Toolkit for DIY workshops with instructions

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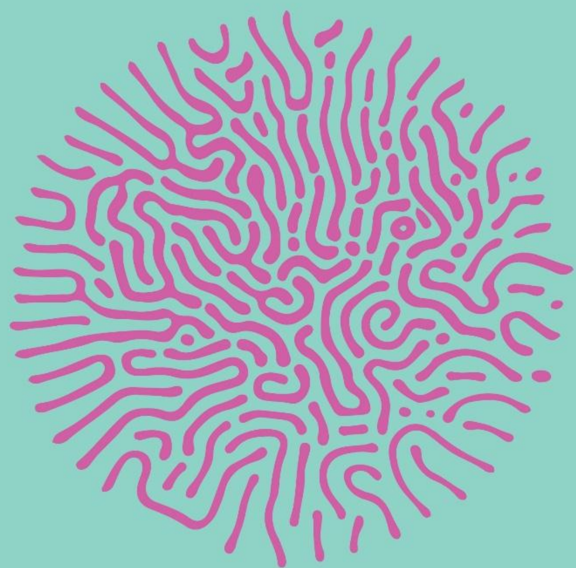
Introduction



The Playground of Citizen Science

1.1.1 DISCOVER

In nature, every being, organism and cell comes into existence without knowing its environment and its working mechanisms; it then seeks to live, find positive stimuli, a hospitable environment and directions in which to grow. This is something worth thinking about, isn't it?

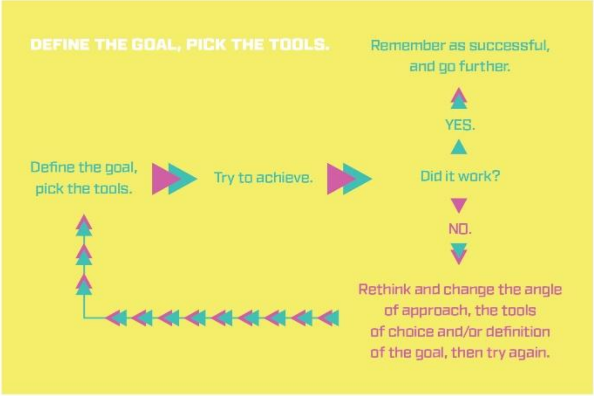
We could say the most important tools for fulfilment come in the form of:

- the ability and skill to explore and analyse the environment, whatever it might be (in search of hospitable and stimulative conditions),
- the ability to critically compare findings, pick the best and avoid the negative,
- the ability to make the most use of what one has at one's disposal (for construction and growth).

Science and engineering are nothing more than human manifestations of these phenomena. They have evolved into a form that can be shared with others, which allows us to keep building and refining, and to achieve more as individuals and as a human collective.

The natural, innate way of doing science and engineering is deeply embedded in all of us, as that core method of experimentation: trial and error.

If we simplify this process, we can see that it is rooted in the most innate and basic mechanisms of control found in all self-controlling living systems, and recreated through engineering in all artificial automatic control systems – something called a 'feedback loop' in the science of cybernetics. This process re-



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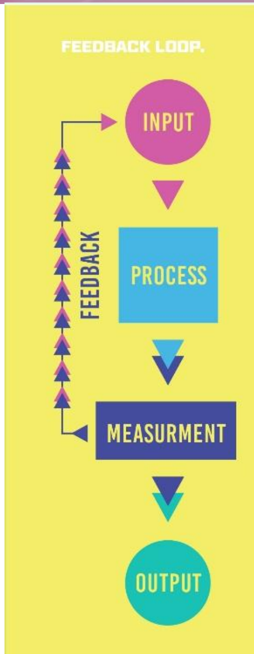

lies on feeding data that has been produced back into itself, learning from its trials and errors, to produce the desired outputs.

But first, let us go back and try to grasp what science is in general terms.

Most dictionaries would say that **science** is a systematic and methodical approach to understanding the natural world through observation, experimentation and the formulation of testable explanations or theories. It represents a systematic way of acquiring knowledge, organising information and making predictions about the world and about the objects, subjects and phenomena within it.

At its core, science as a discipline is based on the principles of empiricism (the idea that all learning can only come from experience and observation) and the practice of objectivity. Objectivity approaches the study of the world with an unbiased and impartial mindset, seeking to uncover truth based on evidence rather than personal beliefs or opinions.

This is a truthful explanation, but it's a bit dull, isn't it? What it does not contain is any sense of the **spark and drive of science**. Why should we relate to and care about science? Well, the answer is that a core of science is embedded in all of us as a natural principle – one of the innate mechanisms of exploring and understanding, even though we might not be aware of it. We could say that science is a tool we are born with, and that it is up to us whether we want to use and develop it.

Since we could say science (as a tool) is in all of us, it is not surprising that many people practise science.

Some people specialise in practising science. These **professional scientists** employ various methods and processes to investigate and understand the natural world, and do so as their job.

Some people seek to practise science non-professionally – perhaps for personal development or as a way of spending their free time constructively. These are **citizen scientists**.

From this we can cook up a wide definition of a scientist as an individual who practises science and follows scientific methodology.

The **scientific methodology** usually comprises these elements:

- **OBSERVATION**
  Scientists observe phenomena in the world, making note of patterns, behaviours, and events.
- **QUESTION**
  Based on their observations, scientists formulate questions that seek to explain or understand the phenomena they have observed.
- **HYPOTHESIS (THEORETICAL IDEA OF PROBABLE CONCLUSION)**
  Scientists propose theoretical, untested explanations or hypotheses that can be tested through further investigation. A hypothesis is a proposed explanation that can be supported or refuted by testable and measurable evidence.
- **EXPERIMENTATION**
  Scientists design and conduct experiments to test their hypotheses. Experiments involve manipulating variables and measuring outcomes to determine cause-and-effect relationships.
- **DATA COLLECTION AND ANALYSIS**
  Scientists collect relevant data during experiments or through other means. They then analyse the data using statistical methods and other techniques to draw meaningful conclusions.
- **CONCLUSION**
  Based on the analysis of the data, scientists reach conclusions about the validity of their hypotheses. If the data supports the hypothesis, it may become a theory or a well-established explanation. If the data does not support the hypothesis, scientists may modify or reject it, and then go on to develop new hypotheses for further investigation.

These elements of professional science usually follow the sequence listed – but not always. Sometimes questions do not come directly from the object of focus or the domain of science itself, but through inspiration – seeing similarities, perhaps, or seeking connections with other objects and domains. **Making connections** (correlation) and comparing the comparable and the incomparable are therefore important processes.

There is a saying: "We shouldn't compare apples and pears". But that just isn't true. When comparing apples and pears, we can discover more about both fruits than we can when we compare apples with apples, pears with pears. It is important to correlate – and to develop the skills of correlation.

It is important to knows that we can sometimes also find questions, new knowledge and ideas for experiments in pure data – such as in the hybrid field of data science, which represents one of the newest branches on the science domains tree.

In addition to good methodologies for learning, science teaches us about **knowledge itself**. It teaches us not to take knowledge (and things) for granted, since it considers knowledge to be dynamic, and subject to change and revision when new evidence emerges. This process of self-correction and refinement contributes to the cumulative advancement of scientific understanding over time, and to the growth of the body of human knowledge itself.

Science shares another interesting characteristic with living organisms by being **organic**. Science encompasses a wide range of disciplines (including physics, chemistry, biology, astronomy, geology, psychology and many others), which grow and branch out just like a living tree. Each field of science has its specific methodologies and areas of focus, but they all share a commitment to the systematic study of the world and what it contains, and a desire to uncover and explain underlying principles and processes.

Ultimately, science is a powerful tool for human progress, driving innovation, technological advancements and a deeper understanding of the universe and of our place within it. It provides a reliable and evidence-based framework for exploring and explaining the phenomena that shape our world.

1.1.2 CITIZEN SCIENCE

As we pointed out above, there are people who choose to practise science and scientific methodology in a non-professional capacity and/or get involved in the process of professional science as citizens. As a group, they form the body of citizen science.

Citizen science, also known as community science or public participation in scientific research, is a collaborative approach to professional scientific inquiry or hobbyistic practice in which members of the general public (citizens not academically trained in science) actively contribute to scientific research projects. It can involve engaging non-professional scientists in various stages of the scientific process, including data collection, hypothesis production, experimentation, analysis, data interpretation and producing conclusions. On occasions, such non-academically trained individuals can, if they have developed sufficiently through self-learning and scientific experimentation, produce scientific research comparable in quality to the work of professionals – and even take it a step further into true (patentable) inventions. Perhaps the most shining example of an ideal citizen scientist, innovator and inventor would be Hedy Lamarr, with her impressive body of work in various fields of science, or that genius for the ages Leonardo da Vinci, who helped lay the foundations of several fields of science through self-learning by experimentation.

The concept of citizen science is founded on the belief that scientific research should not be limited to the realm of professional scientists and researchers. Instead, it recognises that individuals from diverse backgrounds and with different levels of

INTRODUCTION

We should compare apples and pears.

