Making Sense of Variations in the Visual Depiction of DNA

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Abstract
Depictions of DNA span a variety of aesthetic choices for presenting the details of DNA. One important consideration is the didactic intent of the illustrator: what does he or she want the audience to know? Another consideration is change over time; knowledge about DNA becomes increasingly sophisticated over six decades, and this contributes to the variety of visual depictions. One way to make sense of these aesthetic decisions is to trace them historically through four phases.

All of us have seen hundreds of depictions of the DNA molecule. Each requires two basic elements: a view of the double helix, that is, the two sugar-phosphate chains on the outside of the molecule, and the base pairs connecting the two sides of the helix.

Aside from those two requirements, there can be great variation in the aesthetic choices that illustrators make when they depict DNA. For example, the helix can be represented as a flat ribbon, or as a solid rail, or as a chain of sugar and phosphate molecules. The four bases can be distinguished from each other with different colors, or by labeling them A, T, G, and C. Sometimes a base pair is depicted as one line, like a step on a spiral staircase, and other times as two distinct bases. The DNA molecule is usually shown as a vertical structure, but it could also be shown horizontally or diagonally.

This is not to say that pictures of DNA are whimsical choices. There are reasons why illustrators make certain aesthetic choices. One reason can be didactic intention: what does the illustrator want the audience to know about DNA? After all, different illustrators have different audiences in mind. A second reason is that depictions of DNA change as more is known about it.

The first published image of DNA, from April 1953 [1], is simple, and there are reasons why this is so. Later, genetic engineering and synthetic biology required different depictions because the scientific knowledge became more specialized. In addition, there is a golden age of DNA pictures in which we see almost unlimited variety in depictions of DNA.

Here it is worth revisiting a series of theories about relationships between science and art. This is an extraordinarily rich topic; here I present a condensed account which gives context to my history of depicting DNA.

One notable landmark is “Eye and Mind”, by Merleau-Ponty [2]. This statement begins with a vehement denunciation of science and its ways of representing what it examines. In science, writes Merleau-Ponty, “there is neither truth nor falsity concerning man and history”.

The author’s antidote to scientific description is to appreciate art, especially painting, this way: “It is by lending his body to the world that the artist changes the world into paintings”. There
must be no Cartesian dualism of mind-versus-body, he says, because “we are the compound of soul and body”. From this paper one concludes that, in the worldview of Merleau-Ponty, scientific description is incompatible with artistic insight.

But there is another approach which generates an opposite conclusion. One can find art in nature because nature contains beauty, and science helps us see this. In plants, in animals, in galaxies, and in drops of water, there is much that is worth seeing. This does not refer to beauty created by humans; instead, nature is the artist who presents us with beauty. Balaji notes that certain proteins have structures which mimic snails, crabs, and butterflies, so that these creatures serve as mnemonics for referring to proteins [3].

Another aesthetic is the idea that science, too, produces beauty. Sometimes a scientist is an artist. Consider the creation of the C$_{60}$ molecule in September 1985. One book about C$_{60}$ is titled The Most Beautiful Molecule [4], and another one is Perfect Symmetry [5].

A more recent case of scientists creating beauty was the 2011 Symposium on Molecular Aesthetics at the ZKM (Center for Art & Technology) in Karlsruhe, Germany. A series of chemists showed how they had created symmetrical molecules, and then added additional elements so that these structures looked like butterflies. In another example, scientists convert information about proteins and molecules into musical sounds. John Dunn and Mary Clark call their conversions “the sonification of proteins” [6], and Thierry Delatour says that his are “the songs of the molecules” [7].

One more idea is that theories from artistic thought enrich our understandings of scientific images. Simultanéité is the Cubist principle that one should show an object from two or more perspectives in the same work of art. I showed how simultanéité helped the audience appreciate a structure called the nano flower bouquet. Secondly, one can depict the passage of time, as does Duchamp’s Nude Descending a Staircase, for nano images [8, 9, 10, 11].

