PRINCIPLE 1:
NATURE RUNS ON SUNLIGHT

How does nature generate energy?

Erasmus+

AGE RANGE

11–13

DURATION

Preparation:
about 20 min.
(Activity 3 might take longer the first time it is delivered)

Activity:
about 45 min. / 1 lesson

KEYWORDS

Biomimicry principles; energy; photosynthesis

SUMMARY

This module is about energy. Most of the energy used in nature comes from the sun through photosynthesis. Students play the process of photosynthesis in two different ways.

BIOMIMICRY PRINCIPLES

1 – Nature runs on sunlight

LEARNING OBJECTIVES

- Students understand the process of photosynthesis.
- Students understand why green plants are vital for life on Earth.
- Students understand how organisms are interconnected.

LEARNING OUTCOMES

- Students provide a practical demonstration of photosynthesis.
- Students reflect on the importance of this process.

SUBJECT(S)

This module is part of a series of modules introducing the nine principles of biomimicry. The table below shows possible KS3 Programme of Study links for all the modules. Many of the activities will also be suitable for upper KS2.

This learning module can be used flexibly within the curriculum to support key knowledge about Biology and develop working scientifically competences. The learning links with the Sustainable Development Goals and provides a broader context for student learning. It is suitable for adapting as a STEM activity or Eco Club.

Programme of Study Reference	Working Scientifically
Biology: Material cycles and energy - Photosynthesis • the reactants in, and products of, photosynthesis, and a word summary for photosynthesis. • the dependence of almost all life on Earth on the ability of photosynthetic organisms, such as plants and algae, to use sunlight in photosynthesis to build organic molecules that are an essential energy store and to maintain levels of oxygen and carbon dioxide in the atmosphere. • the adaptations of leaves for photosynthesis. Interactions and interdependencies – Relationships in an ecosystem • the interdependence of organisms in an ecosystem, including food webs and insect pollinated crops. • how organisms affect, and are affected by, their environment, including the accumulation of toxic materials. Genetics and evolution – Inheritance, chromosomes, DNA and genes • changes in the environment may leave individuals within a species, and some entire species, less well adapted to compete successfully and reproduce, which in turn may lead to extinction. • the importance of maintaining biodiversity and the use of gene banks to preserve hereditary material.	Students successfully completing this module will have had the opportunity to access these statements: **2a, 2b, 3b, 3c, 3d, 3f**. See Annex 1 for full statements.

BIOLEARN COMPETENCES

- Students are able to abstract principles of sustainability from the way the natural world functions.
- Students are able to work in groups.
- Students are more motivated in learning STEAM and experience that STEAM knowledge can be widely used.

SUMMARY OF THE ACTIVITIES

	Activity Name	Short description	Method	Duration	Location
1	Introduction	Presenting the principle 9_principles.ppt	• Teacher presentation • Discussion	10	Indoor
2	Playing photosynthesis	Students understand the process of photosynthesis through a play	• Role play	20	Indoor/ outdoor
3	Modelling the reaction of photosynthesis	Students act out the chemical reactions of photosynthesis	• Role play	20	Indoor/ outdoor
4	Review	Discussion after the activities	• Discussion	10	Indoor/ outdoor

Note: Activity 2 and 3 can be delivered in parallel, so the whole module can fit into 45 minutes. Activity 3 can be omitted if time is short.

BACKGROUND FOR TEACHERS

See at Activity 1: Introduction.

For interconnections see *Nine Principles of Biomimicry* module.

Health and Safety
Appropriate consideration needs to be given to health and safety when working outdoors, but this should not prohibit regular use of the outdoor learning environment.

For guidance on using the outdoor learning environment review the Council for Learning Outside the Classroom suggestions on Plan and Deliver. CLEAPSS also provides guidance for members. We recommend you read and act on L196 – Managing Risk Assessment in Science. Finally, check your school policy on learning outside the classroom.

The Institute for Outdoor Learning provides a good overview into the risks and benefits of outdoor learning here. They also offer specific guidance and advice for schools here.

LOCATION
Indoor

TOOLS AND MATERIALS

- 9_principles.ppt, 2nd slide

PREPARATIONS

Arrange the classroom for presentation and discussion.

RESOURCES

Benyus, J. M. (2002): Biomimicry – *Innovation inspired by nature.* HarperCollins Publisher, New York, U.S.A.

1| INTRODUCTION

» QUESTION

Present the slide about Principle 1: 9_principles.ppt, slide 2.

Nature uses sunlight as the main source of energy. Organisms use heat and UV radiation from this never-ending source. So, we can say that nature is powered by sunshine. Humans use fossil fuels, these sources are not renewable, and burning them creates CO_2 which is one of the gases causing climate change. Why don't we do the same and prevent the climate crisis? A wise person would mimic nature and rely on renewable power.