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expertise can make valuable contributions to scientific knowledge and understanding.

We should not forget that no father or mother of a scientific discipline has been formally educated in that discipline – simply by virtue of the fact that the discipline did not exist until they turned up. As they were giving birth to the field, they were citizen scientists in it.

It is therefore no surprise that citizen scientists today are involved in almost all domains of science – collecting environmental data, identifying species, monitoring bird populations, tracking weather patterns, analysing astronomical images, analysing water quality, solving problems of protein folding (necessary for developing solutions to target and eradicate diseases, as well as create biological innovations), and so on.

In citizen science, as in professional science, we distinguish between two main practices of research and experimentation: individual **do-it-yourself (DIY)** and collaborative **do-it-with-others (DIWO)** experimentation.

The concept of citizen science is founded on the belief that scientific research should not be limited to the realm of professional scientists and researchers.

'Sam svoj majstor',
1st issue, 1975.

The professional scientific community derives several **benefits from citizen science**. Researchers are able to gather large amounts of data over large geographical areas and extended periods, something that would be otherwise challenging or impossible to achieve. This process helps scale up data-collection efforts, leading to a richer and more comprehensive understanding of various phenomena.

Citizen science also fosters public engagement with science, and promotes scientific literacy in citizens and communities. By actively participating in research projects, individuals gain hands-on experience and develop a deeper understanding of scientific processes and concepts. Citizen science empowers people to contribute to important societal issues, and increases their appreciation of scientific inquiry; it can also actually strengthen connections between scientists, the public, policymakers and industry, and foster collaboration and dialogue. Professional researchers benefit from the expertise and local knowledge of citizen scientists, while citizen scientists gain insights into the professional scientific community's work, and can contribute to real-world scientific advancements.

In recent years, technological advancements have played a significant role in expanding the scope and impact of citizen science. The widespread availability of smartphones, internet access and data-sharing platforms has facilitated the participation and collaboration of citizen scientists on a global scale.

Overall, citizen science offers a collaborative and inclusive approach to scientific research, harnessing the power of collective intelligence, and contributing to a more informed and engaged society. Through the diversity of individual backgrounds, citizen science has the potential to address complex scientific and social challenges, and to drive meaningful change in the world.

1.1.3 DIY ENGINEERING

Practical **engineering** utilises knowledge to design, create and construct tangible outputs; and just as citizen science relates to professional science, there are some interesting cultural practices that relate to engineering fields. Prominent examples include the **do-it-yourself (DIY) repair cultures** found in socialist and communist countries. These often emerged from necessity, because local resources were scarce. Their goal was to utilise these resources to the maximum.

DIY repair cultures were common in the former Yugoslavia (1945–1992) and are very much part of society in present-day Cuba. Their approaches to DIY repair differed slightly, whether they involved buying sustainable domestic products at an economical price (e.g. items from recycled and/or affordable and sustainable local materials) or avoiding wasteful consumption and related unsustainable practices. The DIY culture became quite rooted in Yugoslavia, and was further fostered through 'Sam svoj majstor' and similar magazines, which gave practical detailed instructions on how to build and repair household items – and even how to build houses themselves.

At its core, maker culture encourages individuals to become active participants in the process of making things (and making things better) rather than simply being passive consumers.

While Cuba followed a similar path, economic constraints mean that the country's repair culture has become unique and recognisable, with highly innovative ways of repurposing items in DIY engineering and for repair. Its aesthetics have famously become an essential part of everyday life.

These examples are interesting in the context of the relatively recent public policies on sustainability, such as the United Nations Sustainable Development Goals (UN SDGs), which see global resources as limited and as things that must be cherished if we are to live comfortably. If you are interested in the subject of the problem of resource scarcity and responsible consumption and production, it is important to mention that one of the current UN SDGs is precisely 'Responsible consumption and production', which has been recognised as a global challenge we need to solve as citizens.

Emerging relatively recently, in the 2000s, and swiftly gaining public attention, **maker culture** is a cultural movement similar to repair culture and related to citizen science. It is a social movement that emphasises DIY and hands-on learning, exploration and creation, a global community of individuals who engage in various creative activities, such as designing, building, tinkering, inventing and prototyping, and often leveraging technology and digital fabrication tools.

At its core, maker culture encourages individuals to become active participants in the process of making things (and making things better) rather than simply being passive consumers. It values creativity, collaboration, and the sharing of knowledge and skills. Makers embrace an open mindset, seeking to learn and experiment with different tools, materials and techniques.

'Make:',
1st issue, 2005.

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DIY tinkering spaces/ household laboratories

Every invention requires a place of birth. In citizen science, these are often household laboratories or 'DIY tinkering spaces'. Depending on what you are interested in and what resources you have at home, these spaces can come in a variety of forms. The trend among citizen scientists in the US is to turn garage spaces into tinkering spaces and DIY laboratories, while in people Europe seem to be keen on using kitchens for biological experimentation. But sometimes, a small corner in any room is more than sufficient. The first lab of Gjino – one of the authors of this book was exactly like this: an old, unused wooden cabinet repurposed into a bedroom workbench and storage space for all my improvised research tools and materials. So if you decide to go a bit more seriously into citizen science, we invite you to be creative with your creative corner – customise it to your needs and desires. A DIY tinkering space or household laboratory is your gateway to a world of endless innovation and boundless curiosity.

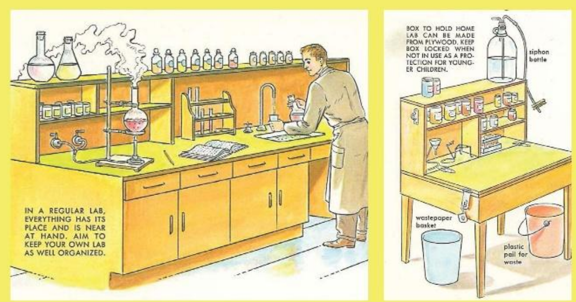
Workspace

Since we are all unique, with different interests and desires, it is not easy to describe an average tinkering workspace or household lab. Depending on your interests and needs, you can customise it to best fit your current field of study. If you decide to explore the realm of chemistry, it will have to be customised to ensure that you can work safely with chemicals, with easy-to-clean surfaces that do not absorb liquids. Be sure to put it in a nicely ventilated space as well (next to the window is fine). The same goes for biology, as things can get smelly. If you are looking to experiment with modern engineering, such as 3D printing, it might be better to work in a room other than the bedroom – the hum of 3D printing can become annoying after a while. The possibilities are vast and endless.

So before constructing your creative corner, put it on paper first. List what you think you will need, sketch the layout, think about safety and be sure to know the limits. Start small and let it develop gradually. For example, if you're into biology, a basic microscope will be more than enough to kick start your citizen science research; if electronics are your thing, a cheap multimeter, a soldering iron, a few screwdrivers and some old electronics to disassemble will set you on your way.

Start small and let it develop gradually.

Here's a lovely example of a DIY chemistry lab from 1960. Various designs can be found online – just find one for the domain you're interested in.



Regular chemistry lab (left) vs. a small, improvised DIY chemistry lab (right)

(Illustration from The Golden Book of Chemistry Experiments, 1960)

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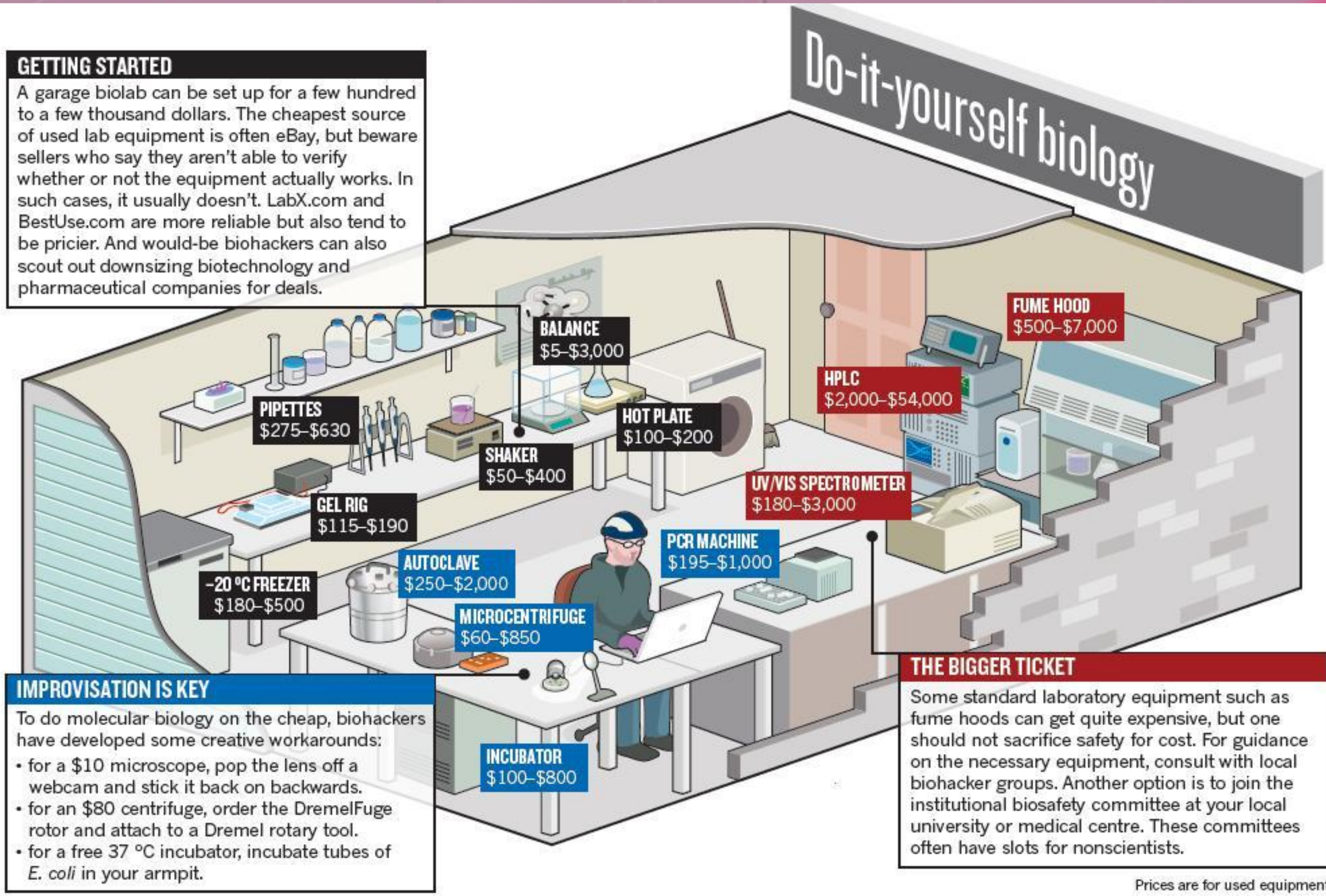

