Discover the topic of genomics and see how something as small as DNA has a big impact on the world and our lives.

Age: 11+

**Mindfulness colouring**
Get a feel for the areas of research genomics covers.
[https://yourgenome.org/activities/mindfulness-colouring](https://yourgenome.org/activities/mindfulness-colouring)

**DNA origami**
Try your hand at a bit of origami and fold yourself a DNA helix from paper!
[https://yourgenome.org/activities/origami-dna](https://yourgenome.org/activities/origami-dna)

**Function finders BLAST**
Run some code cracking software and unlock nature’s potential from your computer!
[https://yourgenome.org/activities/function-finders-blast](https://yourgenome.org/activities/function-finders-blast)

**Genome generation express**
Just because we can doesn’t mean we should. Explore societies concerns.
[https://yourgenome.org/activities/genome-generation-express](https://yourgenome.org/activities/genome-generation-express)
A genome is an organism’s complete set of genetic instructions. All living things have genomes - each genome contains all of the information needed to build that organism and allow it to grow and develop. Genomics is the study of genomes.

Scientists study the DNA of all sorts of organisms from microscopic pathogens to the largest animals and plants in the world. By looking at DNA data we can find out what makes us similar and what makes us different, what makes us ill, what makes us healthy and even how life on the planet has evolved.

Through this pack you will explore some of the cutting edge science that goes into understanding the world around us. Work through the activities and by the end you’ll know what genomics is and how it can be used to understand health, disease and the natural world.

**CHALLENGE 1: MINDFULNESS COLOURING**

On the next few pages we’ve got some mindfulness colouring sheets for you to colour in. Can you guess what each image represents? What area of genomic research do you think it relates to? Write your ideas at the bottom of the sheet.

Visit [yourgenome.org](http://yourgenome.org) to see if you can find your image and write down three facts from the fact page.
Genomics looks at the DNA code packaged within the chromosomes found in the nucleus of a plant or animal’s cell. You can also look at the genomes of bacteria and viruses to understand how they cause disease, and how they can be treated. Studying bacterial genomes can reveal the amazing potential of the microbial world, which can be harnessed for biotechnological applications. Did you know that there are bacteria in the soil that can generate electricity?! By looking at changes in DNA code you can discover a lot about the natural world around us. But what does this molecule of life look like?

DNA has a unique double helix shape, and looks a bit like a twisted ladder. This shape is really important for containing all the instructions to make a living organism. The double helix structure of DNA enables it to be compacted and packaged up into chromosomes so that it fits into the nucleus of a cell.

**CHALLENGE 2: ORIGAMI DNA**

Try following the instructions on page 10 to fold your own DNA double helix out of paper! There is a template on page 11, just after the instructions so you can make your own.
**ORIGAMI DNA**
Folding 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!

Origami model: Alex Bateman, Thoki Yenn
DNA contains four basic building blocks or ‘bases’: adenine (A), cytosine (C), guanine (G) and thymine (T). The bases on one strand of the DNA molecule pair together with complementary bases on the opposite strand of DNA to form the ‘rungs’ of the DNA ‘ladder’. The bases always pair together in the same way, A with T, C with G.

The order, or sequence, of these bases form the instructions to make proteins and other molecules essential for making all living things function. By reading the DNA code, we can work out what protein the specific section of the DNA – the gene – codes for.

Proteins are like tiny molecular machines that do lots of jobs inside our bodies whether it is forming muscle, breaking down food or facilitating the complex biochemical reactions that keep us alive. Every three letters of DNA makes what we call an amino acid. These amino acids bond together, like beads on string, then fold into specific shapes to make the whole protein.

CHALLENGE 3: FUNCTION FINDERS BLAST

Your task is to decode some DNA sequences to find out what protein they produce. Use the codon wheel on page 13 to translate the DNA codes on your worksheet into a protein sequence. Once you have your protein codes, follow the instructions to carry out a BLAST search using the UniProt database where you will find out what your protein is and what it does.

When you have completed the challenge, think about these questions, and if you can discuss them with your teacher, friends or family:

- What was the most interesting protein you found?
- Are there other features or abilities in the natural world that you would like to find out the DNA code for?
- Do you think you could use this research in human health applications?
Use the codon wheel to translate DNA codons into amino acids:

To decode a codon find the first letter of your sequence in the inner circle and work outwards to see the corresponding amino acid. For example: CAT codes for H (Histidine).

