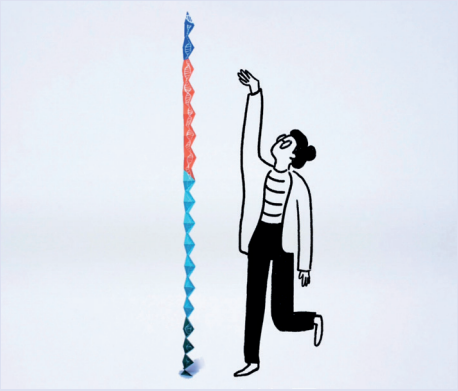
DNA Origami:
How do you fold a genome?

Activity Pack

The Royal Society
Summer Science Exhibition 2017
Tuesday 4 July – Sunday 9 July

DNA - deoxyribonucleic acid - (let's just call it DNA!) has the instructions for making you and every other living thing.



Inside every cell in your body is 2 meters of DNA - folded carefully into a structure smaller than the width of a human hair.

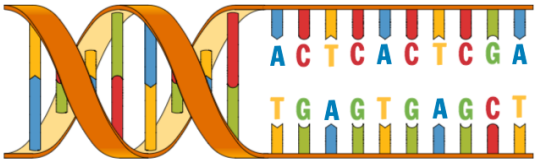
DNA folding isn't random, and changes in how DNA is shaped has consequences for human health.

Our technology helps us understand how DNA folds and may lead to treatment for common diseases.

We can study DNA at different levels

At the lowest level, DNA is a double helix (two strands wound around each other) made of four chemical "letters": A, T, C, and G.

These letters are known as "bases".



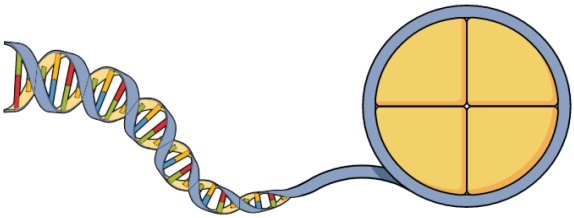
Each letter on each strand of the double helix pairs up with a letter on the other strand.

A always pairs with T and
C always pairs with G.

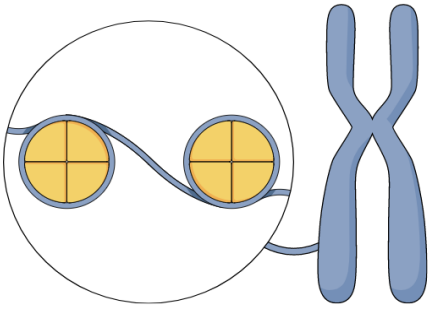
Lots of these letters form a special code known as genes, which control how our cells and bodies work.

At the next level,
DNA wraps around molecules called histones.

This DNA-histone complex is called the **nucelosome**.

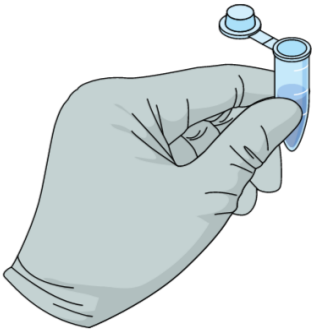


DNA connects nucleosomes and forms **chromatin**.



Chromatin forms "X"-shaped chromosomes and we have 46 chromosomes in each cell. You find these chromosomes in a special part of the cell called the nucleus.

At the highest level, we can collect DNA in the laboratory.



It looks like "goo".
All of your DNA - this 'goo' - is called your genome.

Find the 12 hidden words!
Use the clues below!
Words are hidden forward, backwards and diagonal!

1. *You have many of them and they form your body. C_ _ _*
2. *The DNA forms this X-shaped structure. C _ _ _ _ _ _ _ _ _*
3. *The genetic material in your body. D _ _*
4. *A,T, C & G combine to form codes known as G _ _ _*
5. *They are the DNA building blocks and there are four different types. B _ _ _ _*
6. *The special part of the cell where you can find DNA. N _ _ _ _ _ _*
7. *One of the four DNA building blocks (2x). A _ _ _ _ _ _, G _ _ _ _ _ _*
8. *The shape of the DNA. D _ _ _ _ _ H _ _ _ _*
9. *This is what all of the DNA in your body is called. G _ _ _ _ _*
10. *The DNA is wrapped around this protein. H _ _ _ _ _ _*
11. *Bases can always be found in a specific P _ _ _ _ _ _ (A and T, C and G).*