DIY laboratory. Picture taken from Nature article by H. Ledford [Ledford H. (2010). Life hackers. Nature vol. 467, October 2010, 650-652]

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Safety

It is better to be too careful than not careful enough.

Ensuring personal protection and safety in a workspace is paramount in any scientific endeavour, particularly in environments where DIY experimentation with biological, chemical and electrical materials is to take place. Before embarking on any project, it's crucial you wear the appropriate gear: safety goggles to shield the eyes from chemical splashes and flying debris, lab coats or aprons to protect against spills and splatters, and gloves to protect the hands from hazardous substances (although beginners should avoid those, generally speaking).

It is essential that you adhere to strict safety protocols and warning signs. Chemicals must be clearly labelled and properly stored. When working with electricity, it is imperative that you use insulated tools and equipment, and deploy proper wiring techniques, to prevent electrical shocks and fires. It is best practice to have all electric appliances in your DIY lab or on your workbench connected to a central switch that you can easily turn off in case of emergency, and to have a small fire extinguisher to hand nearby. You should also have a small basic medical kit containing plasters, bandages, etc. Even the most careful professionals can injure themselves.

The general rule is to always play it safe. It is better to be too careful than not careful enough.

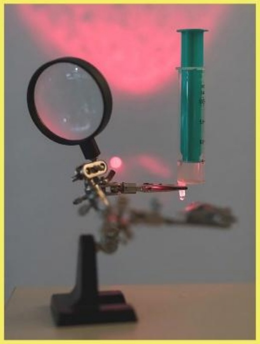
By integrating personal protection and safety practices into every aspect of their work, DIY scientists not only protect themselves, but also create a culture of safety that benefits the entire community. Again, do your research on safety before carrying out any experiments.

Basic equipment

Embarking on a DIY science journey, whether in biology, chemistry or electronics, requires a solid foundation of basic equipment to facilitate experimentation and innovation.

At the heart of any DIY laboratory is a versatile workbench – a sanctuary where ideas take shape and discoveries unfold. Here, an array of essential tools and instruments stand ready to assist in the pursuit of knowledge and creativity.

As we have already pointed out, the tools and materials you require differ greatly depending on your needs and interests. It would be impossible to list them all, so we will mention just a few of the most common ones. We will also give you pointers to some tutorials on how to make your own.



Affordable commercial microscope/ digital magnifier (left) and DIY water drop microscope projector (right)

Keeping a laboratory log is common practice in all good labs. It is essentially a simple book in which you enter your notes, and is the most essential piece of material in your thinking space. Making good research notes is the best way to self-learn science and engineering.

2.3.1 WET LAB EQUIPMENT (BIOLOGY AND CHEMISTRY)

The tools most usually encountered in biology and/or chemistry labs are:

- a microscope and related consumables (glass slides) for studying the smallest objects
- (today there are many affordable ones, both digital and classic optical)
- a magnifying glass (for studying the surfaces of large objects)
- tweezers, scissors, scalpel and a chopping board for preparing samples for study
- a wide variety of containers, such as glass jars for collecting your samples and objects of study (you will use these things very often)
- a hotplate for cooking and heating
- volumetric glassware (glass cylinders, pipettes, droppers, etc.)
- glass containers (jars, etc.) that can be sterilised

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If you decide to pursue research in microbiology, you will also need:

- a DIY Bunsen burner (e.g. a portable gas camping cooker) for sterilising tools and making sterile microenvironments for microbiology experimentation
- sterilisation equipment for liquids and tools: a pressure cooker (DIY autoclave) for sterilising liquids and metal and glass tools, or a microwave oven (for sterilising liquids) + a regular oven (for sterilising metal and glass tools)

For those who decide to go deeper into the field of serious biotechnology at some point, there are affordable educational tools such as PCR kits (e.g. PocketPCR by GaudiLabsor or PCR by OpenPCR), and even DNA/RNA sequencers (Oxford Nanopore), that can be used to explore the mysteries of the biological world.

Again, it is not easy to list everything, so we encourage you to do your own research. Explore the literature to find out what will meet your needs.

RECOMMENDATIONS

If you're starting out with DIY chemistry, we would recommend the classic Golden Book of Chemistry Experimentation (1960) by Robert Brent, which is available from the Internet Archive (https://archive.org).

For DIY biology and biotechnology, you could try the online Hackteria wiki at https://hackteria.org/wiki/Generic_Lab_Equipment (where you'll find amazing tutorials on how to make your own microscope cheaply from an old webcam, for example).

MATERIALS

Materials for DIY biology and chemistry experimentation are all around us. We invite you to be creative and explore. Read the labels on products in grocery stores, as you'll be able to find most of the materials and reagents there.

Weak acids and bases/alkalis are among the reagents most commonly used in biology and chemistry labs, and can be found in vinegar, lemon juice, sodium bicarbonate and baking powder, for example. Polar solvents are easy to get hold of (water, alcohol), while Zippo fluid, easily available from your local corner shop, makes a good non-polar solvent for DIY chemistry experiments.

In biology, dyes and stains are often used to colour and analyse samples. You can also find those easily find on the retail market: methylene blue, for example, which is used to colour cell nuclei and cytoplasm, and malachite green (for colouring endospores, pollen and fungi) can both be found in pet shops as anti-fungal agents for aquariums.

Next to acids, bases, solvents and stains, the most common tools in biology and chemistry labs are those used to measure pH. We can measure pH value (how acidic/basic a substance is) with digital or chemical pH meters. But one of the best and most fun to play with is a pH meter you can make yourself, from cabbage juice. So here's the recipe.

TUTORIAL: DIY CABBAGE JUICE pH METER

YOU WILL NEED

- Red cabbage
- Blender or food processor
- Strainer or cheesecloth
- Clear glass or plastic container
- Distilled water
- Something acidic and basic to test it with (e.g. drop of lemon juice as acid, a drop of soap as base)

STEP 1:
Chop the red cabbage into small pieces and place them in the blender or food processor. Add enough distilled water to cover the cabbage pieces and blend until smooth.

STEP 2:
Strain the cabbage mixture through a strainer or cheesecloth to remove any solids, leaving the purple cabbage juice behind.

STEP 3:
Pour the cabbage juice into a clear glass or plastic container. Note the colour.

STEP 4:
Place a teaspoon of cabbage juice in a glass, add a drop of lemon juice and stir. Notice the change in colour.

STEP 5:
Place a tablespoon of cabbage juice in a glass, add a drop of liquid soap and stir. Notice the change in colour.

DIY cabbage juice pH meter.

