

Overview

Aims

The Barcoding for beginners project aims to get students carrying out authentic, novel scientific research. Within this overarching ambition, students will:

- Get hands-on and develop confidence in molecular biology techniques
- Gain transferable skills from a longer term, novel scientific investigation that will contribute to the body of scientific knowledge
- Experience the working environment of a genome campus, with career insights from staff

Educators will access free CPD, consumables, resources, a scientific partner and support. Equipment will be loaned for free. They will become part of a barcoding community, with links to support further funding opportunities and projects. Creation of student posters on their research will generate increased knowledge about genomics as well as a buzz of enthusiasm around barcoding for biodiversity.

Schools and colleges will benefit from the careers link, with closer ties to a scientific organisation contributing towards the Gatsby good career guidance benchmarks. There will be learning gains from overlap of practical experience with curricula and increased transferable skills for students from participation in the scientific process. Reporting on cutting edge research being done in an education environment provides excellent publicity opportunities with potential for local media coverage.

Activity outline

There are 10 sessions, each fitting within one hour. These can be used as 10 weekly slots, during off-timetable days or in a different way that fits with timetabling!



A brief summary of the 10 sessions is given below.

01 | Buzz about barcoding

A scene-setting introduction to this novel scientific investigation. Our scenario will aim to create a buzz by barcoding invertebrates for awareness of biodiversity in the school environment.

The introduction could be an assembly to the year group, or a recorded presentation for interested students. It will provide information about practical techniques, scientific skills and rewarding careers in investigative science.

It is anticipated that this session will be delivered by some combination of the Connecting Science team, STEM professional and lead teacher.

02 | Barcoding basics

An explanation of how barcoding works is followed by a bioinformatics exercise performing a BLAST (Basic Local Alignment Search Tool) activity using barcodes from another project to identify the invertebrates sampled.

Students begin planning how they will obtain their own invertebrate samples.

During this session students will complete a questionnaire, to be repeated at the end of the project enabling impact to be assessed.

03 | Pipetting for electrophoresis

A practical hands-on experience, building confidence in micropipetting and electrophoresis skills.

A reminder that samples need to be ready to use for the following session.

04 | DNA extraction

A practical hands-on experience of DNA extraction, from student invertebrate samples, using laboratory-grade reagents to obtain quality DNA for further investigation.

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- 05 | Performing PCR** An explanation of PCR, followed by practical hands-on experience to amplify the animal DNA barcode, the mitochondrial cytochrome c oxidase subunit I gene, using PCR.
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- 06 | DNA sequencing** A practical session building on skills in agarose gel electrophoresis. Gels are prepared and used to verify the presence of the amplified barcode gene in the PCR product.
- Successfully amplified samples are aliquoted ready to send for DNA sequencing.
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- 07 | Becoming a scientist** A student visit to the Wellcome Sanger Institute to experience first-hand the environment of a research campus. Equipped with increased practical capabilities and scientific skills, students will witness how techniques that they have encountered are used, and engage with STEM professionals to inspire career choices.
- Funding is available to support this student visit, whilst awaiting receipt of their DNA sequence.
- On campus they will experience first-hand the environment of a science campus. They will witness how techniques that they have encountered are used, and engage with STEM professionals to inspire career choices.
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- 08 | Bioinformatics: DNA identity** Using free-to-access online software, and the DNA barcode sequence generated, students will assess how accurate their DNA sequence is and try to identify their invertebrate from comparison to a database.
- Invertebrates from which accurate DNA sequence is obtained, but which do not match a known invertebrate in the database, can be used in further analysis.
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- 09 | Bioinformatics: family tree** An optional activity exploring evolutionary relationships between the organisms identified. This session will demonstrate how the DNA barcode sequences from the group can be used to generate a 'Tree of Life'.
- Alternatively, students begin to prepare their scientific posters.
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- 10 | Science communication** Students work collaboratively to present their research methodologies, results and conclusions, by producing scientific posters. These posters can be submitted to the Wellcome Connecting Science team for printing. Subsequent display in school, will ensure that results of the investigation are shared not only between the participating students, but within the whole school or college community.
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Age range

Key stage 4 and above (14 years and older).