H	N	G	E	P	A	I	R	I	N	G	A	E	R
N	N	E	T	E	S	X	O	E	G	U	D	N	I
G	O	N	A	I	E	I	L	E	S	D	G	O	D
E	A	E	E	N	E	L	E	N	N	N	C	E	G
N	O	D	I	D	G	E	H	I	S	T	O	N	E
O	C	U	O	B	N	H	O	N	L	U	H	S	L
M	D	D	A	D	C	E	E	A	A	N	L	N	E
E	L	S	S	U	E	L	C	U	N	N	L	U	E
O	E	E	H	B	L	B	E	G	B	B	O	E	C
S	E	E	N	A	L	U	N	H	O	B	G	E	L
M	C	H	R	O	M	O	S	O	M	E	E	H	X
A	L	N	A	N	H	D	N	S	I	N	O	N	N
R	N	E	E	N	I	N	E	D	A	D	S	E	A
B	N	A	E	E	U	G	S	N	N	B	S	N	O

Solution on the last page

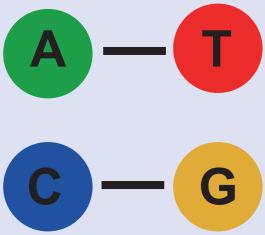
Build your own DNA bracelet!

Our genetic code or DNA tells our body what to do. Small differences in our genetic code make us all different and special. DNA is made of bases that always form a specific paring, A with T and C with G. In this activity, you can build a bracelet in the same way your body builds a protein (by following a code). Choose a code/sequence from below and

You will need:

- Beads in four colours (for example **green**, **red**, **blue**, **yellow**)
- Thin elastic cord
- Sequence template (optional)

Base pairs:



DNA sequence template:

Insulin – *helps to keep your blood sugar at a normal level*

C C A T A G C A C G T T A C A A C G T G A A G G T A A

Haemoglobin – *helps your blood to carry oxygen to your tissues so they can do work*

A A A C A G A C A C C A T G G T G C A C C T G A C T C C T G

Build your own DNA bracelet!

Instructions

1. Tie the ends of the two elastic cords together
   (young children may need an adult to help with this step)
2. Find a sequence of DNA you want as your bracelet
   (see templates)
4. Match the letter of the sequence to its corresponding colour
5. Thread the coloured bead of the first base on to one piece of elastic cord
6. Thread a coloured bead that pairs with the first bead on to the second strand

Don't forget, A pairs with T and C pairs with G!

7. Complete your sequence
8. Tie the ends together and you have finished your DNA bracelet

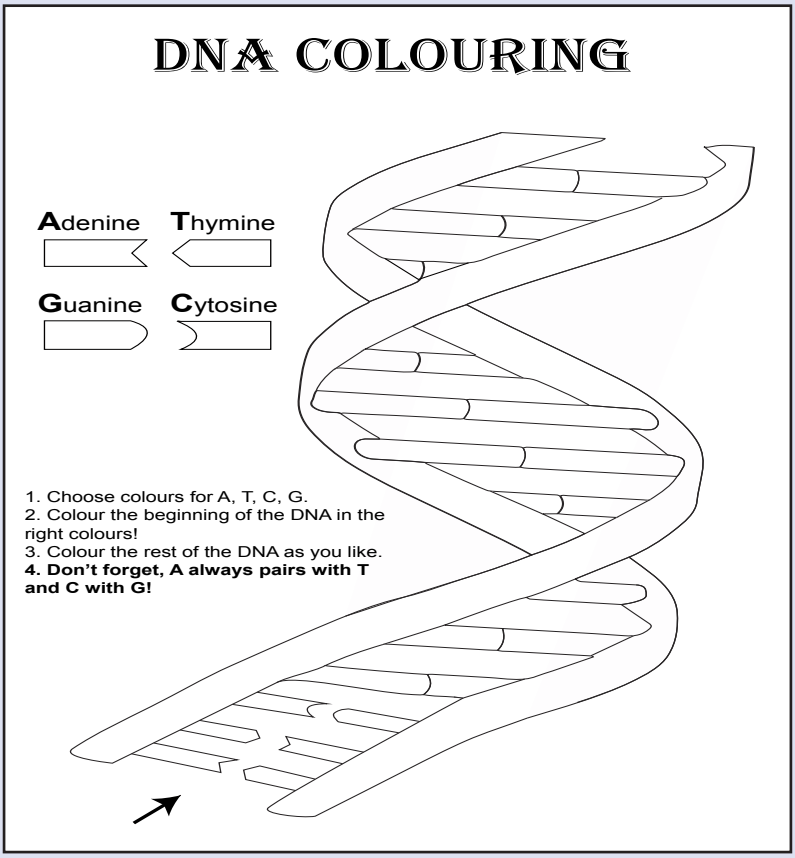
What does my DNA actually look like in my cells?

Let's find out!

You can:

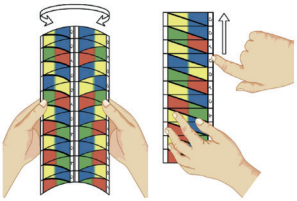
1) colour DNA
2) fold your own 3D DNA model
3) get real DNA from strawberries

In your activity bag:



Let's build your own 3D DNA model!

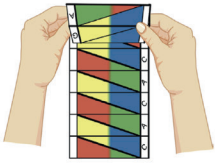
Take the printed DNA sheet from the activity bag and follow the instructions!