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DIY webcam microscope – picture taken from: Hackteria (https://hackteria.org/wiki/DIY_microscopy)

Tutorial with instructions at -> https://hackteria.org/wiki/DIY_microscopy

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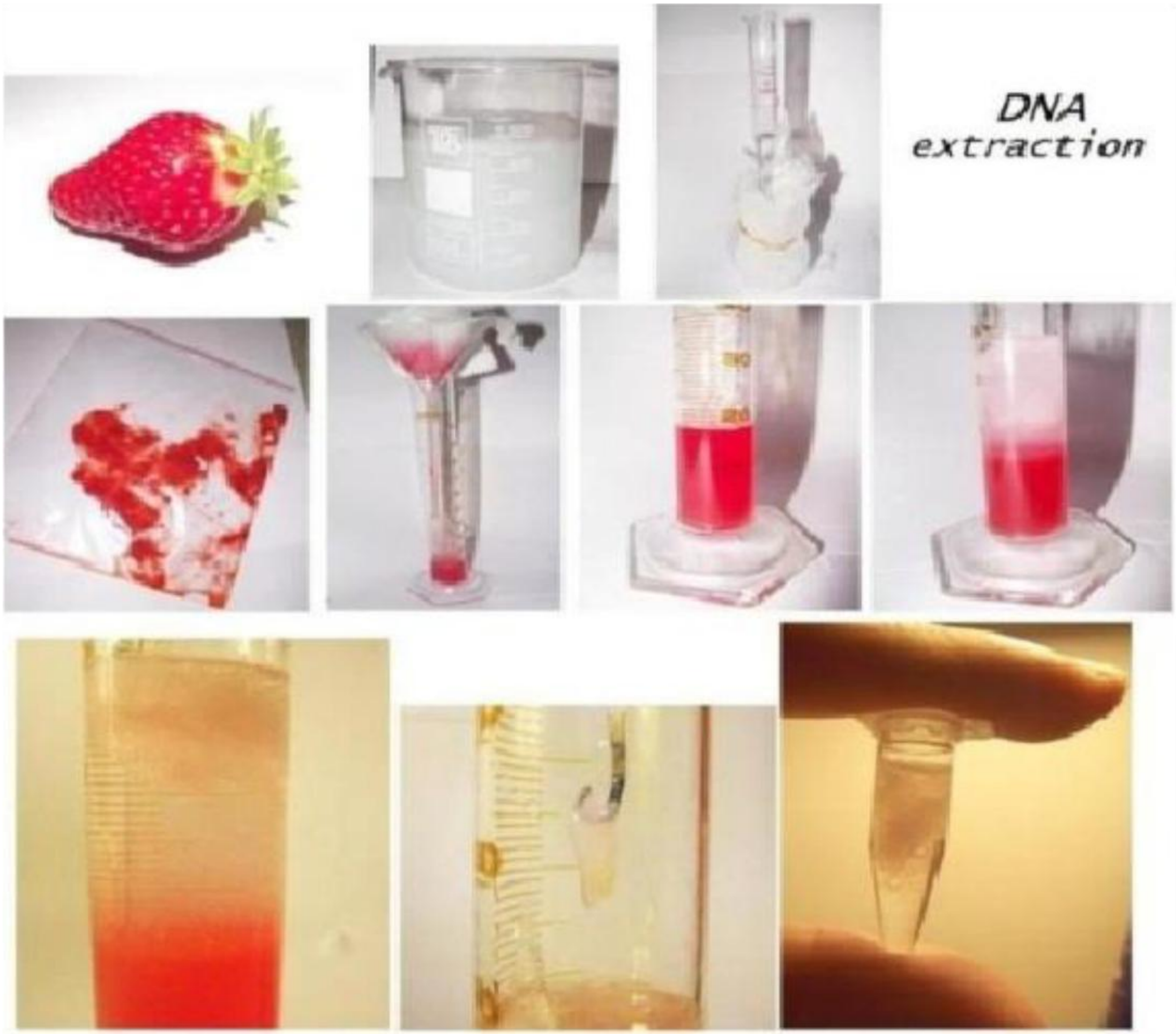
PRACTICAL EXPERIMENT 1.

DNA extraction from strawberries or banana



Steps:

0. chill ethanol (>60%) on ice or in freezer

1. put a strawberry or half of banana in zip lock bag, and mush using hands

2. add 5 mL of DNA extraction buffer (water with few drops of dish soap and a bit of salt)

3. mush again

4. filter through the coffee filter paper

5. transfer a bit of collected fluid (cca 1-2 cm high / or 1-2 fingertips) to a test tube or similar narrow glass cylinder

6. add chilled ethanol to test tube, almost up to the top

7. wait 5-20 min for extracted DNA to float to

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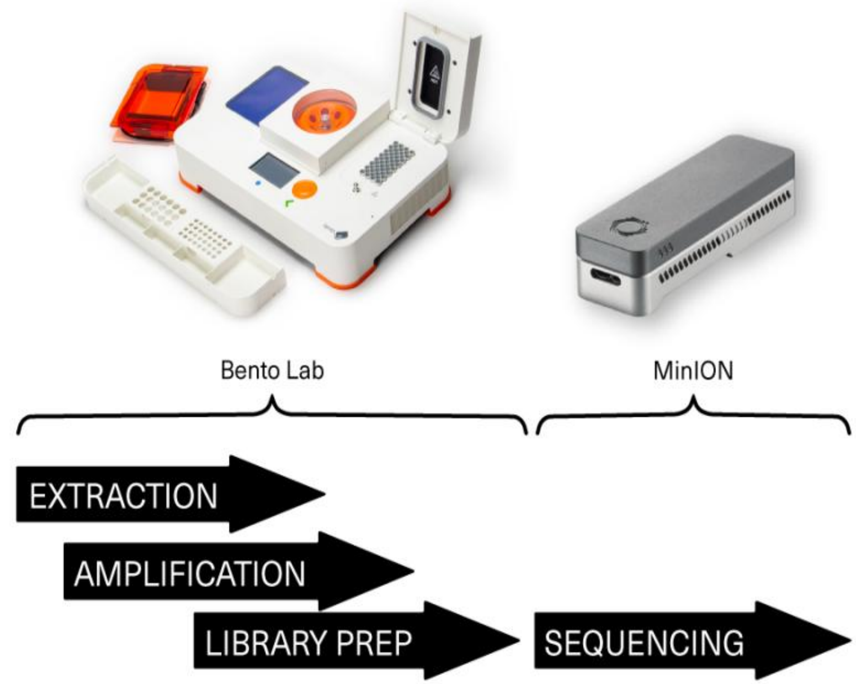
Advanced DIY biohacking / BioArt laboratory tools for DNA analysis

PCR, electrophoresis and sequencing



Bento Lab (left)

Bento Lab + Oxford nanopore MinION sequencer (right)

pictures taken from: https://bento.bio/

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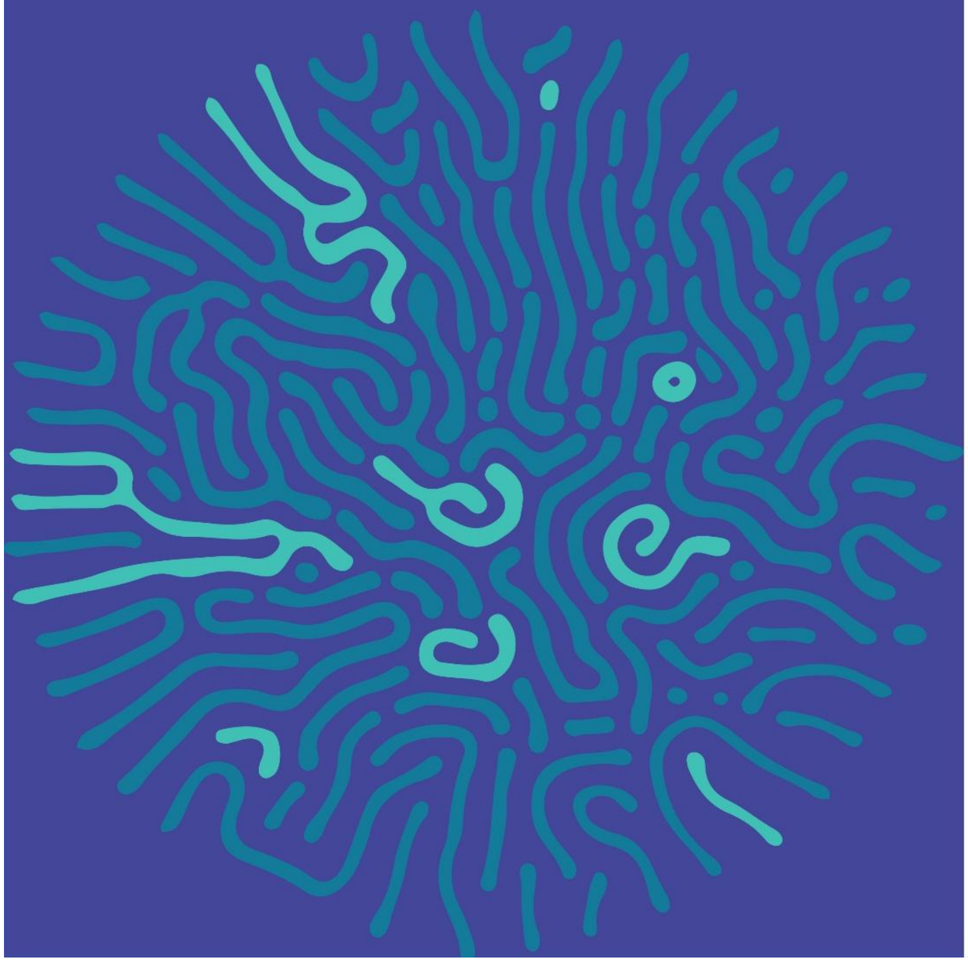
Explore



Open Environments, Natural Systems and the Cybernetic Approach

Most of the world around and within us can be seen as an open system – the human body, a specific organ, a single cell, a tree, a forest, a lake, the sea or planet Earth itself. In the realm of open systems, objects continuously interact with their environment, exchanging energy, materials and information. In living systems, this dynamic exchange often fosters adaptation and evolution, as systems respond to external stimuli to maintain stability and functionality. Whether it's the intricate web of ecosystems balancing nutrients and energy flow or the complex network of social interactions shaping human societies, open systems highlight the interconnectedness of all things.

