11: Construction of a DNA molecule

DNA is the genetic support of all living organisms. It can be seen as a very long right-handed spiral ladder made of different constituents. Each of the two peripheral chains is a succession of sugar and phosphate groups brought together by the pairing of four distinct bases or nucleotides: adenine (A), guanine (G), cytosine (C) and thymine (T). An adenine will always pair with a thymine whereas a cytosine will pair with a guanine. This nucleotides' complementarity is essential for the specific double helix arrangement of DNA molecule in space.

Themes: DNA, structure, DNA polymerase, base complementarity.

Construction of a DNA molecule

What shall we use to materialize the DNA?

In order to construct a long DNA molecule with children or students, we were looking for various supports. We found that the most suitable one consists of *Playmais* flakes. A box of *Playmais* (Fig. 1) contains hundreds of little colourful flakes made from cornstarch, thus recyclable and safe for the environment. Despite its playful appearance, this support is attractive in many ways. It is safe for children, very easy to use (a humid sponge is enough), light, malleable and easy to obtain. Because it does not take long to build a DNA molecule with this model, the teachers will therefore have time to explain more precisely the concept of it before the pupils begin the construction.

Fig. 1 - A box of *Playmais* contains more than 500 flakes. It may be ordered on the official website www.playmais.com or bought in common supermarkets as the brand is widely distributed in many countries.

Material

A box of *Playmais* and a humid sponge are the only material needed. Each colour of flakes represents a given component of the DNA molecule (Fig. 2) as it is summed up in the following table.

Flake's colour	stands for
Green	A
Blue	C
Yellow	G
Red	T
White	Deoxyribose
Grey	Phosphate group

Fig. 2 - From left to right, the flakes representing the bases (red, blue, green and yellow), the phosphate groups (grey) and the deoxyriboses (white).

In Sanger sequencing method, the four bases are detected using different fluorescent labels and are represented as peaks of various colours which can then be interpreted to determine the base sequence (Fig. 3). Normally the G curve should be drawn in yellow but as this colour is not easily readable, it is here represented in black.

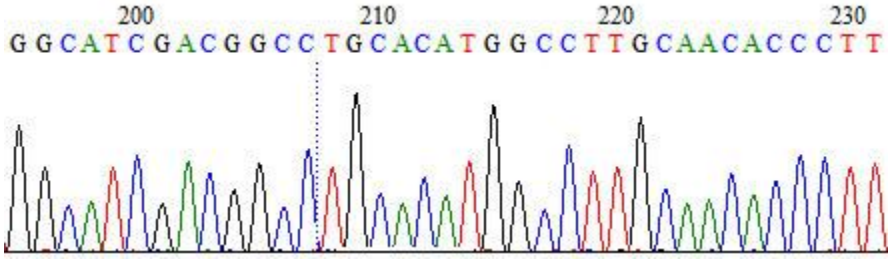


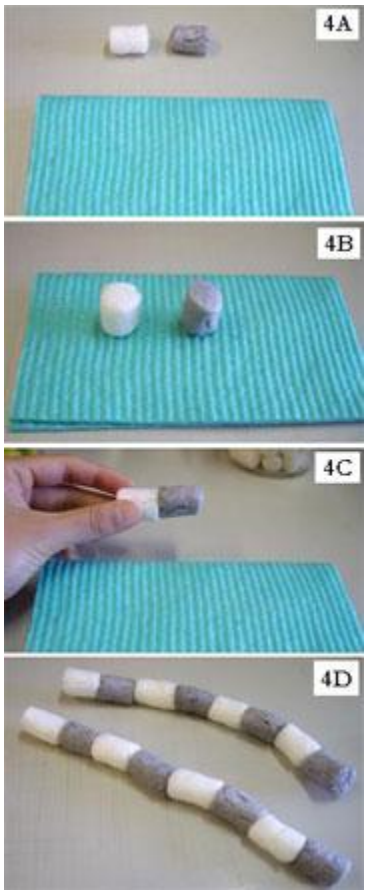
Fig. 3 - Example of a Sanger sequencing read. The base sequence is represented at the top of the graph.

Methods

We will present two methods to assemble the DNA molecule. The first one is the simplest and maybe the most suitable one for a class of young children. It encourages the children to understand the structural concept of DNA rather than its biological process of formation. The second one exposed in point 2 will allow the students to understand the polymerization process of DNA.

1. Simple method

1.1 Construction of the phosphate-sugar backbones



The first step of the construction is to assemble the two side chains with sugar molecules (white flakes) and phosphate groups (grey flakes), alternatively (Fig. 4A).

For that, take a flake and wet each of its extremities by pressing them on the humid sponge (Fig. 4B).

This flake is ready to be stuck to two other ones at each humid end (Fig. 4C).

All you need to do is repeat this technique for every flake you want to put together (Fig. 4D).