Timing

To provide flexibility for delivery of Barcoding for beginners in schools, the project has been split into 10 distinct, short sessions, to fit within one term. The aim is to ensure that the project fits within the time constraints of the delivery structure within school (for example, STEM club, lunchtime enrichment, timetabled sessions or off-timetable sessions).

Venue

Session 1 is anticipated to be a presentation to a wide cohort.

Sessions 2, 8, 9, 10 require students to have access to computers.

Sessions 3, 4, 5, 6 require students to be in a school science laboratory.

Session 7 is a visit to the Wellcome Sanger Institute.

Preparation

This section describes the organisation required to make this project run smoothly. It includes information on:

- Practical work: equipment, consumables, logistics and risk assessment
- Software (free-to-access applications that need to be downloaded)
- Evaluating the project impact (consent forms and surveys)
- Arranging your visit to the Wellcome Sanger Institute
- Accessing support

Practical work: equipment

This project includes equipment loaned to your school by the Wellcome Sanger Institute. The total equipment will fit into an average car boot and is described in more detail below, alongside the sessions in which it is used.

Equipment supplied	Sessions used
15 Sharpie markers	2 or 3, 4, 5, 6
15 P20 micropipettes	3, 4, 5, 6
15 boxes of P20 micropipette tips	3, 4, 5, 6
15 laminated micropipetting target practice sheets	3
16 microfuge tube racks	3, 4, 5, 6
4 MiniOne gel electrophoresis systems (including casting trays, combs, gel trays, gel tanks, black back-plates, electrophoresis units and orange photography hoods)	3, 6
1 Vortex	3, 4, 6
4 P200 micropipettes	4
4 boxes of P200 micropipette tips	4
1 Microcentrifuge	3, 4, 5, 6
15 plastic pestles	4
15 PCR tube racks	5
2 MiniPCR thermal cyclers	5

The equipment that it is assumed schools or colleges will have is listed below, alongside the sessions in which it is used.

Equipment in school / college	Amount needed	Sessions used
Safety glasses	30 pairs	3, 6
Beakers to use as waste containers	15	3, 4, 5, 6
Measuring cylinder(s) and beakers / bottles to dilute 10 x TAE buffer	2 or 3	3, 6
Electronic balance to weight out the agarose	1	3, 6
Conical flask to melt the agarose	1	3, 6
Microwave and heatproof glove for melting the agarose or alternative heating equipment (for example, Bunsen burner, tripod and gauze)	1	3, 6
White paper	15 sheets	3
Waterbath at 95°C-100°C or a kettle and polystyrene cups to make waterbaths	1 waterbath or Kettle + 15 polystyrene cups	4
Pieces of aluminium foil to make a flotation device for the microfuge tubes	15 pieces	4
White cutting tile / dissection boards	15	4
Scalpels	15	4
Stopwatches	15	4
Freezer (-20°C)	1	4
Devices with MiniPCR app downloaded to programme and control the PCR thermal cycler (laptops or phones via Bluetooth)	2	5

Practical work: consumables

The consumables supplied for the Barcoding for beginners project are listed below, alongside the sessions in which each is used and storage requirements. Reagents that need to remain cold will be transported in an isofreeze box.

Reagents supplied	Storage requirements	Sessions used
15 Ziplock bags	Room temperature	2 or 3
1 box of small gloves	Room temperature	3, 4, 5, 6
2 boxes of medium gloves	Room temperature	3, 4, 5, 6
2 boxes of large gloves	Room temperature	3, 4, 5, 6
1 box of extra large gloves	Room temperature	3, 4, 5, 6
Bag of microfuge tubes	Room temperature	3, 4, 6
Tube of food dye	Room temperature	3
Tube of dye solution 1	Room temperature	3
Tube of dye solution 2	Room temperature	3
Tube of dye solution 3	Room temperature	3
Tube of dye solution 4	Room temperature	3
Tube of agarose	Room temperature	3, 6
Bottle of 10 x TAE buffer	Room temperature	3, 6
10% Chelex	Room temperature	4
A length of Parafilm	Room temperature	4
Bag of 0.2 ml PCR tubes	Room temperature	5
Microfuge tube of Forward primer	-20°C (freezer)	5
Microfuge tube of Reverse primer	-20°C (freezer)	5
Microfuge tube of PCR master mix	-20°C (freezer)	5
Tube of nuclease-free water	Room temperature	5, 6
Tube of loading dye containing GelGreen	Room temperature in blackout bag / aluminium foil (light sensitive)	6
Tube of 100 bp DNA ladder, premixed with loading dye containing GelGreen	4°C (fridge) in blackout bag / aluminium foil (light sensitive)	6