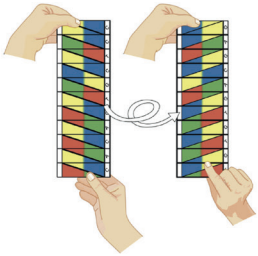
1 Fold in half lengthwise. Make all creases as firm as possible (use your fingernail!)

2 Hold the paper so that the thick lines are diagonal and the thin lines are horizontal. Fold the top segment down and then unfold.

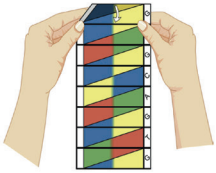
3 Fold the top two segments down along the next horizontal line. Unfold.



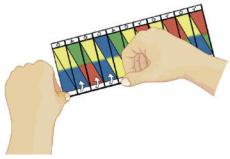
4 Repeat for all segments.



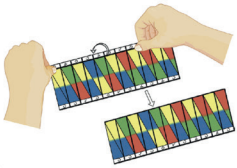
5 Turn the paper over.



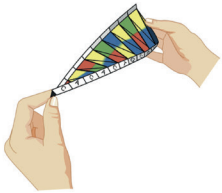
6 Fold along the first diagonal line. Unfold and fold along the second diagonal line. Repeat for all diagonal lines.



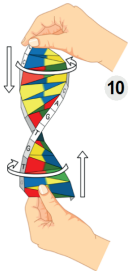
7 Fold the white edge without letters up.



8 Fold the other edge away from you. Partly unfold both edges.

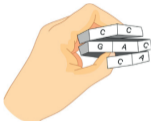


9 You can now see how the model is starting to twist.

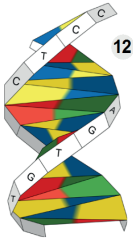


10 Twist and turn the paper while pushing the ends towards each other.

Be brave!



11 Now let go!



12 Admire your completed DNA double helix!

Only another 2,999,999,989 (or so) more to complete your whole genome!

Get some real DNA from strawberries!

You will need the help of an adult for this activity!

In this experiment, washing up liquid and salt are used to break-up the nucleus and the cells. This releases the DNA. Alcohol is used to make the DNA appear or 'precipitate' from the solution, right before your eyes! Strawberries have 8 copies of each chromosome (octoploid genome), which is why so much DNA appears!

You will need:

- 1 resealable plastic bag
- Strawberries (fresh or frozen)
- 2 teaspoons of dish detergent
- 1 teaspoon of salt
- ½ cup of water
- 2 plastic cups
- Fine sieve or coffee filter and funnel
- Ice cold 90 percent rubbing alcohol/ethanol
- 1 wooden popsicle stick or plastic coffee stirrer

Get some real DNA from strawberries!

Part 1

1

Put a large strawberry into a food bag. Seal bag and mash the strawberry.

2

Prepare the DNA extraction mix by mixing the washing up liquid, salt and water.

3

Add 2 teaspoons of the DNA extraction mix and mash again.

Get some real DNA from strawberries!
Part 2

4

Carefully pour the mix into the sieve or filter, so that the liquid drips through the funnel into the cup.

5

Gently add the ice cold rubbing alcohol/ethanol to the side of the cup (as much as the strawberry mix). Do not mix, just slowly tip the cup to the side a couple of times and wait until some grey strings appear, the DNA. You can take it out with your wooden stick. If nothing happens after a while, you can also start to carefully mix the liquid with your stick and see if DNA strings appear.

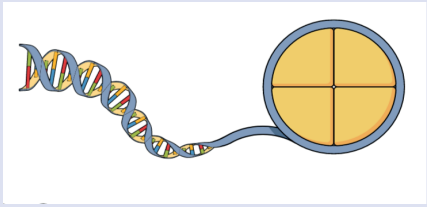
Congratulations, you just extracted some DNA!

How does all my DNA fit inside a cell?

Now that you know everything about what DNA is and what it looks like, we can show you how it all fits into a cell!

(Remember, there are two meters of DNA in each cell of your body)

Easy, it's all about the folding!



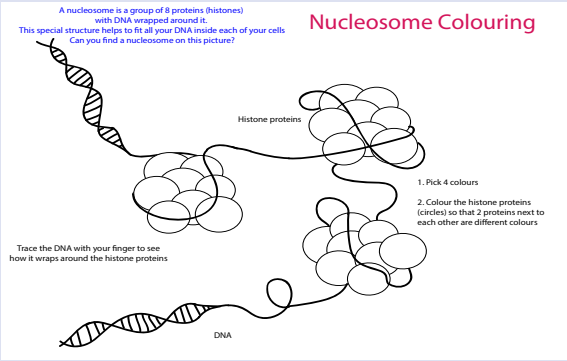
The **DNA double helix** strand wraps around proteins, called **histones**. Histones can be turned on or off and control the DNA. DNA and histones together are called a **nucleosome,** which basically looks like thread on a spool. Many of these nucleosomes are like beads on a string and are closely packed to form X-shaped **chromosomes**.