We obtain two chains of about ten flakes each on which the nucleotides will be stuck on the next step. It is better not to make too long side chains because we will need to twist them progressively while adding the bases. The torsion will therefore be facilitated with shorter chains.

Fig. 4 - Construction of the phosphate-sugar backbones. Construction of the phosphate-sugar backbones. (4A) A humid sponge and the flakes for the side chains are required for the first step of the construction. (4B) Humidify one extremity of each flake by pressing them slightly on the sponge. (4C) Stick the two humid extremities by pressure to obtain the beginning of a side chain. (4D) After repeating this simple technique, you get the two side chains (composed of approximately ten flakes each).

1.2 Base-pairing

The second step is to pair the bases together, that is to say stick an A with a T on one hand and assemble a C with a G on the other hand (Fig. 5A). Once the base-pairing is done, the pairs will be added to the deoxyriboses of a side chain one after the other so that it makes a spiral around the chain (Fig. 5B). In order to respect the real DNA structure, ten base pairs will be added per turn of the double helix.

Fig. 5 - Base-pairing and assembly of the whole DNA structure. (5A) Base-pairing of an A with a T on one hand and of a C with a G on the other hand. (5B) Adjunction of the base pairs as a spiral to the deoxyriboses of a side chain. (5C) Assembly of the second side chain to the rest of the structure.

1.3 Assembly of the whole DNA structure

The last step is to assemble the second side chain to the structure that has just been built. The second side chain needs to be twisted like the other one so that it follows the double helix model (Fig. 5C).
Practically, students may work by teams and gather their work at the end of the period.

In the end, you obtain a DNA molecule which can be as long as you want (Fig. 6). This figure is a picture taken on the 13th of June 2009 for the 450th birthday of the University of Geneva in Switzerland. A stand called "Build the DNA molecule" addressed to children from 8 to 12 years old was spearheaded by BiOutils (www.bioutils.ch), a platform which provides material for modern biology experiments in schools.

Fig. 6 - Example of a 30m long DNA molecule built by children during the 450th birthday of the University of Geneva. For further pictures of this successful event, please check out the following link: http://medweb2.unige.ch/bioutils/archives2009.php.

2. Advanced method considering the biological process

2.1 Construction of the DNA units

A deoxynucleotide is a DNA unit is composed of a phosphate group, a deoxyribose and a base. In order to build this unit, you will need to assemble the flakes (technique described in section 1) as shown in Fig. 7A. After having built several nucleotides using the available bases, you will be able to construct the DNA strands.

2.2 Building the DNA strand

In order to build the first DNA strand, you will need to assemble each unit butt joint so that you obtain a long phosphate-sugar backbone combined to the bases forming a right-handed spiral (Fig. 7B).

2.3 Building the complementary strand like a polymerase

Now, the student will act as if he/she were a DNA polymerase to build the complementary strand. Using the remaining units, the student will add them one by one to the first strand previously built. It will be necessary to the respect the law of base-pairing (Fig. 7C)!

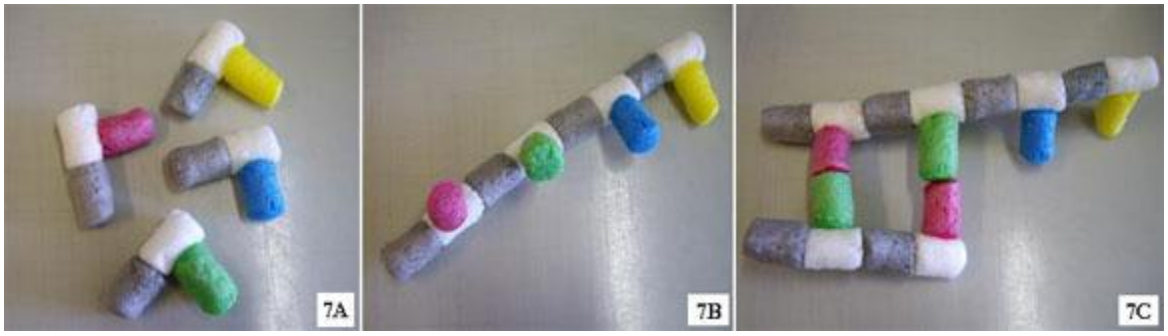


Fig. 7 - (7A) DNA units composed of a phosphate, a deoxyribose and a base. (7B) Assembly of the DNA units in a strand. (7C) Building the complementary strand with the remaining nucleotides.

Conclusion

By using this easy and interactive technique, students will be able to understand the basic notions related to the structure of DNA molecules. It is a satisfying way to illustrate a lesson describing the support of life. While manipulating the DNA molecule, students are likely to remember and assimilate better the concept which will probably be useful for the understanding of the upcoming mechanism involving DNA (replication, transcription…).