Science in School
The European journal for science teachers

ISSUE 70 – November 2024 Topic Biology

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Handmade DNA: a tactile model to explore the basics of DNA

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Hold a double helix in your hands: the model that will reveal the secrets of the DNA molecule

A bacterium, a fish, a tree, and a child: what do they have in common? DNA, of course! DNA is simple molecule capable of guiding all living beings and all the extraordinary functions of the human body.

DNA is not visible, and therefore, understanding its structure is difficult for students. What if they could build it with their own hands?

We propose a hands-on model that allows you to do just this; a few essential elements replicate the fundamental properties of DNA in a concrete and accurate way. Unlike other models, both the types of bond and their strength are realistic and can be touched. You and your students can use it countless times to synthesize a strand of DNA, duplicate it, and even wrap it into the famous double helix.

The main element of the model is made of wood: it is therefore resistant, versatile, and long-lasting. Its construction may seem a bit laborious, but it is an investment that lasts over time and can be a way of involving parents or colleagues who love DIY.

These activities are designed for children aged 11–14, who, according to the Italian curriculum, must know "the biological bases of the transmission of hereditary characteristics by acquiring the first elementary notions of genetics". However, they can also be used with older students to explore the function of nucleic acids in more detail or to discuss scientific models.

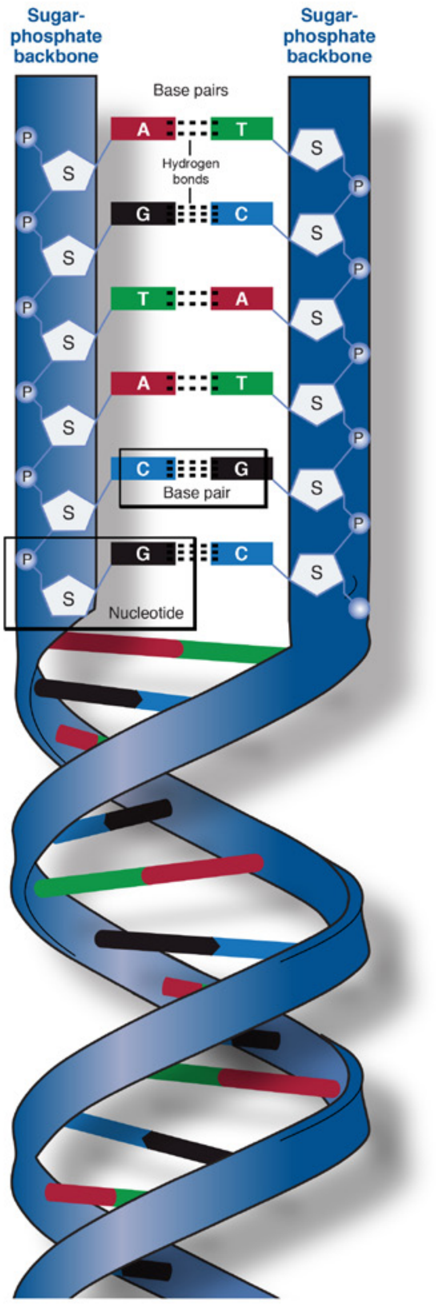

Figure 1: Structure of DNA with a sugar phosphate backbone and bases

Image: Shubjt/Wikipedia, Public Domain

Background

How is DNA made? It is a very long polymer, that is, a chain made up of similar repeated elements, monomers. The monomers that make up DNA are called nucleotides and in turn are composed of various elements, each with a specific role:

- a nitrogenous **nucleobase**; there are four different ones in DNA: adenine (A), thymine (T), guanine (G), and cytosine (C);
- a ring-shaped **sugar**, deoxyribose; and
- a **phosphate** group, capable of easily binding to other molecules.

The three parts that make up each nucleotide, namely, a nitrogenous base, sugar, and phosphate, are present in the model. The nucleobase is represented by the wooden block, the sugar by the ring formed by the chenille wire on one side of the block, and the phosphate by the free ends of the chenille wire.