A typology of aesthetic styles is helpful here. Robinson produced a typology derived from issues regarding nanoscale images. His four types are: schematics, that is, the selective presentation of scientific information; documentation, or images with photo-like reality; fantasy, which has “illustrative speculation”, but is not anchored in “accurate science”; and hybrids which combine two or three of the types [12].

To explore variations over time in the visual depiction of DNA, I focus on schematic images. Illustrations of DNA are selective presentations: the illustrator decides which parts of the molecule to show, and how to show them. Here are four historical phases, such that each phase evokes decisions about which details of DNA to depict.

**Phase One: April 1953**

James Watson and Francis Crick published their description of the structure of DNA in Nature on 25 April 1953 [13]. Their paper included a drawing of the molecule, complete with the sugar-phosphate chains of the double helix, and the base pairs that connect the two chains.
The artist who created the drawing was Odile Crick, wife of Francis. In the words of James Watson, “Francis can’t draw, and I can’t draw, and we needed something done quick… [the drawing] showed the essence of the structure” [14].

There is something unique about that drawing: DNA has a vertical line running up the center of the structure. Why?

I suggest two possible reasons. The first I derive from a famous photo taken on 21 May 1953 [15, p. 240]. It shows Watson and Crick observing their three-dimensional metal model of DNA. In the photo there is a vertical rod running up the center. The 3D model could not support itself with the parts that represented the sugar-phosphate double helix. The four bases of the model are clamped horizontally to the vertical rod, and the two sides of the double helix are attached to the bases.

This is ironic. Ordinarily the double helix is supposed to be the stable structure: it consists of strongly bonded sugars, phosphates, and bases, whereas the base pairs are the more unstable part in the sense that they break when the molecule comes apart to generate RNA and when it is reproduced in polymerase chain reaction. Mutations arise when insertion, deletion, or substitution disrupts the sequence of bases. It is rare for this to happen when the double helix is intact.

The three-dimensional model is older than the photo, so it might be the basis for Odile Crick’s drawing.

And there is another possible antecedent. On 15 March 1953, Crick wrote to his son about what he and Watson had discovered [16]. The letter includes a rough sketch of DNA, including the double helix and the base pairs. This sketch has a vertical line running up the center of the molecule [17; also 16, p. 260]. Imagine that Odile Crick’s professional drawing was a refined version of Francis Crick’s sketch.

The drawing by Odile Crick seems to be either an artefact of the rod supporting the three-dimensional model, or an improved version of the sketch by Francis Crick.

After I made the point about the vertical line in the 1953 drawing, on Brigitte Nerlich’s blog, this comment came from Kindra Crick, granddaughter of Francis Crick: “interesting interpretation. I believe the central line was intended to call attention to the three dimensional shape. A reference line similar to the arrows which very simply indicate that the strands run in opposite directions” [18]. And after her comment, Peter Ellis added: “There’s no mystery here. In the caption of the figure in the original paper, it states, ‘the vertical line marks the fibre axis…” the line does not represent anything physical and is simply a guide to the underlying symmetry” [19].

The caption [20] says that “this figure is purely diagrammatic”. And then it says that “the two ribbons symbolize the two phosphate-sugar chains, and the horizontal rods [symbolize] the pairs of bases holding the chains together” [21]. If “purely diagrammatic” means non-representational, then the ribbons and the rods are representational, and the reader could infer that the line is just as representational as the ribbons and the rods.

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And there is a problem with the “underlying symmetry”: the base pairs are symmetrical one way, and asymmetrical another way. Adenine is wider than thymine, and guanine is wider than cytosine. All four base pairs have the same total width, namely, 2.0 nanometers (which Watson and Crick described as 20.0 Å), so the DNA molecule is externally symmetrical. But the hydrogen bonds connecting each pair of bases are off-center.