Explanation to 9_principles.ppt, 2nd slide:

Photosynthesis is a chemical reaction that takes place inside a plant, producing food for the plant to survive. Carbon dioxide, water and light are all needed for photosynthesis to take place. Photosynthesis takes place in the part of the plant cell containing chloroplasts, these are small structures that contain chlorophyll. Photosynthesis takes place in two stages, the light reaction and the dark reaction. The light reaction converts the energy of sunlight into chemical energy (ATP – adenosine triphosphate and NADPH – nicotinamide adenine dinucleotide phosphate), and during the dark reaction chemical energy is converted to produce sugars from carbon dioxide (Calvin cycle).

The process is described by the equation:

$$6CO_2 + 12H_2O + \text{sunlight} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

The slide shows a tree, leaves and chloroplasts in cells seen through a light microscope.

It is worth mentioning that there are bacteria that do not use sunlight to generate energy. They use chemical compounds (e.g. hydrogen, ammonia, iron, sulphur compounds), this is called chemosynthesis. One of them is chemolithotrophs which use an inorganic electron donor for breathing. These bacteria usually live in anaerobic condition like ponds, or in extremely mineralized areas where sunlight is completely missing, e.g. iron geysers and springs, deep sea smokers (volcanoes). All autotrophs (they build up organic matter from inorganic materials in their environment) use carbon dioxide as the carbon source for photosynthesis to build up their organic matter. Heterotrophic organisms derive their energy from organic materials produced by autotrophic organisms.

LOCATION
Indoor / Outdoor

TOOLS AND MATERIALS

- Student worksheets: W2.1, W2.2
- Any costumes, decorations for the play (students can prepare these before the class)

PREPARATIONS

The play can be performed indoors or out. The costumes and decoration can be made by students, or place in the classroom a box with old clothes, rags, etc. so students can select what they need.

RESOURCES

https://sbsciencematters.com/5th/life/5.15PhotosynthesisPlay.pdf

2| PLAYING PHOTOSYNTHESIS

» DISCOVER

Key to life on Earth is that green plants produce organic compounds from water and carbon dioxide using sunlight. Energy can be stored in these organic compounds.

Probably all students have learnt about photosynthesis. The basic equation of photosynthesis is:

$6CO_2 + 6H_2O + \text{photon energy} = C_6H_{12}O_6 \text{ (glucose)} + 6O_2$

The real equation is $6CO_2 + 12H_2O + \text{photon energy} = C_6H_{12}O_6 \text{ (glucose)} + 6O_2 + + 6H_2O$, as oxygen molecules of O_2 come from H_2O.

Student worksheet W2.2 describes a photosynthesis play. In the play, students play the roles of different parts in the process of photosynthesis. Select students for the different roles and let them practise for a couple of minutes, and then have a performance. After the performance discuss with students, why are green plants are the basis of life on the Earth?

Resources:
Science and Plants in Schools (www.saps.org.uk) provides excellent resources for follow-up experiments.

LOCATION
Indoor / Outdoor

TOOLS AND MATERIALS

- **Discs** (about 10 cm diameter) attached onto kebab sticks (about 3–4 mm diameter and about 20 cm long) with the chemical symbols of the elements within the photosynthesis process: 6 discs with C; 18 discs with O; 12 discs with H. In case you choose to show the real equation another 6 O and 12 H are needed. See picture on T3.1.
- **Hint:** the diameter of the symbols can differ by the size of element: H can be the smallest, C medium and O the largest.
- **Teacher's pages:** T3.1, T3.2

PREPARATIONS

Prepare the discs described above. You will need space either inside or outside for modelling the reaction with students.

3| MODELLING THE REACTION OF PHOTOSYNTHESIS

» CREATE

Depending on the number of students, hand out the symbols of the elements e.g. if there are 12 students, 6 of them can hold the formula of water (H_2O) and another 6 the carbon-dioxide (CO_2). One pupil can play the role of light, and when he/she shines, the elements are rearranged: students become $6O_2$ and one $C_6H_{12}O_6$ (of course, in case you use the real equation, you need more elements.) You can find the arrangement for glucose in T3.2.

Students can prepare the plays/models of 2nd and 3rd activity in parallel and perform to each other after practicing.

EXTENSION(S)

You can learn how to make solar cell from here: https://www.learningwithnature.org/ Education Materials / Engineering Curricula – Middle/High School / 8. The Largess of Leaves (p. 96) / Activity procedure (p. 102)

LOCATION
Indoor / Outdoor

PREPARATIONS

Arrange the classroom for discussion.

4| REVIEW

» QUESTION

After the activities talk with students about the principle:

