensor feels this and starts showing the reaction.

First, blue lights representing the rhodopsin molecules, then green lights representing transducin molecules and lastly yellow lights representing PDE, light up one after the other. In addition, the orange lights, which represent cyclic GMP, were programmed in such a way that they stop glowing when exposed to light. This makes the model light sensitive like the actual rods in our eyes. As soon as the cascade has occurred, the red lights which represent the dark current are also turned off.

To hide all the cables and the engine, a wooden box was built. The model is assembled on top of this box.

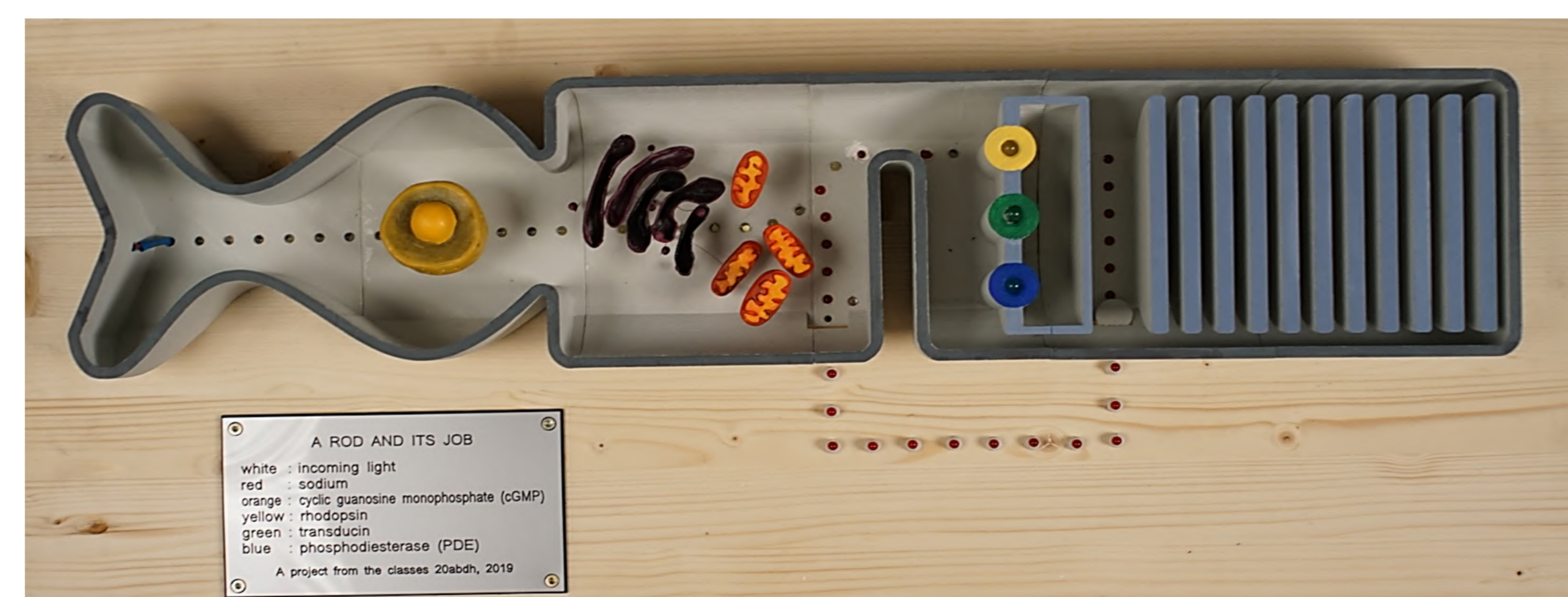


Fig.4: A photo of the original model

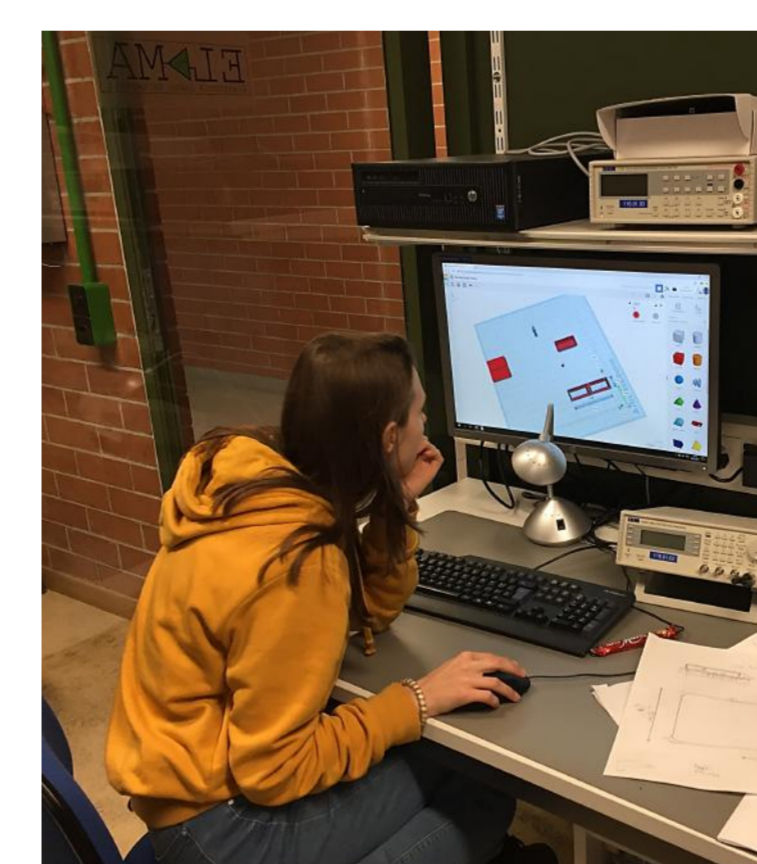


Fig.5: One of our teammates programming and working on the computer

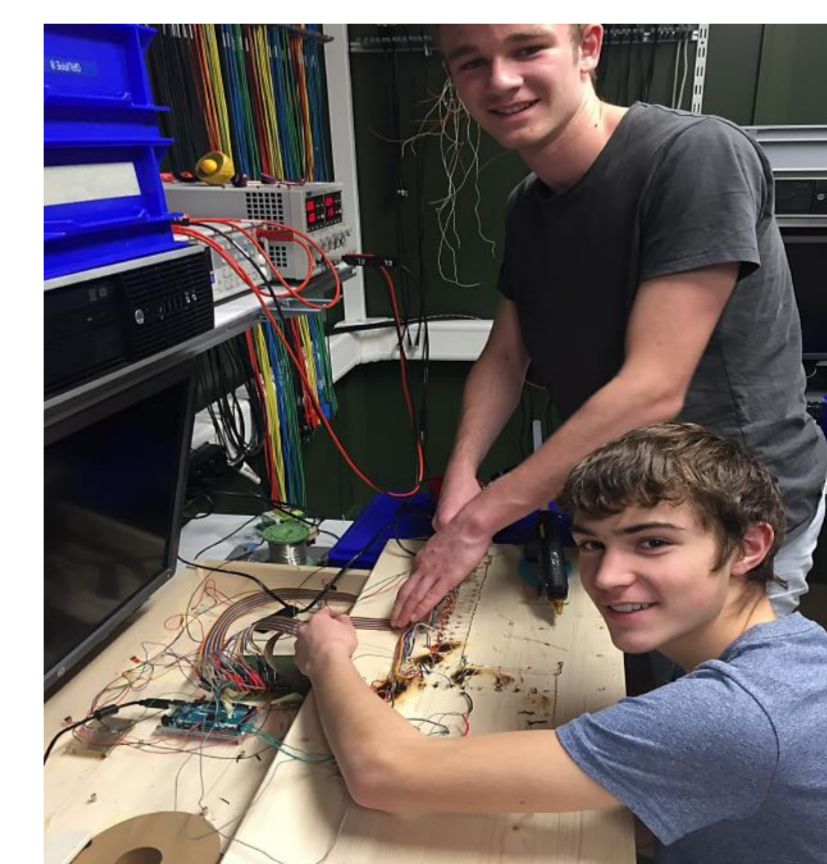


Fig.6: Our teammates working on the model



Fig.7: The crew

4. References:

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- 3) Membrane potential, https://en.wikipedia.org/wiki/Membrane_potential, retrieved 27.2.19