Now you can:

1) colour in nucleosomes

2) build your own eatable nucleosome!

In your activity bag:



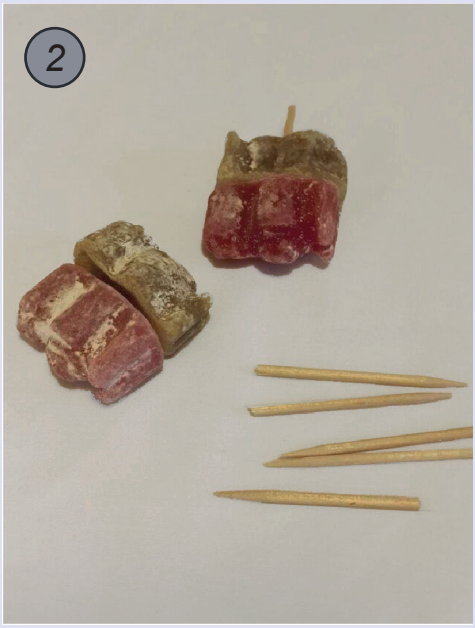
Build your own eatable nucleosome!

Part 1

You will need:

- Toothpicks
- Strawberry laces
- Large jelly babies in different colours
- Smaller jelly babies or other small sweets

Strawberry laces are your DNA string and large jelly babies are histones. Small sweets are like flags on histones - they say which ones are turned on or off.

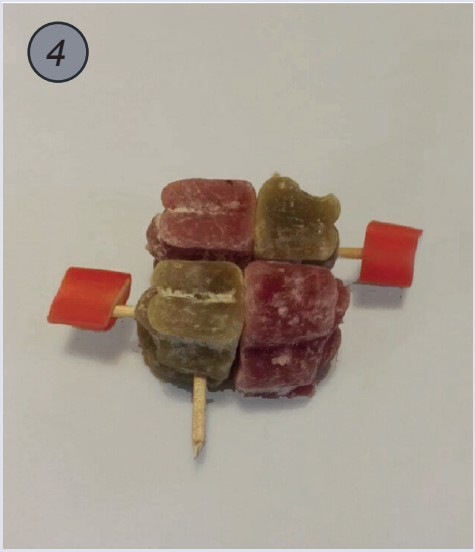


Break your toothpicks in half. Stick them through two large jelly babies.

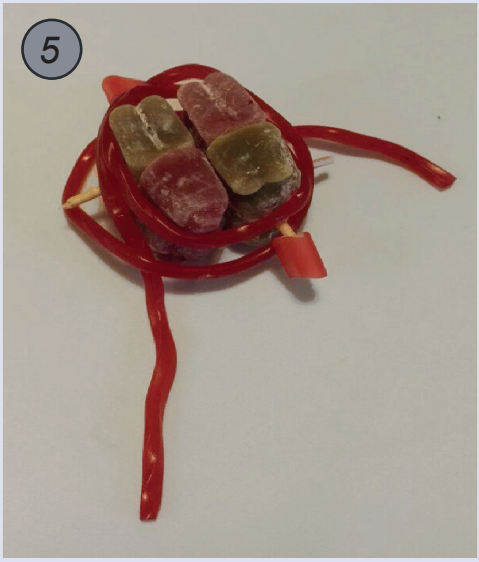
Build your own eatable nucleosome!

Part 2

Connect two of the histone or jelly baby pairs with more toothpicks.



Decide which histones you want to turn on and put small sweets on the tooth-picks.



Wrap the strawberry laces (DNA) around your nucleosome.

This is how DNA is packaged in the cell!

Why are we interested in DNA folding?

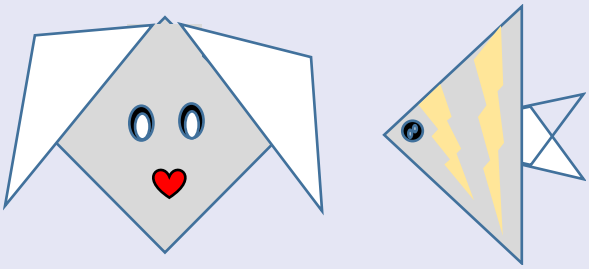
This brings us back to our main question and we can show you the importance of DNA folding with the help of some activities:

Origami folding

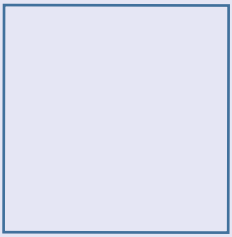
In this activity, how you fold the paper will change what animal you have at the end.
This is the same as with our genome! Imagine your blank, square piece of paper is like your DNA, if it is folded slightly different to normal, this can have huge effects on how we develop and our life.