By contrast, closed systems (such as engineered closed environments) provide a controlled environment in which internal processes unfold without external interference. This controlled setting allows for precise experimentation and analysis, enabling scientists to isolate variables and study fundamental principles in depth. Closed systems offer valuable insights into the underlying mechanisms of complex phenomena, from chemical reactions in a sealed chamber to the workings of a closed-loop feedback system in engineering.

A cutting-edge example of a closed system would be the Large Hadron Collider (LHC) built by CERN for subatomic particle research, or the bioreactor, which is an essential instrument in biotechnology and is a

A human body, a tree and planet Earth

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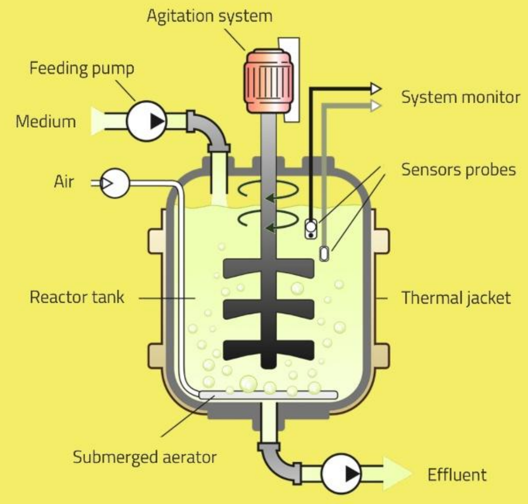

Basic schematic of a common bioreactor (by Yassine Mrabet CC BY-SA 3.0 2009)

vessel containing finely controlled environmental factors (temperature, pH, gas concentrations, etc.) used for cultivating single cells and tissues in vitro, and for the production of biological compounds, living cells and derivatives.

By studying the interplay between objects and their environments, as well as the principles of cybernetics, scientists gain a deeper understanding of the fundamental dynamics that govern the world around us.

As the science of communication and control in systems, cybernetics bridges the gap between open and closed systems. It explores how feedback loops and regulatory mechanisms enable systems to maintain stability and achieve goals in both natural and artificial contexts. It provides a framework for understanding the processes of homeostasis, communication and control that underpin the functioning of complex systems, for example in the regulation of body temperature in living organisms and the design of autonomous robots,

By studying the interplay between objects and their environments, as well as the principles of cybernetics, scientists gain a deeper understanding of the fundamental dynamics that govern the world around us. This interdisciplinary approach not only sheds light on the intricacies of natural systems, but also informs the design of more efficient technologies and the development of strategies for sustainable living in an interconnected world.

DIY Case Study – Exploring an Open Environment of your Choice

EXPLORE

Here we invite you on a small journey of exploration. We would like you to choose an open system, study it carefully and examine its intricate interconnections with the environment.

3.2.1 OBJECT

IDENTIFY YOUR INTERESTS

Consider your interests, passions and goals for the study. Are you intrigued by plant biology, fascinated by aquatic ecosystems or smitten with horticulture? Identifying your interests will help you select an object of study that aligns with your curiosity and objectives.

RESEARCH POTENTIAL OBJECTS

Conduct preliminary research on the various objects that you're considering studying. Learn about their characteristics, ecological roles, habitats and significance within the broader environment. Explore the diversity of options available, from individual organisms such as trees and plants to entire ecosystems such as gardens, ponds or forests.

ASSESS ACCESSIBILITY AND FEASIBILITY

Evaluate the accessibility and feasibility of studying each potential object. Consider factors such as proximity to your location, ease of observation and data collection, availability of resources and equipment, and any legal or logistical restrictions that may apply.

CONSIDER RELEVANCE AND IMPACT

Reflect on the relevance and potential impact of studying each object. Choose an object that not only aligns with your interests, but also contributes to broader scientific knowledge, conservation efforts or personal growth. Selecting an object with ecological significance or educational value can enhance the relevance and impact of your study.

FIELD RECONNAISSANCE

Conduct field reconnaissance visits to potential study sites to assess their suitability first hand. Observe the object's condition, surrounding environment, accessibility, and any potential challenges or opportunities for study. Take notes, photographs and preliminary data to inform your decision-making process.

SELECT YOUR OBJECT OF CHOICE

Based on your research, assessment and field reconnaissance, make an informed decision on which object to study. Choose an object that excites and inspires you, aligns with your interests and goals, and offers practical opportunities for observation, data collection and analysis.

Choose an object within an open environment that intrigues you. It could be a species of plant or animal, a geological formation, a body of water, or any other component of the ecosystem.

GIVE THE OBJECT A NAME

This might seem silly, but giving your object a name makes it more likely that you will connect more closely with it and have more motivation to explore. So we encourage you to do so.

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A bush and a lake

PLAN YOUR STUDY APPROACH

Develop a study plan outlining your research objectives, methodologies, timelines and the resources needed. Consider the specific research questions you aim to address, the methods you'll use for data collection and analysis, and any permits or permissions required for conducting research at the chosen location.

RESEARCH – BEGIN YOUR STUDY

Once you've selected your object of choice and planned your study approach, begin your investigation with dedication. Implement your research plan, collect data, analyse findings and draw conclusions that contribute to your understanding of the object and its broader ecological context. Make sure you use your research log/diary – a notebook in which you can enter all measurable data, notes, ideas and thoughts.

Conduct comprehensive research on your chosen object. Gather additional information from reputable sources such as scientific journals, textbooks and academic publications. Learn about the object's characteristics, habitat, ecological role, interactions with other organisms, environmental factors affecting its survival, and any ongoing research or conservation efforts related to it. Map your findings in a notebook.

FIELD OBSERVATION

Visit the location at which your object exists in its natural environment. Spend time observing and documenting its behaviour, physical attributes and interactions with its surroundings. Take detailed notes, photographs and videos to capture your observations accurately.

DATA COLLECTION

Collect quantitative and qualitative data relevant to your case study. This may include measurements of environmental variables such as temperature, humidity and pH levels, as well as behavioural observations, population counts and habitat assessments. Use the tools you have at your disposal.

ANALYSIS

Analyse the data you've collected to identify patterns, trends and correlations. Consider how environmental factors influence the object's behaviour, distribution and survival. Use scientific principles and analytical tools to interpret your findings and draw meaningful conclusions.

DOCUMENTATION

Compile your notes, observations, data and analyses into a comprehensive case study report of around two or three pages. Organise your findings in a logical manner: an introduction followed by sections on background information, methods, results, discussion and conclusions. Use clear and concise language, supported by visual aids such as charts, graphs and maps, to present your findings effectively.

PEER REVIEW

Introduce peers to your case study and seek their feedback. Constructive criticism is a great tool for learning. Incorporate their suggestions to improve the clarity, accuracy and rigour of your analysis in this case study and in your future work.

By following these steps, you can create a comprehensive case study exploration of an open environment object of choice, enriching your understanding of its ecological significance and contributing to scientific knowledge and conservation efforts.

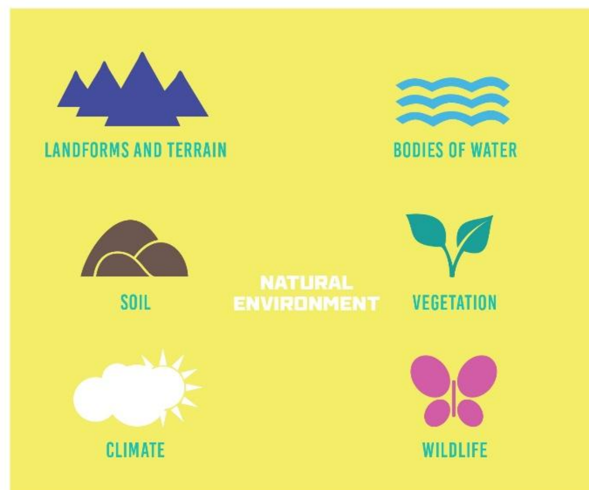
3.2.2 ENVIRONMENT

3.2.2.1 INTRODUCTION

The natural environment includes our planet's living and non-living components – the land, water and all living things. It includes everything from the highest mountains to the deepest oceans, from the tiniest microorganisms to the mightiest predators. This environment is always changing and full of life. It's not like a still picture, but more like a lively, moving scene that supports many different forms of life.