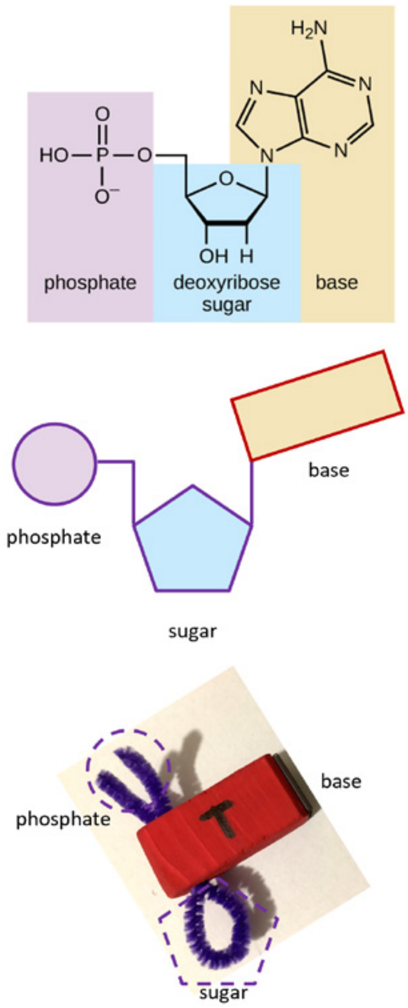

Figure 2: The chemical structure of nucleotides and how they correspond to the parts of the model

Image: CNX OpenStax/Wikimedia commons, CC BY 4.0

As in the real DNA molecule, the ends of the wire (phosphate) can bind to the ring (sugar) of another nucleotide, creating the repeated bonds that form the DNA strand. Another feature of the model is that the bases can only pair in a specific way, since A and T end with magnetic tape, and G and C with Velcro.

Constructing the model

The basic element of the system is a wooden block (dimensions 1.8 cm × 1.8 cm × 4 cm) with a through hole at one end with a diameter of 6 mm.

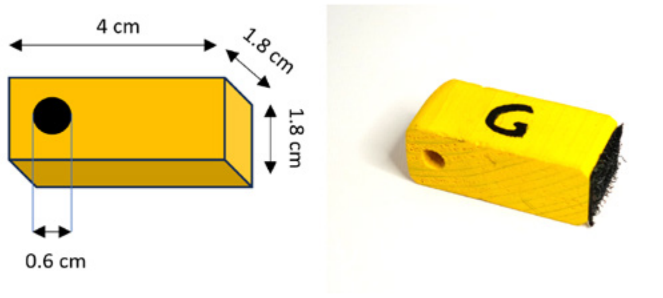

Figure 3: Dimensions of the block used as a base and a photograph of a finished block
Image courtesy of the authors

The block is completed with magnetic tape or adhesive Velcro on the side opposite to that of the hole and a 15 cm long chenille wire (pipe cleaner).

The complete building instructions for the constructing the blocks and a list of materials are provided in the supporting material.

The minimum quantity of blocks that allows you to carry out all the proposed activities are described as a set. A set is made up of 32 complete pieces (wooden block + chenille wire). The first 16 are necessary for the construction of the first DNA molecule, the rest for the duplication activity. In our experience, it is better not to increase the length of the strand beyond eight nucleotides in sequence, because the assembly becomes too fragile and difficult to manipulate.

The activities can be introduced with a single set; in this case, each student will prepare one or two nucleotides individually. The subsequent phases, that is, the assembly of the single and double strand and the duplicate, can be carried out by the teacher or by the children in turn, perhaps using a portable video camera (document camera) to show the operations to the whole class. If several complete sets have been prepared, the class can be divided into as many groups as there are available sets and the work of each group organized so that all components build at least one nucleotide and one bond.

Activity 1: Assemble the DNA molecule

The activity can be introduced with a brief group discussion, asking the students some questions: what do you know about DNA? What comes to mind when you hear the word DNA? How do you imagine DNA? What shape do you think it looks like? Is it big or small? To answer these questions, the activity proceeds with the construction of the DNA molecule.

The practical part will take 15–30 minutes, depending on the manual skills of the students; for the discussion, plan for at least 20 minutes. The discussion can be extended at the discretion of the teacher.