Please note that this wheel uses the sense DNA codons (5’ to 3’).
**FUNCTION FINDERS BLAST**
Worksheet

Translate the DNA sequences to find the matching protein using Uniprotein BLAST search:

<table>
<thead>
<tr>
<th>DNA sequence 1</th>
<th>atg</th>
<th>aag</th>
<th>tca</th>
<th>gct</th>
<th>att</th>
<th>tta</th>
<th>acc</th>
<th>ggt</th>
<th>ttg</th>
<th>ctt</th>
<th>ttc</th>
<th>gtc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translated sequence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DNA sequence 2</th>
<th>atg</th>
<th>agt</th>
<th>aaa</th>
<th>gga</th>
<th>gaa</th>
<th>gaa</th>
<th>ctt</th>
<th>ttc</th>
<th>act</th>
<th>gga</th>
<th>gtc</th>
<th>gtt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translated sequence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DNA sequence 3</th>
<th>gaa</th>
<th>aac</th>
<th>atg</th>
<th>gag</th>
<th>aac</th>
<th>gat</th>
<th>gaa</th>
<th>aat</th>
<th>att</th>
<th>gtg</th>
<th>tat</th>
<th>ggt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translated sequence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DNA sequence 4</th>
<th>ggt</th>
<th>tgg</th>
<th>gct</th>
<th>ttg</th>
<th>cgg</th>
<th>atc</th>
<th>atg</th>
<th>ttt</th>
<th>cta</th>
<th>cat</th>
<th>ctg</th>
<th>tac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translated sequence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Translate the DNA sequences to find the matching protein using Uniprotein BLAST search:

<table>
<thead>
<tr>
<th>DNA sequence</th>
<th>Translated sequence</th>
<th>Protein name</th>
<th>Organism</th>
<th>Protein function</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>cct ggg gag aac cta tgc tat aga aag atg tgg tgc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>ccc aga gag atc cag acc gcc gtg aga ctg tta ctc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>gag aag aga aag ctg ttt atc cgt tcc atg ggt gaa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>atg gag ttt act ttg agg caa gag gct tta gtt aat</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HOW TO COMPLETE THE WORKSHEETS

1. Use the codon wheel to translate the DNA sequences on the worksheet to amino acids.

2. Type the amino acid sequence in to the Uniprot Blast search [www.uniprot.org/blast/](http://www.uniprot.org/blast/).

   Press Run BLAST to get results (it may take a few seconds for results to appear).

3. When the search results appear, filter the results to only show reviewed entries (gold file icon with a star). Each result is known as a “hit.”
4. After filtering the hits should look like this. **Scroll down** to the Overview section.

Look at the info column. This will give you an idea of how reliable your hits are. The Expect value (E-value) indicates the number of random hits you would expect by chance for the given query sequence and the size of the sequence database against which the BLAST is performed.

For example, an E-value of 1.0 means that you would expect on average to get one match in the database for the submitted query simply by chance. The lower the E-value, or the closer it is to zero, the more "significant" the match is. In general, the E-values should be in the range of 0.01 to 0.1 to be statistically significant.

The identity % describes how similar your sequence is to the hit, i.e. whether the amino acids are in the same position when aligned. 100% means the sequences match exactly.
5. **Click on the hit** that you think best matches your sequence. Find out the name of the protein which species the sequence is from (common and species name) and what the protein does. Is the protein found in other species?

You can reduce the amount of information on the screen by unticking the blue display categories on the left hand side of the screen.

If you cannot find all the information you need, try using a Google search or Wikipedia to find out more.

6. To start a new BLAST search click **Edit and resubmit**, and enter your next set of amino acids. Repeat steps 3 to 5.
Much of the research at the Wellcome Genome Campus focuses on exploring DNA to discover potential new ways to diagnose and treat human health conditions. The technology used in this research has developed quickly over the last couple of decades. When the human genome was first sequenced (the process of working out all the DNA code in our DNA instruction manuals) in the early 2000s, the project took around 13 years and cost $3,000,000. The sequencing machines used today can sequence a Human Genome in a matter of days and the process costs less than $1000! This technological achievement has allowed huge growth in the field of genomics and led to many new discoveries that are already saving many lives across the world. However, the accessibility of the technology has started to raise ethical concerns around how the technology is used and what we as a society want the future of our civilisation to look like.

CHALLENGE 4: GENOME GENERATION EXPRESS

Read the two case studies on pages 20 and 23 and write down your initial thoughts on the blank viewpoints worksheets (pages 21-22 and 24-25).

If possible, chat to someone else about their thoughts. If you are at home, talk to a family member or maybe a classmate online. Were their views the same as yours? What was their reasoning? Reflect on your answers using the annotated viewpoint sheet on pages 22 and 25. Were there things you hadn’t thought about or anything that made you think differently? Write down some more ideas on this sheet.

Keep in mind throughout this activity that there are no right or wrong answers!

To take this challenge further why don’t you write a one page summary on your scenario, outlining the pros and cons of the situation and what would you do in that situation?
SHOULD A BABY HAVE ITS GENOME SEQUENCED?

Olly and Lily are expecting their first child. The baby, currently known as ‘Bump’, is scheduled to be born by caesarean section on the 1st of March. Angie, Lily’s midwife, is running through the paperwork in preparation for the birth and asks the couple if they would like Bump’s genome sequenced.

Angie explains that along with being weighed, measured and having a heel prick test, a simple swab taken at birth will reveal Bump’s genetic background, indicating the various conditions he or she may or may not be at risk of developing. The results will be presented on an ID card and will form part of Bump’s medical records. Olly thinks it’s a great idea but Lily is concerned that the information revealed could lead to discrimination and inequality later in life.