COMPONENTS OF THE NATURAL ENVIRONMENT

The natural environment isn't merely a collection of separate elements. Its main components interact with each other, shaping the kind of ecosystem that develops and impacts the lives of its inhabitants. It's like a well-coordinated team, where each part plays a crucial role in supporting life. For example, plants release oxygen through photosynthesis, supporting animals, while animals produce carbon dioxide, which is essential for the growth of plants. This interdependence stretches across all levels of the ecosystem.



EXPLORE

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VARIABLES FOR MEASUREMENT AND STUDY

To understand the natural environment, we rely on various variables, which are specific aspects or characteristics that can be measured and studied. These variables help us figure out how different parts of the environment are connected. Here are some key variables:

A. TEMPERATURE
Measures the warmth or coldness of the air, water or soil, and influences the behaviour and distribution of living organisms.

B. HUMIDITY
Reflects the amount of moisture in the air. It affects plant growth, animal behaviour and weather patterns.

C. PRECIPITATION
Includes rainfall, snowfall and other forms of water falling from the atmosphere. It is crucial for the water cycle and the sustenance of ecosystems.

D. WIND SPEED AND DIRECTION
Describes the movement of air. It impacts climate, plant pollination and the spread of seeds.

E. LIGHT
This tells us how much sunlight reaches an area. It is essential for plants to grow and for animals to find their way around. Different plants and animals need different amounts of light.

F. SOIL COMPOSITION
The composition and quality of soil are critical for plant growth and serve as a habitat for many organisms.

G. PH LEVEL
Measures the acidity or alkalinity of water or soil. It influences the types of plants and animals that can thrive in a particular environment.

H. POLLUTION LEVELS
Quantifies the presence of harmful substances in air, water or soil. Monitoring pollution helps protect the health of ecosystems and human populations.

I. BIODIVERSITY
Refers to the variety and abundance of living organisms in a given area. It indicates the health and resilience of an ecosystem.

J. VEGETATION COVER
Describes the density and types of plants in an area. It is crucial for understanding habitat quality and ecosystem services.

Various variables help us figure out how different parts of the environment are connected.

By measuring and studying these variables, we gain valuable insights into the complex interactions that shape the natural environment. This helps us make smart and informed choices about taking care of our planet and using its resources in a way that keeps ecosystems healthy for as long as possible.

3.2.2.2 GUIDED OBSERVATIONAL STUDY QUESTIONNAIRE FOR "IN SITU" EXPLORATION

EXPLORE

All variables influence each other and create an environment. Study the patterns of interdependence among the variables. (Depending on the object of observation you have chosen, you might not be able to measure all the variables.)

Each variable will be measurable by the DIY tool listed in 2.3 Basic equipment (e.g. temperature and humidity by Arduino/ESP equipped with a DHT11 sensor. The same goes for all observations and experiments.)

1. **Measure the variables throughout the day.**

Variable	8:00	12:00	16:00	20:00
Temperature				
Humidity				
Precipitation				
Wind speed and direction				
Light				
pH				

2. **Draw graphs of the data you have collected, with the x-axis being the time of collection and the y-axis being the data. Try to put more than one variable on the same graph to make it easier to visualise the interdependence of the variables (e.g. temperature and humidity).**

3. **What is the relationship between these variables? Have you noticed any rules in their behaviour?**

4. **Find a flower (daisy, dandelion, etc.). Notice the relationship between the amount of sunlight and whether the flower is open or closed. Why would the flower open and close depending on the amount of available sunlight?**

All variables influence each other and create an environment.

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3.2.2.3 EXPERIMENT: DIY LABORATORY SOIL COMPOSITION EXPERIMENTS

Soil, often overlooked but crucial to life on Earth, is a dynamic and complex mixture of mineral particles, organic matter, water and air. It serves as the foundation for terrestrial ecosystems, supporting plant growth and providing habitats for a myriad of organisms. Soil also plays a pivotal role in nutrient cycling, water filtration and carbon storage. Its properties vary widely across different regions and climates, influencing agricultural productivity, land use and even cultural practices. Soil health and conservation are vital for sustainable agriculture and biodiversity, and for mitigating the impacts of climate change. This makes it a precious and often undervalued natural resource.

One of the most important characteristics of soil is texture. Soil texture refers to the relative proportions of sand, silt and clay particles in a soil sample. These particles determine the physical properties of the soil, including its ability to retain water and nutrients, its aeration and its workability for plant roots. Sandy soils have larger, coarser particles, allowing for good drainage but often requiring frequent irrigation and fertilisation. Silt soils have intermediate-sized particles, offering better water retention and fertility. Clay soils, with the smallest particles, retain water exceptionally well, but can become compacted and poorly aerated. Understanding soil texture is essential for successful agriculture and gardening, as it influences plant selection and the need for soil amendments to optimise growth conditions.

Soil pH is also a very important characteristic. It greatly influences the availability of nutrients to plants – for instance, acidic soils may have limited access to essential nutrients like calcium and magnesium, while alkaline soils may lock up iron and other micronutrients. Understanding and managing soil pH is therefore crucial for optimising the health of crops and plants because it directly affects their ability to take up vital nutrients from the soil. Soils with a pH below 7 are classed as acidic and those above 7 as alkaline.

The last component of soil is biological. Soil is a bustling ecosystem teeming with a myriad of organisms, from microscopic bacteria and fungi to larger creatures like earthworms and insects. These soil organisms play essential roles in nutrient cycling, decomposition and the overall health of the soil. They break down organic matter (which releases nutrients for plants), improve soil structure and help control pests. Their contribution to the productivity and sustainability of terrestrial ecosystems is therefore indispensable.

In this experiment, we will determine the main characteristics of soil through three smaller experiments to determine soil type and composition, test the pH of the soil and carry out microscopic observation.

Soil samples.

EXPLORE

YOU WILL NEED

- Soil samples
- Water
- Glass jar or measuring cylinder
- Cabbage juice
- Dropper
- Microscope
- Ruler

PART 1: DETERMINING SOIL TYPE AND COMPOSITION

STEP 1: PREPARE THE SOIL-WATER SOLUTION

Mix a sample of soil with water in the jar and shake well to create a suspension. Transfer the mixture into a measuring cylinder, if you have one; otherwise, you can use a DIY alternative, such as a thinner jar or a cylindrical glass, and use a standard ruler for measurement.

STEP 2: LET IT SETTLE

Allow the mixture to sit undisturbed for a while (about 48 hours, or until the water becomes completely transparent again). Over time, the different particles in the soil will settle into layers. The first settled layer will be sand and the next one will be silt. The third layer (clay) will take the longest to settle.

STEP 3: OBSERVE MINERAL AND ORGANIC SEPARATION

Note that the settled layers primarily consist of mineral components, while the organic matter tends to float on top or remain suspended.

Water-soil solution in a jar.

STEP 4: MEASURE AND CALCULATE

Use a ruler to measure the volume of each layer in the jar. If you are using a volumetric cylinder, carefully measure the volume of each layer (sand, silt, clay). Record these volumes.

STEP 5: CALCULATE PERCENTAGES

Using the recorded volumes, calculate the percentage of each type of soil in the mixture.

$$\left(\frac{\text{VOLUME OF THE COMPONENT LAYER}}{\text{TOTAL VOLUME}}\right) \times 100 = \text{PERCENTAGE OF THE SOIL COMPONENT (\%)}$$

STEP 6: USE THE SOIL COMPOSITION TRIANGLE

Refer to a soil composition triangle to determine the soil type based on the percentages of sand, silt and clay.

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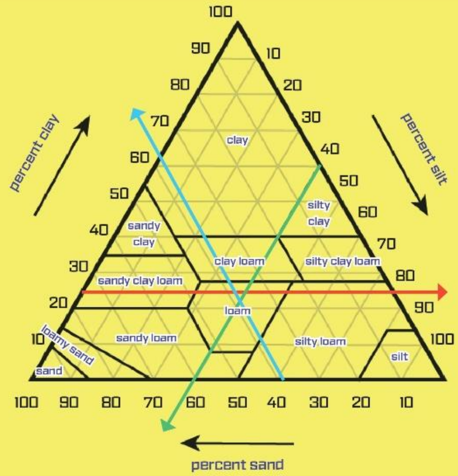


The soil composition triangle

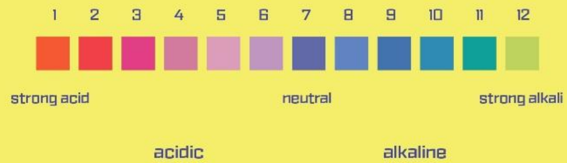
PART 2: TESTING SOIL PH

STEP 1: CREATE A CABBAGE JUICE INDICATOR

See Chapter 2.3.1.

STEP 2: APPLY CABBAGE JUICE

Place a small amount of soil in a dish and add some drops of cabbage juice. Observe any colour change. Pink to red indicates acidity, purple is neutral, while blue and green to yellow indicates alkalinity.