Practical work: logistics

Movement of equipment

When you visit the Wellcome Sanger Institute for the CPD session prior to starting the Barcoding for beginners project, you can pick up the equipment and consumables for use in school or college. During the student visit to the Wellcome Sanger Institute in session 7, you can return the equipment and any unused consumables to the Wellcome Sanger Institute.

Insurance during transport

Please note that if when collecting kit to borrow from Genome Research Limited, an individual may not be insured in case of an accident unless the vehicle is covered by 'business use' on the insurance. All individuals transporting equipment in their personal vehicle should therefore ensure they have the relevant insurance cover for this activity.

Practical work: risk assessment

Risk assessment of the practical activities included in Barcoding for beginners has been undertaken by Wellcome Connecting Science for the educator CPD. There are model risk assessments available for each of the sessions involving molecular biology work, for schools and colleges to refer to alongside teaching resources. All procedures are also explained in detail during the educator workshops.

Teachers and Technicians are reminded their employer is responsible for health and safety within their institution. Risk assessments must be carried out for all practical activities included in this programme at the school and college, to include considerations for their particular laboratory, situation and group of students involved. Individual risk assessments should be carried out for each practical activity with each different group (a model risk assessment provides considerable guidance but will not suffice). If the risk assessment indicates that the practical activities are too risky to carry out in that situation, the employer is responsible for ensuring that it is not undertaken.

Schools should be aware of guidance from CLEAPSS (Consortium of Local Education Authorities for the Provision of Science Services), and where applicable, a school or college should refer to local authority guidelines with regards to specific local rules and guidelines about health and safety.

Software

Prior to **session 5** you will need to download the free MiniPCR software to run these PCR machines. This can be downloaded from www.minipcr.com/downloads. Note that MiniPCR machines will need to be linked to a laptop, or controlled on a device using Bluetooth. The PCR cycle is easily set up, but can be programmed in advance if you wish and saved within the downloaded MiniPCR App library.

Prior to **session 8**, looking at the chromatograms to judge the accuracy of the DNA sequencing, download the free Chromas software, to enable viewing of the chromatogram from Sanger sequencing. This can be downloaded from technelysium.com.au/wp/chromas, and is compatible with Windows (XP, Vista, 7, 8, 10, 11).

Evaluating the project impact

To assess the impact of Barcoding for beginners, with the intention of improving its impact and reach, Wellcome Connecting Science (part of the Wellcome Sanger Institute) would like to track the project's impact on practical molecular biology skills, transferable skills and STEM (Science Technology Engineering and Maths) career awareness.

For us to complete this evaluation, students will be asked to fill in a questionnaire before and after involvement with the Barcoding for beginners project. Involvement in Barcoding for beginners is **not** dependent on answering these questionnaires.

To agree to questionnaire responses being used to evaluate the Barcoding for beginners project, students should complete the declaration of consent form, which needs to be countersigned by a parent or guardian. Please check these forms and only allow submission of questionnaires by students with completed declaration of consent forms.

To be able to match responses from questionnaires completed before and after participation, without information that can be used to identify students individually, we are requesting that each student uses a 7 character code. This should consist of 3 letters that allow identification of the school or college, which for uniformity we request are supplied by the course leader, then a hyphen, followed by 3 initials that the individual will remember (eg; I am from Wellcome Connecting Science and my hamster is called Nibbles, so I could use WCS-NIB). Whilst answering the questionnaire, please also ask students not to include any personal information that could be used to identify them.