Materials

- Half a set for each group (wooden blocks and chenille wire of the same colour)
- Activity 1 question sheet or activity 1 question cards (the cards don't have the extension questions)

Procedure

Build the basic element, the nucleotide

1. From the set, take two blocks of each type (2A, 2T, 2G, 2C) and eight wires of the same colour, for example, purple.
2. For each block, pass the bent wire through the hole; widen the joined part into a ring (figure 4b); and bend the free ends at 90° for approximately 1 cm, forming two small hooks (figure 4c).

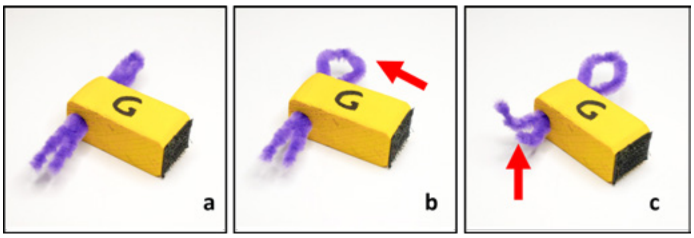

Figure 4: The combination of wire and block representing the nucleotide
Image courtesy of the authors

Build a single strand

3. Bring the free ends of the strand of one nucleotide closer to the ring of another nucleotide; the bases (the blocks) must be oriented in the same direction.
4. Insert only one of the two folded ends into the ring (fig 5a); twist the two ends together to close, forming the bond between two nucleotides in sequence (fig 5b).
5. Continue adding the other nucleotides (fig 5c).
You will obtain a strand of eight elements. In this phase, the order in which they bind, that is, the sequence, is completely free.

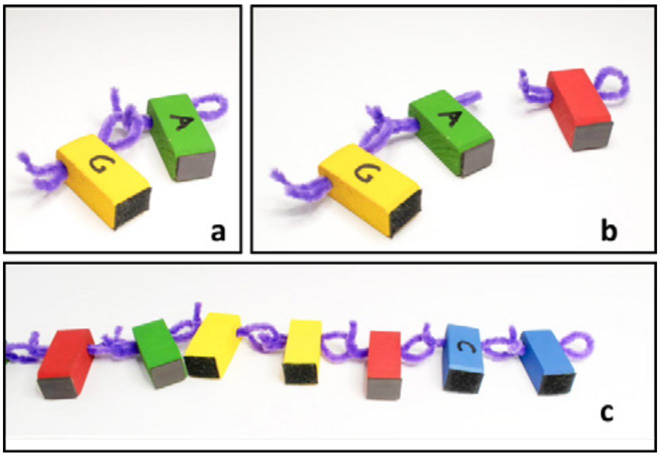

Figure 5: Constructing a single strand by sequentially ligating multiple nucleotides

Image courtesy of the authors

Build the double strand

6. Take another two blocks of each type (2A, 2T, 2G, 2C) and eight wires of the same colour as that used previously, and prepare all the nucleotides as in step 1.
7. Start working from the end of the strand where the free loop is and choose a nucleotide to start making a complementary strand. It is no longer possible to choose the nucleotides randomly. You must respect the rules of complementarity: pairing is only possible between A and T and between G and C.
8. Position the new nucleotide next to the first strand but in the opposite direction, that is, hook→loop instead of loop→hook (figure 6a, arrows).
9. Bring the new nucleotide closer to the strand, so that the Velcro or magnet adheres.
10. Then select and adhere the second complementary nucleotide (figure 6b).
11. Join the second nucleotide to the first using the hooks (figure 6c) as before.
12. Continue until the complementary strand is completed. This results in a double strand with 16 nucleotides in total (figure 6d)