You will need:
- A square piece of paper
- Colouring pens/crayons

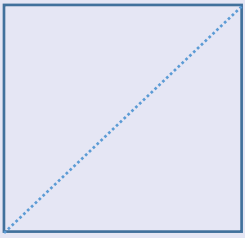
On the next pages, you can find the folding instructions for a fish and a dog!
See how you start with the same piece of paper and you will end up with two completely different animals!



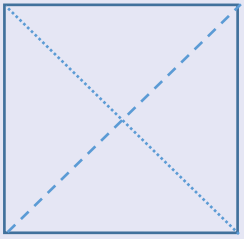
Fish origami



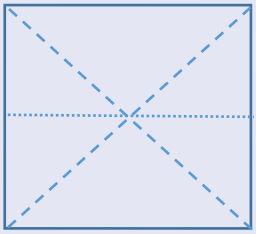
1) Start with a square piece of paper



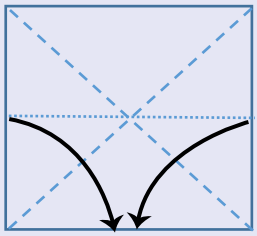
2) Fold across the diagonal then unfold the paper



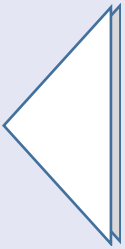
3) Now fold across the opposite diagonal, then unfold the paper



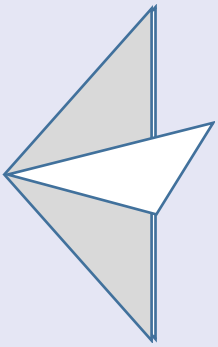
4) Fold the top half of the square backwards, then unfold



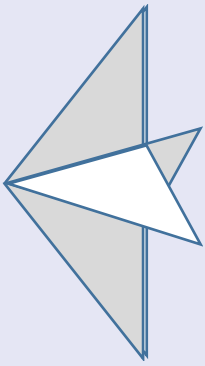
6) Fold the sides of the square in towards the centre so that you get 2 triangles on top of each other. Flatten down.



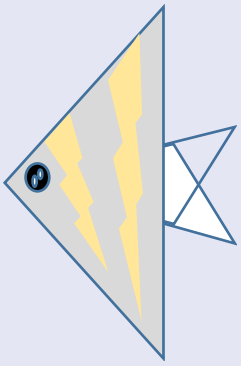
7) Rotate the triangle 90 degrees to the left (counter-clockwise)



8) Fold the bottom corner up to the central point as above

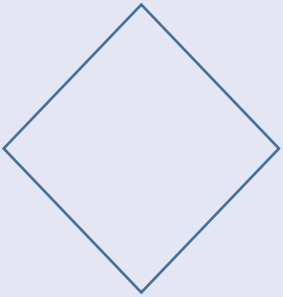


9) Repeat for the top corner, folding down to the central point

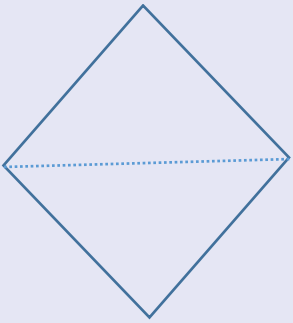


10) Flip the paper over and add colour to your fish!

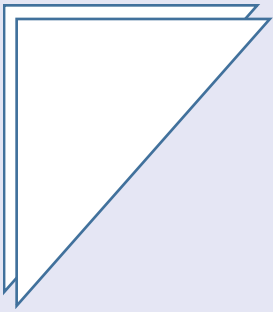
Dog origami



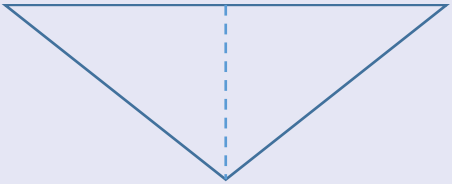
1) Start with a square piece of paper



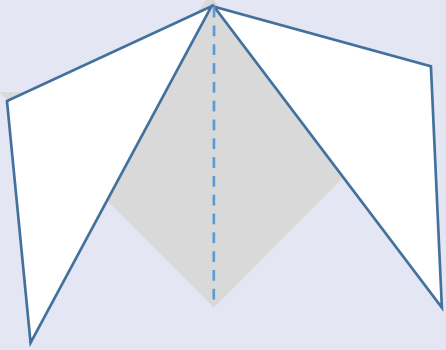
2) Fold the square in half



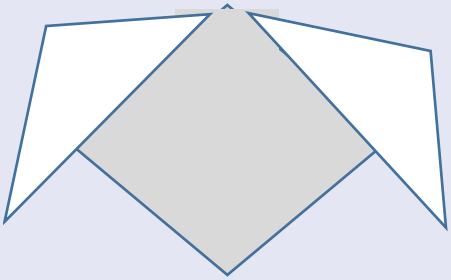
3) Then fold the triangle again



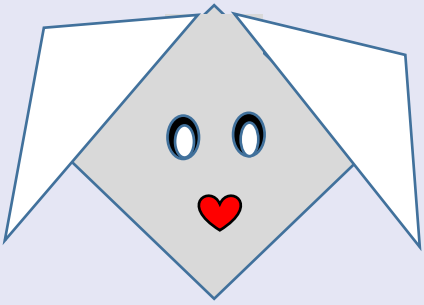
4) Unfold the paper to get the triangle above



5) Fold the top corners of the triangle down at an angle to make the ears



6) Fold the top corner of the head backwards
(dogs don't have pointy heads!)