Anyone can imagine whatever internal symmetry they want to, but it seems to me misleading to depict the internal symmetry of a molecule which is internally asymmetrical. The vertical line represents a non-existent symmetry.

This raises another point. The model, the sketch, and the drawing all depict DNA as a vertical object. But DNA itself can be vertical, horizontal, or diagonal within a genome. I conclude that it is an aesthetic convention, not an empirical conclusion, to depict DNA as vertical. Indeed, the recent illustrated edition of Watson’s *The Double Helix* [22] shows DNA horizontally on the dust jacket.

This reminds us that it is often difficult to depict a natural object in models and drawings. This can be especially problematic for nanoscale objects, e.g., molecules, because they cannot be seen with optical microscopes [23]. As best I can tell, the vertical line disappeared from illustrations of DNA not long after the paper of 25 April 1953. It still appears in some three-dimensional models because those models need a vertical rod to support itself. Yet if a two-dimensional depiction of DNA included it today, implying that it was representational, then scientists would object that DNA includes no such thing.

**Phase Two: The Golden Age of DNA illustrations**

As the importance of the discovery by Watson and Crick became known to scientists and nonscientists, there arose a great variety of depictions of DNA. Some variations are these:

- The sugar-phosphate chains can be depicted as flat ribbons, or round rails, or a series of sugar and phosphate molecules.
- The base pairs can be indicated as one horizontal piece, or as two different parts of a horizontal piece. In the latter case, the parts may be labeled as A, T, G and C.
- The bases are can be depicted as symmetrical pairs or as asymmetrical pairs.
- DNA can be depicted in monochrome, or its different parts can be shown in different colors.
- In most cases, DNA is shown vertically, but it could also be shown horizontally or diagonally.

There is a limit to these variations, namely the underlying structure of DNA. Even so, these variations bring us to a question: why would an illustrator choose one combination of aesthetic features, while a different illustrator chooses a different combination? What does the illustrator want the audience to know about DNA?
Here I speculate about those questions. There are two principal populations which consume visual depictions of DNA. One comprises scientists and science students, plus physicians and medical students. When they see DNA in their textbooks, it is helpful that visual depictions provide precise details: that the sugar-phosphate chains look different from the base pairs, and that each base has its own unique signal, whether color or labels of A, T, G or C. This is important information to the population in question.

Another population consists of consumers who need little detail in the depictions they see: it is enough to perceive only that DNA embodies a double helix and four base pairs. Why is this?

I suggest that simpler depictions of the molecule have minimal didactic value because they serve audiences which have little need to know what the parts are. It is sufficient for this audience that a stripped-down picture of DNA tells the viewer that if a product, a vision, or a brand includes a picture of DNA, then it is scientific. Before April 1953, one might have claimed that something is scientific by showing the outline of an optical microscope, or by showing a two-dimensional image of an atom, with electrons orbiting a nucleus.

Now we are in a different epistemic moment. A common way to say that something is scientific is to associate it with a simple depiction of DNA, and for this purpose there is no reason to differentiate the physical details of DNA with aesthetic details.

Between those two audiences and their needs, there are more kinds of audiences. The most notable constitutes nonscientists who are curious about science, e.g., those who read the science section in the *New York Times* or the *Guardian*. What does this audience expect of illustrations of DNA? Perhaps more empirical detail than the simpler depictions, but not the same detail that one finds in medical textbooks.

My comments may sound elitist: scientists need many empirical details while nonscientists are satisfied with few. But I emphasize that there is a spectrum of consumers. It includes scientists, physicians, science teachers, medical students, and more. There is no single formula for how to depict DNA because there is no single audience for depicting it.

And the golden age of depicting DNA continues. Illustrations in genetics textbooks may become more detailed for the purpose of communicating more empirical knowledge, but the simpler pictures remain useful for conveying a simpler message that here is something scientific.

Next I add two more phases.