The red cabbage juice pH scale

PART 3: MICROSCOPIC OBSERVATION

This experiment requires a microscope with a minimum magnification of 40x, which means any microscope will suffice: a child's toy microscope, a professional microscope or a DIY microscope assembled from an old webcam or laser pointer (instructions can easily be found online from places such as https://hackteria.org/wiki/DIY_microscopy).

STEP 1: PREPARATION

Take a tiny amount of soil and place it on a microscope slide. Add a drop of water and cover with a coverslip.

STEP 2: OBSERVE UNDER THE MICROSCOPE

Examine the soil particles under the microscope. Note their shapes, sizes and structures. Try to use different magnification levels. Is everything inorganic and still, or are there live organisms 'running around'?

EXPLORE

1. **How much time did it take for your sample to settle down?**
2. **Using soil composition analysis, determine your soil type.**
3. **What is the soil pH of your sample? What does that mean for organisms living in and on it?**
4. **Observe the soil sample under the microscope and draw the different inorganic particles that make up your soil sample. Try to identify whether they are sand, silt or clay.**
5. **Is there any dead organic matter? If so, draw it and try to identify it.**
6. **Are there any living organisms in your sample? If so, draw them and try to identify them.**

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3.2.2.4 EXPERIMENT: DIY LABORATORY WATER ANALYSIS

YOU WILL NEED

- Water samples
- Small dishes or containers
- Dropper or pipette
- Microscope
- Microscope slides and coverslips
- Water pH test strips (optional)

PART 1: TESTING PH LEVEL WITH CABBAGE JUICE

STEP 1: COLLECT WATER SAMPLES

It would be best to test several water samples in parallel. Try to compare outdoor water samples (from a lake, the sea, a pond, a bird feeder, etc.) with tap water.

Gather water samples from different sources in separate containers, and mark them (so as not to mix them up).

STEP 2: APPLY THE CABBAGE JUICE INDICATOR

Using a dropper or pipette, add a few drops of cabbage juice indicator to each water sample. Observe any change in colour. Pink to red indicates acidity, purple is neutral, while blue and green to yellow indicates alkalinity. For comparison, you can also use pH test strips (from pet stores for testing aquarium water) to verify the results.

PART 2: MICROSCOPIC OBSERVATION OF WATER SAMPLES

STEP 1: PREPARE THE MICROSCOPE SLIDE

Using a dropper, place a small drop of water from the sample onto a clean microscope slide.

STEP 2: COVER AND OBSERVE

Gently place a coverslip over the water drop, ensuring there are no air bubbles. Carefully place the slide on the microscope stage and focus on the water sample. Use the microscope to explore the microscopic organisms present in the water sample. Note their shapes, movements and any observable features.

STEP 3: RECORD YOUR FINDINGS

Make sketches or take pictures to document your observations.

1. **What are the pH levels in your samples? How does that affect the organisms living in the water?**

2. **Try to take multiple samples from different water sources (pond, river, sea, sink, etc.) and determine their pH. Is there a difference in pH between water sources? Try to determine what is causing these differences.**

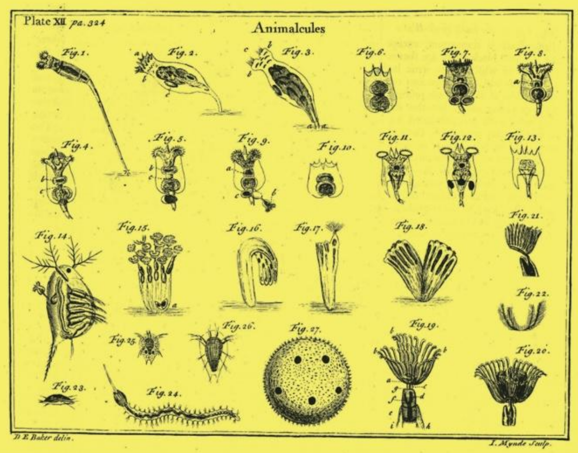
3. **Are there organisms actively swimming around? If so, sketch them and try to identify them.**

4. **Are there any sedimentary (immobile) organisms? Sketch them and try to identify them.**

5. **Can you determine what photosynthetic and heterotrophic organisms are? (The former eat other organisms and the latter feed on organic particulates.) Are all photosynthetic organisms in your sample sedimentary (like plants) or do some of them move? Are all the organisms that you see protozoa and algae, or are there other types of living organism present?**

6. **Have you noticed any difference between water sources in terms of the number of species and organisms you have found?**

EXPLORE



Animalcules by Henry Baker, 1754 (from Wellcome images, Wellcome Trust, UK charity organisation CC BY 4.0)

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Engineer (Design and Create)

Closed Systems, Systems Thinking and Design

ENGINEER (DESIGN AND CREATE)

Imagine being inside a bubble, where everything stays in and nothing comes out – that's a closed system. Closed systems are like little worlds of their own, where all the action happens inside, without any interaction with the outside environment. Within the context of systems thinking and design, closed systems refer to environments in which interactions occur solely within the system's boundaries, without exchanges with the outside. In closed systems, inputs, outputs and processes are contained within the defined system, fostering a self-contained dynamic.

In these systems we need to think about how all the different parts work together, just like the pieces of a puzzle. Systems thinking emphasises an understanding of the interconnectedness and interdependencies within closed systems. Changing one piece can affect everything else, for example – like how adding too much food to a fish tank can make the water murky. So when we design closed systems, we must keep everything steady –maintaining equilibrium while also being ready to adapt when things change – and also maintain system stability (homeostasis). It's like finding the perfect harmony between stability and flexibility so that our little world can keep running smoothly.
Designing closed systems involves careful consideration of feedback loops, emergent behaviours and maintaining equilibrium. Effective design requires balancing stability and adaptability to ensure that the system can function efficiently and evolve over time within its closed environment.

4.2

DIY microcosmos

The easiest way to learn about systems thinking and design is to start small. You can make a fish aquarium your case study example (of a semi-closed system), or you can even go smaller into the world of microbes. Here we give you some interesting and fun examples to play with: a Winogradsky column and microbial fuel cells.

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4.2.1 GUIDED TUTORIAL: MAKING A WINOGRADSKY COLUMN

A Winogradsky column is a fascinating and miniature ecosystem encapsulated in a simple glass or plastic cylinder. Named after the Russian microbiologist Sergei Winogradsky, these columns serve as remarkable models of microbial diversity and ecological interaction. By harnessing the power of mud, water and sunlight, Winogradsky columns allow scientists and enthusiasts to observe the intricate relationships between various microorganisms, such as bacteria and algae, as they thrive in different environmental niches within the column. This unique and self-sustaining microcosm offers valuable insights into biogeochemical cycles, nutrient cycling and the intricate web of life at a microscopic level. Winogradsky columns are not only educational tools, but also windows into the complex world of microbial ecology.

Winogradsky columns are versatile tools with several key applications:

- **MICROBIAL ECOLOGY AND DIVERSITY**
  They are used to study how microorganisms interact and thrive in simulated environments, providing insights into microbial ecology and diversity.
- **BIOGEOCHEMICAL RESEARCH**
  They help researchers understand how microorganisms influence biogeochemical cycles, shedding light on nutrient cycling and environmental processes.
- **ENVIRONMENTAL MONITORING**
  They can be used as bioindicators to assess ecosystem health, detect disturbances, and monitor pollution or nutrient imbalances.
- **EDUCATIONAL TOOLS**
  They serve as engaging educational tools, and allow students to observe ecological processes and better grasp microbiology and ecosystem dynamics.
- **BIOREMEDIATION RESEARCH**
  These columns aid in researching bioremediation strategies by studying how specific microorganisms break down contaminants.
- **ARTISTIC AND OUTREACH**
  Their colourful, dynamic ecosystems make Winogradsky columns engaging for artistic displays and public outreach. This raises awareness of the importance of microbial life to the environment.

This experiment will teach you how to make a Winogradsky column at home.

ENGINEER (DESIGN AND CREATE)

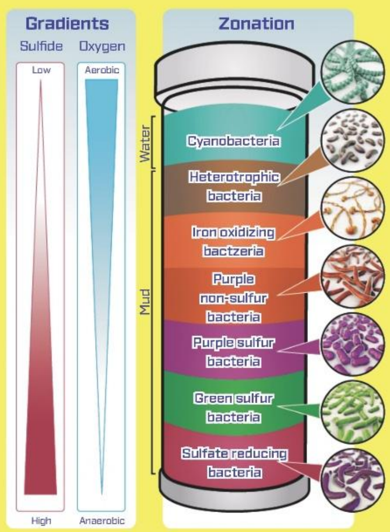

Illustration of a Wingradsky column by HHMI BioInteractive

YOU WILL NEED

- Bucket
- Small shovel
- Soil samples
- Pond water or boiled tap water
- Mud from pond or dirt from garden
- Plastic bottle
- Scissors
- Dried leaves or paper
- Eggs
- Bowl
- Plastic foil
- Scotch tape
- Aluminium foil (optional)

STEP 1

Begin by collecting soil samples from a nearby pond, stream or garden. If you don't have a pond or stream nearby, you can use tap water – but you will need to boil it first to remove chlorine, then let it cool.