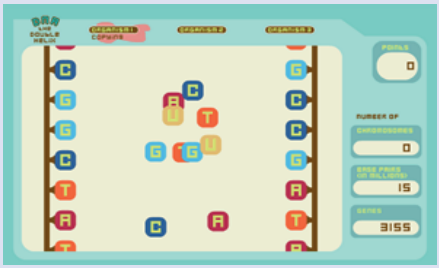
7) You have folded your own dog!
Draw and colour in the eyes, nose and ears!

Do you want to know more about DNA?

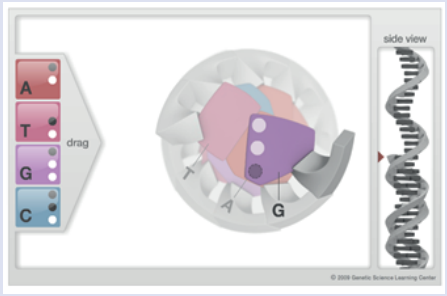
http://owlcation.com/academia/explaining-dna-to-a-six-year-old
http://vimeo.com/60747882
http://kids.britannica.com/kids/article/DNA/390730

Do you want to do some online DNA activities?

Copy DNA against the clock!
http://www.nobelprize.org/educational/medicine/dna_double_helix/dnahelix.html



Build a DNA model!
http://learn.genetics.utah.edu/content/basics/builddna/



Solution for the Crossword:

1. Cell
2. Chromosome
3. DNA
4. Gene
5. Bases
6. Nucleus
7. Guanine, Adenine
8. Double helix
9. Genome
10. Histone
11. Pairing

Goodbye!

We hope you enjoyed these activities and learned a lot about DNA and its folding!
See you next time!

To find out more, visit us at:
http://bit.ly/DNAActivities

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4th July to 9th July, London

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EXHIBITION 2017

UNIVERSITY OF
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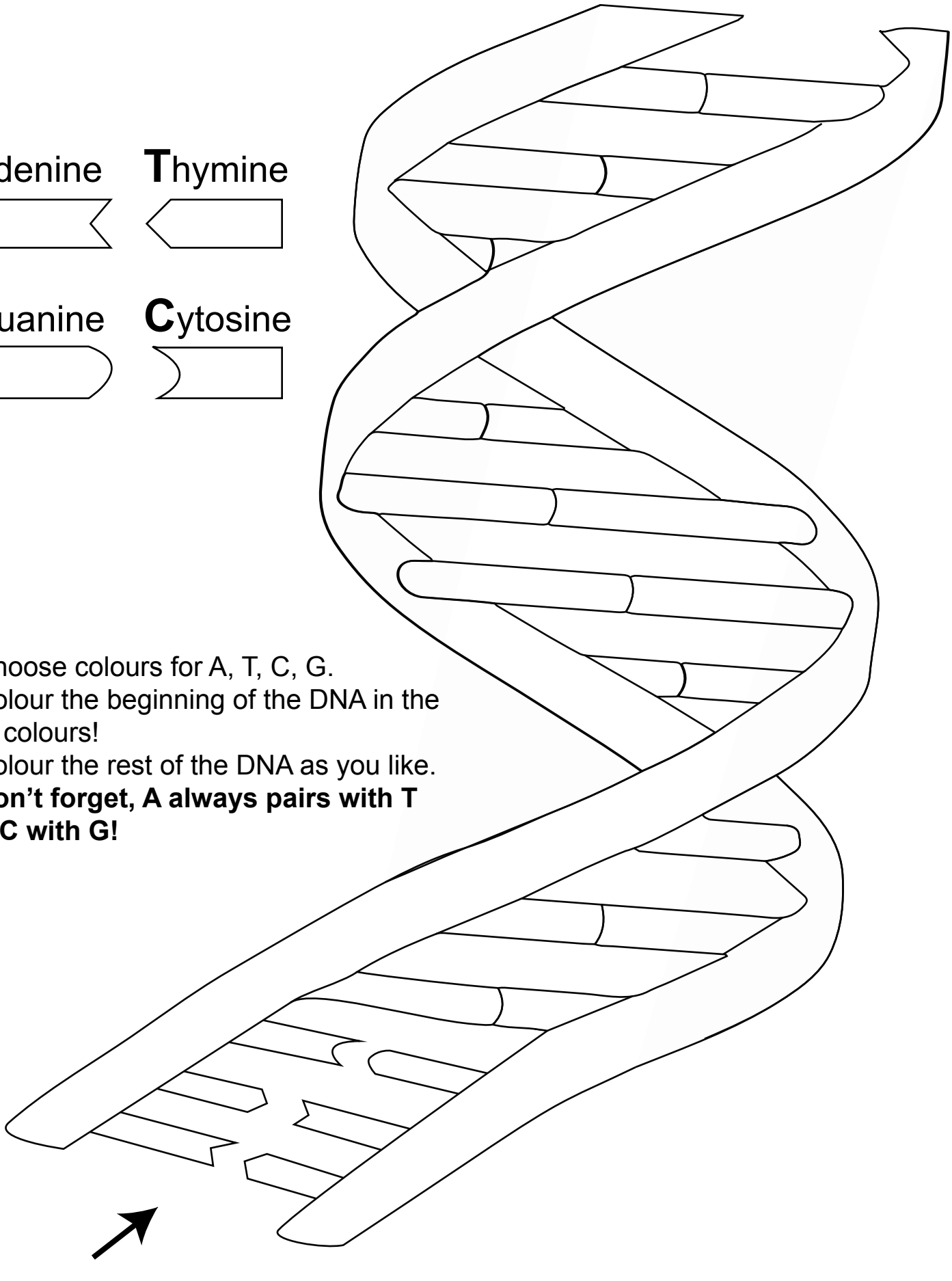
https://www.medsci.ox.ac.uk/folding-genome