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- ☐ 1. Students recruited to Barcoding for beginners
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- ☐ 2. Students and parent / guardians complete the **declaration of consent form**
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- ☐ 3. School or college staff collect the completed declaration of consent form and give a 3-letter school code
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- ☐ 4. Students (with completed declaration of consent form) complete the **questionnaire in session 02** before starting the project
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- ☐ 5. Students (with completed declaration of consent form) complete the **questionnaire in session 10** after finishing the project
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- ☒ 6. Wellcome Connecting Science collates student responses from pre- and post- questionnaires for evaluation and to assess the impact of Barcoding for beginners on:
 - practical molecular biology skills
 - transferable skills
 - STEM career awareness

Arranging your visit to the Wellcome Sanger Institute

To arrange your school visit, please fill out our booking request form on:

www.wellcomeconnectingscience.org/learning/resources-for-teachers/plan-your-school-visit

When registering, please state that you are visiting the Wellcome Genome Campus as part of the Barcoding for beginners project in the 'Additional notes or comments about your visit' section.

A travel reimbursement of up to £375 is available to eligible schools or colleges to facilitate their visit.

Accessing support

In addition to the STEM professional from the Wellcome Sanger Institute, who will partner with your school throughout the Barcoding for beginners project, the engagement team are all familiar with the resources and project. Should you need help / advice during the project then you can contact us and we will get back to you as soon as possible.

Phone number: **+44 (0)1223 496995** | Email: engage@wellcomeconnectingscience.org

Teaching content

This section describes intended learning outcomes from the Barcoding for beginners project and indicates useful prior knowledge for students.

Intended learning outcomes

Subject-specific learning outcomes

After completing Barcoding for beginners, students should be able to:

- Describe the process of DNA barcoding
- Provide examples of how DNA barcoding can be used for bioexploration and biomonitoring
- Understand the scale of DNA from experiential learning
- Manipulate small volumes accurately using a micropipette
- Explain how DNA molecules of different length can be separated using gel electrophoresis
- Separate DNA molecules using gel electrophoresis
- Describe a method for DNA extraction
- Follow a method for DNA extraction
- Explain how PCR can be used to amplify a region of DNA
- Amplify a region of DNA using PCR
- Explain how DNA sequence can be obtained using Sanger sequencing
- Interpret the accuracy of Sanger sequence data from a chromatogram
- Identify the organism that DNA came from using a BLAST (Basic Local Alignment Search Tool)
- Describe the method of binomial classification used for identification of organisms
- Explain that a phylogenetic tree shows evolutionary relationships between organisms
- Understand that DNA sequences can be used to build a phylogenetic tree
- Use bioinformatics (Clustal Omega and Interactive Tree of Life tools) to create a phylogenetic tree
- Create a scientific poster describing an inquiry-based project

Transferable skills

After completing Barcoding for beginners, students will have developed an understanding of:

- Collaborating with others on a research project
- Valuing the ideas of all team members
- Following laboratory protocols
- Risk assessment in a laboratory

- Collecting and recording data on samples for analysis
- Making observations during practical work
- The purpose of using controls in scientific experiments
- Interpreting experimental data
- Identifying limitations of a research method
- Problem-solving to identify and resolve experimental issues
- How bioinformatics is used to support laboratory research
- Presenting scientific results and conclusions
- How positive contributions to science build on the work of others

Career awareness

Barcoding for beginners will contribute to students' career awareness within biosciences through:

- Consideration of the relevance of taxonomy and molecular biology to biodiversity analysis
- Understanding of a large-scale biomonitoring project (BIOSCAN)
- Linking their learning to career opportunities
- Partnering with a member of campus staff who can provide career insights
- Providing an opportunity to visit and experience a working science research campus

Prior knowledge

Useful subject-specific prior knowledge

Before starting the project it is useful if students are aware that:

- Invertebrates are animals without a backbone
- Classification places organisms into groups based on their shared / similar characteristics
- The levels of classification are: domain, kingdom, phylum, class, order, family, genus, species
- Binomial nomenclature is used to identify individual species
- Phylogeny is the identification of evolutionary relationships between organisms with a common ancestor
- Invertebrates are animals, so their cells will have a cell membrane, but not a cell wall
- DNA is contained within the nucleus and mitochondria of animal cells
- DNA is the genetic material of invertebrates
- All information required for life is encoded in the arrangement of nucleotides in DNA
- The nucleotide sequence of DNA can be used to identify organisms using DNA barcoding
- The degree of variation in the nucleotide sequence of DNA can be used to determine relatedness between organisms