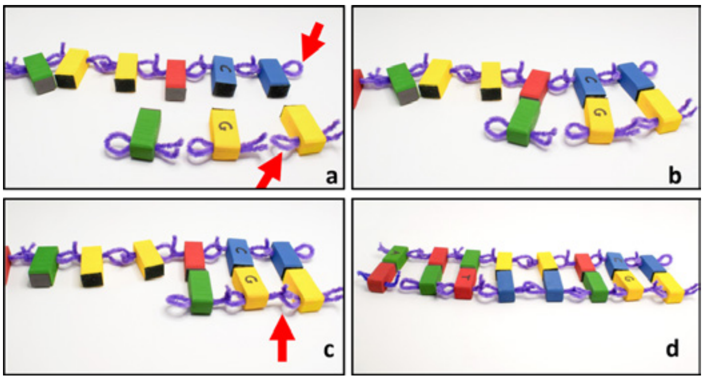

Figure 6: Steps required to build a double strand

Image courtesy of the authors

Shape the double helix

13. If the bonds have been tightened correctly, the double strand thus obtained can be wound into a spiral.

Figure 7. Obtaining the double helix

Image courtesy of the authors

Discussion

The teacher recaps the general concepts of DNA, making parallels with the model just constructed.

Then ask students the following questions. The discussion can be organized in various ways: in groups; as a class; or even in flipped classroom mode, where the students explain the activity they have just completed. You can use the question cards or hand out the Activity 1 question sheet to the students, leaving about 20 minutes, or adequate time, for each group to discuss the best answers.

- What does wooden block correspond to?
- What does the wire correspond to?
- What do they form together?
- How do nucleobases pair with each other? Can mistakes be made? Note: this model does not reflect the different sizes of the purine (G, A) and pyrimidine (T, C) nucleobases, which would normally also discourage mispairing.
- Do the two pairs of nucleotides (A–T and G–C) bind with the same strength?
- Are the two strands identical?
- For older students, or at the discretion of the teacher, questions may be more specific:
- Do the bonds between ribose and phosphate change if the nucleotide sequence changes?
- Is it possible to recognize a direction in each strand of the model?
- In the real DNA molecule, which types of bond form between the nucleobases?

From this comparison, some of the main properties of the DNA molecule should emerge, as they result from the construction and manipulation of the model. For example, students should be able to infer that the paired strands are antiparallel, that the nucleobases only pair well with their complementary bases, and that the two pairs (A–T and C–G) bind with different strengths. Example answers can be found on the Activity 1 answer sheet.

Activity 2: Duplicate the DNA

In this case, the activity starts with the following question: what happens to DNA when a cell has to divide into two daughter cells? By following the instructions, the sequence of events that leads to the duplication of DNA in the cell is reconstructed.

The practical part of this activity will take 20–40 minutes, depending on the manual skills of the students; for the discussion, allow at least 20 minutes. The discussion can be extended at the discretion of the teacher.

Material

- The second half of a set for each group (16 wooden block and chenille wire of a second colour)
- Activity 2 question sheet or activity 2 question cards

Procedure

1. Prepare 16 new nucleotides as described in Activity 1: take the blocks and thread with chenille wire of a second colour, for example, orange.
2. Prepare the template DNA by separating the two strands of DNA constructed previously, carefully detaching the paired bases (the wooden blocks) without breaking the strand (i.e., the bonds created with the chenille wire); each of the two strands obtained will serve as a template (figure 8).

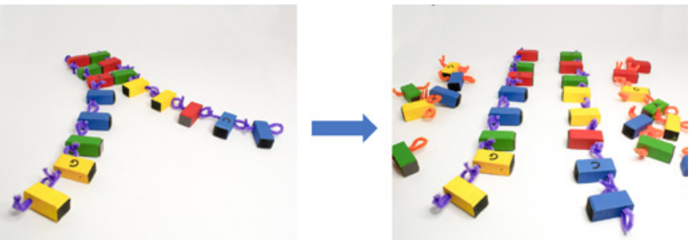

Figure 8: Prepare template DNA and new nucleotides for duplication
Image courtesy of the authors

3. Choose one of the two strands. Always starting from the side with the ring (figure 9a, red arrow), add the complementary nucleotides and attach them (figure 9b).
4. Repeat with the other strand (figure 9c), until you obtain two complete molecules (figure 9d).