STEP 2

Take a plastic bottle and, using scissors or a knife, carefully cut off its top section into three parts. Be careful of any sharp edges.

STEP 3

Separate egg yolks and whites. Crush the eggshells into a fine powder, and cut dried leaves or paper into smaller pieces. Mix half of the collected mud with the egg yolk, eggshells and dried leaves/paper.

STEP 4

In the first third of the bottle, place the mud mixture you have prepared. Add only mud to the second third and only pond/boiled tap water to the final third.

STEP 5

Securely seal the top part of the bottle with plastic foil to create an airtight environment. Place the column in a sunny location for a few months.

STEP 6 (OPTIONAL)

If you choose to take an additional step, create a second column and completely cover it with aluminium foil to block out all light. Position it alongside the first column, and let both columns sit for a couple of months. Remove the aluminium afterwards and notice the differences between the two columns.

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PRACTICAL EXPERIMENT 2.

DYI kombucha scoby cultivation

Kombucha / microbial cellulose based projects of Gjino Šutić (SRCE – scaffold for growing human replacement organs, MeBUMZ – microbial speakers, microphones & drums, BioOptical theremin – experimental music instrument, JUNO prototype – baby biorobot with microbial cellulose skin)

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After several months, examine the column. Notice the different layers and the colours in each layer.

1. How many different layers are there? What is the colour of the water on top? What colours can you see in each layer?
2. We placed egg yolk, eggshells and leaves in the bottom layer. Why? How do they affect the layers?
3. Why did we place them in the BOTTOM layer?
4. What are the concentrations of oxygen in each layer? How does that influence the microorganisms in each layer?
5. If you have performed Step 6, is there a difference between the two columns? Are all the layers present in both columns?

4.2.2 GUIDED TUTORIAL: MAKING A MICROBIAL FUEL CELL

ENGINEER (DESIGN AND CREATE)

Microbial fuel cells (MFCs) are an innovative and sustainable technology at the intersection of microbiology and energy generation. These devices harness the metabolic activities of microorganisms to directly convert organic matter into electrical energy. Essentially, MFCs function as living power sources, leveraging the ability of certain microorganisms to transfer electrons produced during organic substrate degradation to an electrode, and generating an electric current in the process. This fascinating blend of microbiology and energy science holds promising applications in wastewater treatment, bioenergy production and environmental remediation, positioning microbial fuel cells as a frontier technology in the quest for cleaner and more efficient energy solutions.

MFCs come in two types: one- and two-chamber. Two-chamber MFCs have a chamber with anaerobic conditions, an anode and bacteria and their food (mud with dry leaves, wastewater, etc.), a membrane that separates this from the other chamber, and a second chamber with a cathode and a lot of oxygen. A one-chamber MFC has everything in one chamber and just keeps anode and cathode as far away from each other as possible so that the anode can have anaerobic conditions and the cathode aerobic conditions.

In this chapter you will learn how to make a very simple DIY one-chamber MFC with the help of microbes found in mud – a so-called 'mud battery'. For electrodes, we will use graphite for anode and aluminium for cathode. Graphite is conductible material that isn't harmful to bacteria, so they can grow and feed on it; this produces electricity that the graphite captures. As a food source, we will add dry leaves or paper made from cellulose that the bacteria can degrade in anaerobic conditions and use to produce electricity. This is why the anode goes on the bottom where there is no oxygen. The cathode goes into the water, where it releases electrons onto oxygen.

YOU WILL NEED

- Bucket
- Small shovel
- Pond water or boiled tap water
- Mud from a pond or dirt from a garden
- Jar or a plastic urine container
- Copper wires
- Paper
- Scissors
- Dried leaves (optional)
- Pliers
- Hot glue gun
- Paper
- Graphite pencil
- Aluminium foil
- Multimeter
- Small LED light (optional)

STEP 1

Take the bucket and a small shovel and go to a nearby pond or a stream. Dig up some mud and take some of the water with you. If you don't have a pond or a stream nearby, you can use normal dirt from a garden or a park and add tap water. If you are using tap water, be sure to boil it first to remove any chlorine that might harm the microorganisms, then let it cool. While you are outside, try to collect some dry leaves if there are any. If not, you can use paper instead.

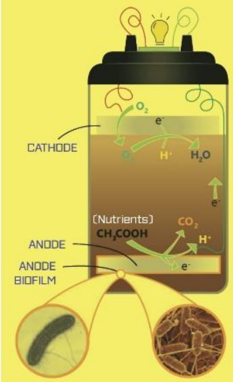

Diagram of soil based MFC (by MFCGuy2010 CC BY-SA 3.0) https://creativecommons.org/licenses/by-sa/3.0/

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STEP 2
Prepare the wires by cutting them into shorter pieces. You need two per MFC. Strip them at both ends.

STEP 3
Take the container you have chosen (we recommend glass jars or plastic urine containers as they are the easiest to get hold of and use) and puncture a hole in the lid big enough for the two wires to go through.

STEP 4
Draw a circle on paper with a graphite pencil the size of the bottom of your container. Fill in the circle with graphite pencil so that it is as dark as it can be. Cut out the circle. This will be the first electrode on which the bacteria will grow and produce electricity.

STEP 5
Glue one stripped end of the wire with a hot glue gun to the circle you have just filled in. Be careful not to burn yourself during the glueing process, and try to not get glue between the wire and paper (as this will isolate it, preventing electricity from being conducted).

STEP 6
Put the electrode on the bottom of the container and then place enough mud/dirt on the electrode to cover it. Then shred a bit of paper or add crushed dry leaves if you have any. Add more mud/dirt on top of that until you fill the container to half the volume. While you are adding the mud, try to compress it as much as you can so that no air becomes trapped.

STEP 7
Pour pond or boiled (and cooled) tap water into the container until it is completely full. Take the second wire and completely cover one stripped side with aluminium foil. Submerge it in the water and try to have it not touching the mud. This will be our second electrode.

STEP 8
Push both wires through the hole you made in the lid and close it. Let it sit for about ten minutes, then use the multimeter to check the voltage the MFC is producing. If you have a small LED light (5V), you can try to connect it and see if it produces any light.

1. **How much voltage is it producing? Was it enough to power an LED light?**

2. **Try to make several MFCs and connect them serially. Is there a difference in the voltage produced? How many would you need to make and connect to be able to charge your phone?**

3. **Try to think of a way to increase the production of electricity. Try changing the size of the electrodes, the soil composition and volume, the electrode material, etc. Write down what you have tried and learned.**

4. **Why did we use the aluminium foil for the second electrode if we know that it is harmful to bacteria?**

5. **Leave the MFC for some time and then measure the voltage. Is there a difference in the electricity produced? If so, when did it start to happen? Did the voltage increase or decrease?**

ENGINEER (DESIGN AND CREATE)

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Innovate

Dear Reader, we have come to the last chapter of this open book. We hope it served at least a little of its intended purpose: to spark a desire in you to explore the amazing world around you and, driven by inspiration, to create new things.

To finish up, we invite you to design a future research/engineering project of your own.

We are sure many ideas came to your mind as you were exploring this book. We would like you to use the knowledge and experience you have gained, and to approach your future endeavours systematically.

We have created a short guided questionnaire to help you plan to make your idea come to life.

But most of all: **Have fun!**

Design your STEAM project

Guided questionnaire on developing personal ideas into TO DO project framework

PROJECT FORM

1. TYPE OF PROJECT **(Mark and fill in.)**

1.1.

- ⊕ Scientific
- ⊕ Artistic-scientific

1.2.

- ⊕ Educational
- ⊕ Research
- ⊕ Development
- ⊕ Public event

1.3. In connection with which scientific and/or artistic fields is the project associated?

2. PROJECT NAME

3. PROJECT GOAL

Activity held under the framework of the Bio Awaking project, co-funded by the Creative Europe program of the European Union (CREA-CULT-2023-COOP, number: 101128497

4. SUSTAINABILITY OF THE PROJECT (What doors does the project open?)

4.1. Does the project contribute to the development of science, art, and community?

4.2. Can the project be further developed? Upgraded? If yes, how?

4.3. What new projects could arise from it?

5. BRIEF DESCRIPTION OF THE PROJECT
(State all essential details. Minimum of 10 sentences.)

6. SPECIFIC GOALS

7. DELIVERABLES (What are the visible/tangible products of the project's developmental process?)

8. ACTIVITIES INCLUDED IN THE PROJECT (List and explain all activities the project encompasses.)

9. PROJECT EXECUTORS (List all executors of the project, their functions, and responsibilities.)

10. ESTIMATED DURATION OF PROJECT ACTIVITIES
(State the total duration of the project, approximate or exact start and end date, and each phase of the project.)

Total estimation:
1st phase: 2nd phase:
3rd phase: 4th phase:

11. DOCUMENTATION
(How will the project and its development be documented?)

12. REQUIRED RESOURCES
(For all materials and equipment, if rented, list the price.)

12.1. Equipment

12.2. Services (Such as printing, telecommunications, rentals, certifications, etc.)

12.3. Material

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