Should Olly and Lily have their baby’s genome sequenced at birth?

What if the test shows that there are problems? If they need to show this ID card for everything, my poor child might get shunted out. If you were going to give out a university place or a job to someone, you would choose the healthiest one wouldn’t you? Not the one that you know might develop a disease.

More and more parents are opting for the test. It means that parents can be prepared for, and avoid, any health issues that may develop later in life. Lots of mums worry about it, but it’s perfectly safe and painless.

It’s a great idea! It will revolutionise healthcare. Doctors can just check the patient’s records and know every kind of treatment they might need further down the line. It will also mean we will be aware of any issues our child might face in the future and make better decisions to overcome them.
SHOULD A BABY HAVE ITS GENOME SEQUENCED?

<table>
<thead>
<tr>
<th>Should a baby have its genome sequenced at birth?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What are the medical impacts (good and bad)?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What are the societal impacts (good and bad)?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
SHOULD A BABY HAVE ITS GENOME SEQUENCED?

### Should a baby have its genome sequenced at birth?

- **How would this work in practice?**
  - (e.g. compulsory, an opt in system, based on family medical history)

- **Who pays for this?**
  - (e.g. governments, individuals)

- **Who has access to the data?**
  - (e.g. babies, parents, caregivers, doctors)

### What are the medical impacts (good and bad)?

- **What if there are increased chances of developing a condition that there is no treatment for?**
  - (e.g. very little is a certainty, knowing can lead to worry)

- **Should the data be used by companies for research too?**
  - (e.g. potentially speeding up new treatment discovery)

- **Can the findings currently be acted upon?**
  - (e.g. do all medical professionals understand genomics)

### What are the societal impacts (good and bad)?

- **Should you then change the DNA?**
  - (e.g. treatments being more than just traditional medical)

- **Would you only change health related genes?**
  - (e.g. make designer babies)

- **What unintended findings might you uncover?**
  - (e.g. parentage, parent’s health conditions)
ANDY’S UNEXPECTED PATERNITY RESULTS

Last year Andy bought himself an online genotyping kit. The results were kind of fun; no big shocks, just a couple of things that made his friends laugh. Last Christmas Andy decided to have some more fun and bought a testing kit for his father, George. Andy had to take his father through the whole genotyping process and was surprised how long it took to explain the basics.

Going through the results together, Andy noticed that there were some major differences between markers on the Y chromosomes of the two men. This was a shock, as the only explanation is that George is not Andy’s biological father. Andy asked his sister, Kate, about this and she just got really angry. Naturally, George didn’t spot the differences and wouldn’t recognise their importance if he did. Andy’s mum died a few years ago, so he can’t ask her about it.

Should Andy tell his father the result?

This genotyping is all very well so far as it goes. It was a bit of fun but Andy seemed to go off the whole thing pretty quickly. I think it’s just a fad.

What does this mean? If Dad isn’t my dad then who is? Does he know he’s not my dad? If he does then why hasn’t he told me?

This is all very strange. I wasn’t at all prepared for this. Andy’s got so many questions but what about me? Should I now get tested as well?
## ANDY’S UNEXPECTED PATERNITY RESULTS

<table>
<thead>
<tr>
<th>Should DNA test results be shared with someone’s family?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What are the medical impacts (good and bad)?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What are the societal impacts (good and bad)?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
ANDY’S UNEXPECTED PATERNITY RESULTS

Should DNA test results be shared with someone’s family?

- Who should decide this?  
  (e.g. doctors, DNA sequencing company, the person themselves)

- How do you know the DNA test is correct?  
  (e.g. the test is only as good as the method used)

- Who gives consent?  
  (e.g. the person having the test done, the people the information relates to)

What are the medical impacts (good and bad)?

- Would you be able to get more accurate medical data?  
  (e.g. biological family medical history)

- Are the right support systems in place to deal with this?  
  (e.g. emotional and mental health support)

- Does this lead to the ‘rich’ having more access to healthcare than others?  
  (e.g. these commercial tests are still relatively expensive)

What are the societal impacts (good and bad)?

- Who has the right to know?  
  (e.g. doctor patient confidentiality, extended family, official records)

- Could you find things out about other people without their permission?  
  (e.g. taking a sample from someone else and using the service)

- Does it give you a sense of identity?  
  (e.g. ancestry, community)
What do you think the future of genomics looks like? The applications resulting from the research have so much potential to improve medicine and lives across the world and yet it also requires society coming together to decide how such a powerful technology is to be used. Genomics gives us a way to explore the world around us to figure out how it all works. Even though DNA is really small, it can hold a lot of data – a lot of which we still don’t fully understand. Genomics is a great field of science that touches on everything from human health and medicine, to animal conservation, to biochemical engineering.

WHAT DO YOU THINK?

Now that you have finished the pack have a go at answering these questions!

www.surveymonkey.co.uk/r/Genomics_and_Genes