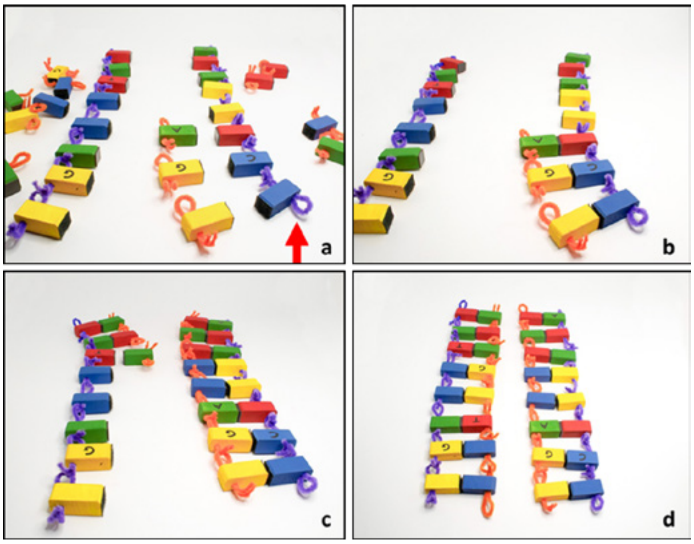

Figure 9: DNA duplication; it can be observed how each molecule contains a strand of the original one with the bonds in purple (the colour of the chenille wires used for the bonds between the nucleotides), and a new one, in orange (semiconservative duplication).
Image courtesy of the authors

Discussion

As in the previous activity, the teacher takes the concept of DNA duplication and poses a set of questions (you can use the Activity 2 question sheet):

- What is the purpose of DNA duplication?
- What is used as a template?
- Which strand is copied?
- Does the process proceed in the same direction for the two strands?
- Are the two molecules obtained similar or identical?
- How were the old and new nucleotides distributed?
- Can mistakes be made?
- Is the sequence preserved?

Example answers can be found on the Activity 2 answer sheet or the question cards. These questions should help the students reflect on the process, starting from the manual experience and trying to describe what they discovered.

Optional extension questions for older students

What are models and what are their advantages and disadvantages? Students can then discuss this model and its accuracy.

What properties of DNA does this model highlight? Are there some properties of DNA that this model doesn't reflect well? For example, the size difference between purine and pyrimidine bases; the relative sizes of the nucleobase, ribose sugar, and phosphate group; the fact that the model shows the nucleobase sitting between the sugar and the phosphate group (rather than attached only to the sugar); or the angle of attachment of the nucleobase to the sugar (which has implications for the double-helix structure: it creates the major and minor grooves).

Conclusion

These activities give students a chance to explore some of the key properties of DNA in a hands-on way. They also provide an opportunity to reflect on scientific models and how they are used, which is relevant across curriculum topics.

Resources

- Read a beautiful and engaging book to discover more about DNA: Flandoli C (2025): *Amber & Blue and the hunt for DNA*. World Scientific Publishing. ISBN 9811291128.
- Watch a beautiful but scientifically accurate video visualizing DNA.
- Discover the challenges of genome sequencing: Dyer S, Jackson B (2024) Plant genetics: explore DNA extraction and the challenges of gene sequencing. *Science in School* **68**.
- Construct a DNA model using cans and bottles: Karounias D, Papanikolaou E, Psarreas A (2006) Modelling the DNA double helix using recycled materials. *Science in School* **2**: 24–28.
- Try this role-playing activity to teach your students about synaptic transmission: Andersen-Gassner M, Möller A (2023) Hold your nerve: acting out chemical synaptic transmission. *Science in School* **63**.
- Learn how to collect relevant data regarding a gene from biological databases: Grazioli C, Viale G (2022) A chromosome walk. *Science in School* **57**.
- Try this detective game to introduce the use of DNA in forensics: Wallace-Müller K (2011) The DNA detective game. *Science in School* **19**: 30–35.
- Sketch graphs from 'story' videos of everyday events to boost your understanding of data visualization: Reuterswärd E (2022) Graphing stories. *Science in School* **58**.
- Read about genetic fingerprinting: Müller S, Göllner-Heibült H (2012) Genetic fingerprinting: a look inside. *Science in School* **22**: 49–56.
- Explore the fascinating world of noncoding RNAs: Koskova Z, Hernandez M (2023) Not just a blueprint for proteins: the importance of non-coding RNAs. *Science in School* **65**.

AUTHOR BIOGRAPHY

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