DNA COLOURING

Adenine **T**hymine

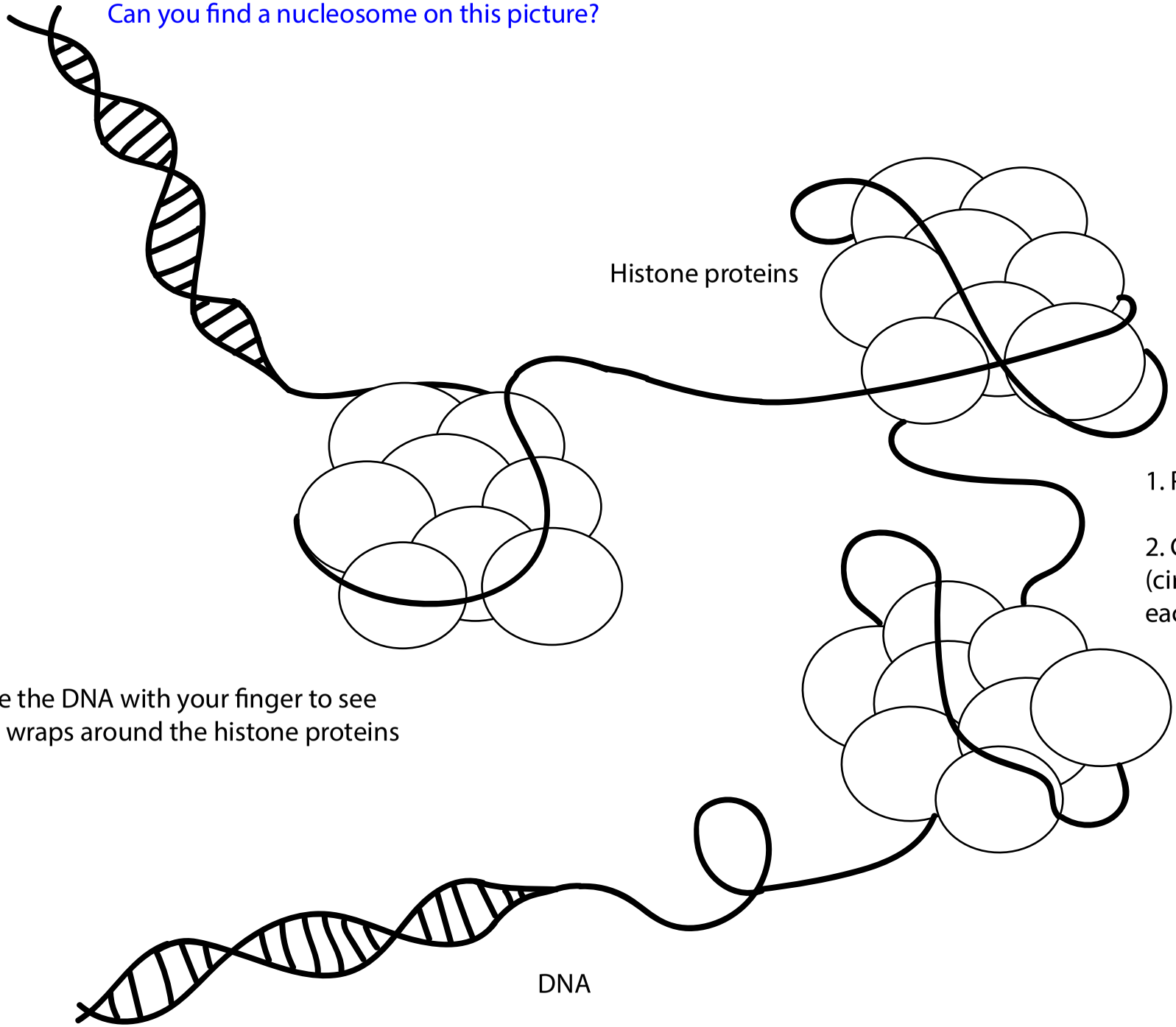
Guanine **C**ytosine



1. Choose colours for A, T, C, G.
2. Colour the beginning of the DNA in the right colours!
3. Colour the rest of the DNA as you like.
4. **Don’t forget, A always pairs with T and C with G!**