**Phase Three: Genetic Engineering**

Genetic engineering is a technology which uses recombinant DNA (rDNA) to transfer the genotype of a trait from one organism to another. A desirable trait is identified; the genes that code for that trait are located; rDNA captures the relevant DNA from the source organism, and then insert it into the genome of a target organism, which can be from a different species. When this works properly, the trait manifests itself in the target organism. Genetically modified foods are the most vivid proof that genetic engineering is real. The ultimate genetically modified
organism is a creature which has acquired bioluminescence, e.g., kittens that glow in the dark because genes for luminescence have been inserted in vitro into their genomes.

So then, how is DNA depicted in genetic engineering? The core of visual depictions of DNA for illustrating genetic engineering is to show that a segment of DNA is extracted from one organism and inserted into another.

But if scientists are doing genetic engineering, then it is desirable to show them doing so. Depictions of genetic engineering often show a person wearing a white lab coat (because this says that the person is a scientist), and they show that the person is in the process of moving a segment of DNA from a source organism to a target organism.

The DNA molecule is much too small to be seen by an optical microscope, let alone the human eye. If the scientist is depicted at a scale at which we see that she is a human, then a piece of DNA could not be depicted at the same scale.

The solution is to exaggerate the size of the DNA segment. The genetic material may seem to be about twenty centimeters in length, which is to say that the illustrator depicts humans at a human scale, but depicts DNA as something millions of times larger than it really is. If one is going to illustrate a nanoscale process like genetic engineering, while also putting scientists into the illustration, then it is necessary to distort the scale of the DNA. Didactic intent determines this aesthetic decision.

Here Google helps us again. Search for “genetic engineering” and select “images”. You can see how the human scale and the molecular scale are made to fit into one image.

Phase Three does not represent an end to Phase Two. On the contrary, the two can occupy the same time period because different illustrators have different didactic intentions.

**Phase Four: Synthetic Biology**

Synthetic biology is a sophisticated variation of genetic engineering. Again, a desirable trait is identified, and the genes that code for that trait are located. But instead of deriving the DNA from a living organism, one can assemble it in a chemistry lab where there are supplies of A, T, G, and C, plus sugar molecules and phosphate molecules. Synthetic biology then acquires a sense that it is a process of design and construction, like civil engineering [24]. Depictions of DNA sequences emphasize that they have been designed, constructed, and delivered to the right places, like the pieces of a building or a bridge. Engineering practices govern the visual representation of DNA.

A good example is the opening page of the Synthetic Biology Project of the Woodrow Wilson International Center [25]. Here there are cranes, construction workers in hard hats, and other signs that synthetic biology builds its own DNA according to its own preferences. How quaint it seems for classic genetic engineering to rely on organic sources of DNA.
Conclusion

My four historical phases do not exhaust the variety of visual depictions of DNA. No doubt there are additional genres, e.g., to illustrate gene editing with CRISPR, and to show how DNA is used in gene drive.

As we notice that visual depictions of the DNA molecule draw upon a great spectrum of aesthetic decisions, we appreciate that all of them convey a visual core of a double helix and a series of base pairs. Beyond those two elements, there is a great variety of creative imagination in the ways that illustrators tell the viewer that this is DNA.

I imagine two principal considerations that influence depictions of DNA. One is the didactic intention of the illustrator: what does he or she want to tell the viewer about DNA? Who needs a lot of empirical detail about DNA? Who needs only a simple representation? Which populations are in between?

The second consideration is change in scientific knowledge about this molecule. Depicting DNA to illustrate synthetic biology is necessarily more sophisticated than the original drawing of April 1953.

Scientific knowledge about the DNA molecule is superb, but there are reasons why illustrators put different pictures of it before our eyes. When we know DNA by seeing these pictures, let us keep in mind that, along with the empirical details, there are aesthetic decisions which shape the ways we see DNA.

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References

[17] Crick [16].
[19] See Ref. [18].
[23] Toumey [8]

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