Nucleosome Colouring

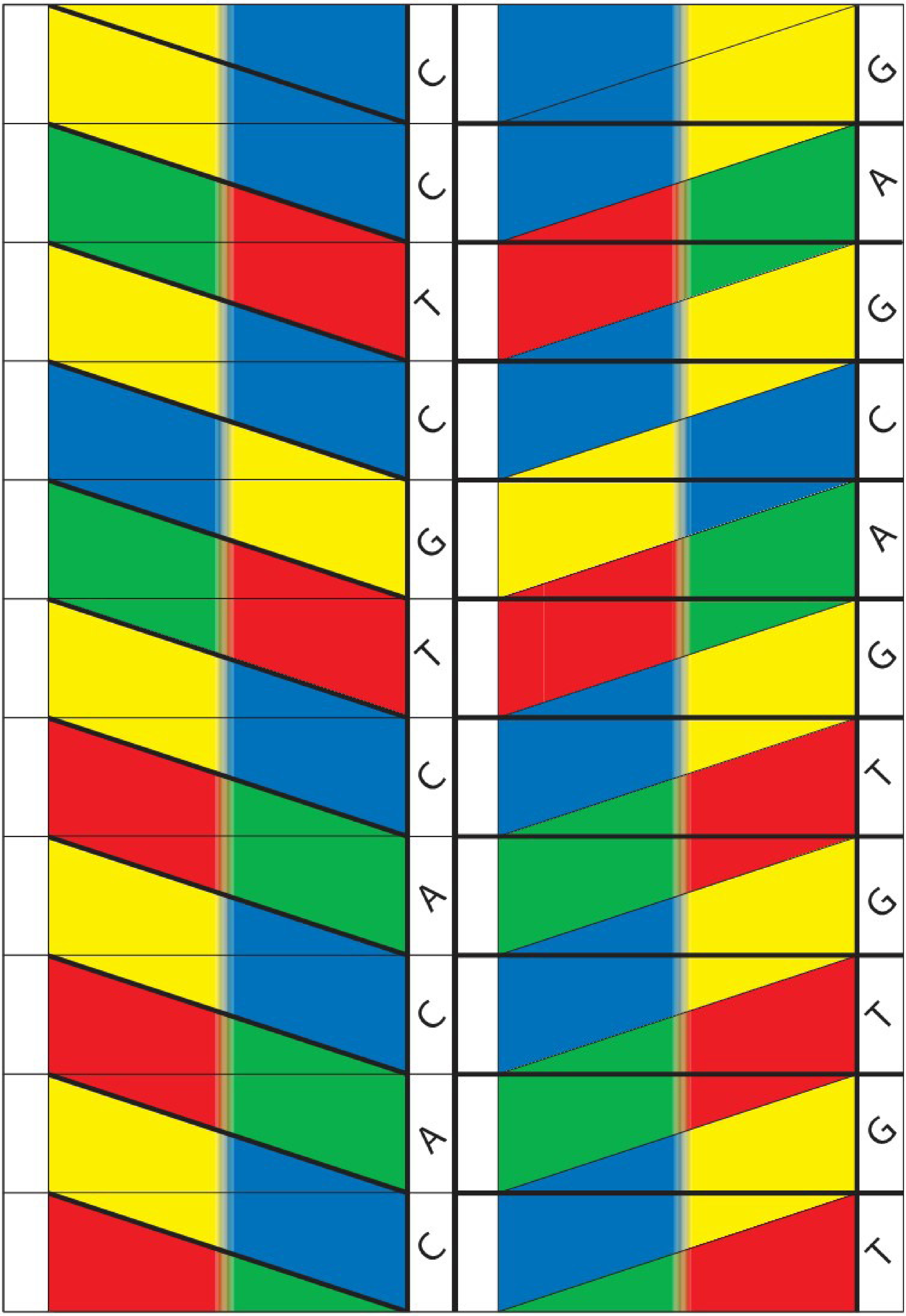
A nucleosome is a group of 8 proteins (histones)
with DNA wrapped around it.
This special structure helps to fit all your DNA inside each of your cells
Can you find a nucleosome on this picture?



1. Pick 4 colours

2. Colour the histone proteins (circles) so that 2 proteins next to each other are different colours

Trace the DNA with your finger to see how it wraps around the histone proteins



C
C
T
C
G
T
C
A
C
A
C
G
A
G
C
A
G
T
G
T
G
T