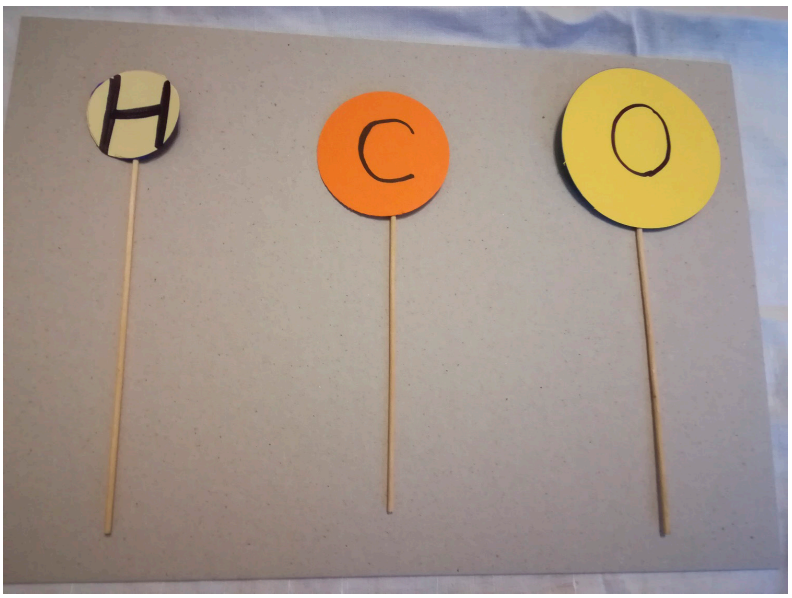
- How does nature catch the energy of the sun?
- Why do we say that the process of photosynthesis provides the basis of life on Earth?
- Where and how could we mimic this process?

LITERATURE, ADDITIONAL INFORMATION

Stier, S. (2014): *Engineering Design Inspired by Nature.* The Center for Learning with Nature, Coralville, U.S.A. https://www.learningwithnature.org/

T3.1 MODELLING THE REACTION OF PHOTOSYNTHESIS

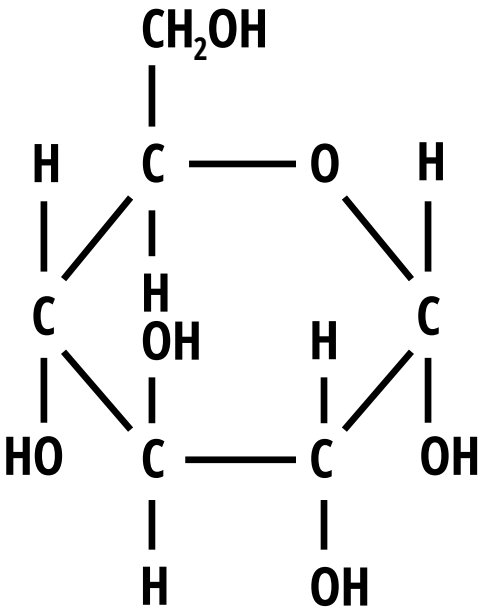
Picture of discs for the elements of photosynthesis



T3.2 MODELLING THE REACTION OF PHOTOSYNTHESIS

The formula of a glucose molecule

GLUCOSE MOLECULE



W2.1 PLAYING PHOTOSYNTHESIS

Character Cards

Sun	**Water (H_2O)**
Norman, the Plant	**Sunlight**
Oxygen (O_2)	**Carbon Dioxide (CO_2)**
Sugar ($C_6H_{12}O_6$)	**Narrator**

W2.2 PLAYING PHOTOSYNTHESIS

Text

CAST OF CHARACTERS:
Narrator, Sun, Sunlight, Water (H_2O), Sugar ($C_6H_{12}O_6$), Carbon Dioxide (CO_2), Oxygen (O_2), Norman the Plant.

SETTING:
For example a garden (students may pick the specific location).

Narrator: There once was a handsome plant named Norman. He was green and lush. He was a happy plant with many other plant friends. But, one day he got really hungry. *(Sun and sunlight stand together on one side of the room and Norman the plant stands on the other side of the room.)*

Norman: I am starving! My friend Bob the Human and Vanessa the Cat eat with their mouth, but do you see a mouth on this face? Nope!

Narrator: Norman sure was hungry, so he lifted his leaves towards the sun.

Sun: What a beautiful day! Let me shoot my rays of sunlight down upon the Earth.

Sunlight: Here I come! *(The sunlight moves quickly from the sun towards the plant).*

Norman: Mmmmm, sunlight, yummy! *(Sunlight high fives Norman's leaf (his hand)).*

Narrator: The sunlight hits Norman's chloroplast and his lunch has begun.

Norman: I have begun to process the sunlight, but I am thirsty too. Water come here!

Water: I will travel through your roots and up your stem. *(Water comes towards Norman's roots)*

Norman: I have sunlight and water, now I need to suck in some carbon dioxide through my many stomata. *(Norman opens his mouth for the stomata).*

Carbon Dioxide: Here I come from the atmosphere! *(Carbon Dioxide flows towards Norman)*

Narrator: The process of photosynthesis is almost complete! Now, the sunlight, water, and carbon dioxide need to perform chemical reactions to produce Norman's lunch. *(Water, Sunlight and Carbon Dioxide link arms and walk in a circle around Norman)*

Norman: I am feeling a chemical reaction occurring. My lunch! My sugary lunch! *(Water, Sunlight and Carbon Dioxide sit down and out runs Sugar)*

Sugar: I am lunch! I can feed Norman's cells. Don't I look delicious? *(Norman pretends to eat Sugar)*

Norman: That was delicious, but now I have to take care of the oxygen I created. *(Oxygen molecule comes and stands next to Norman)*

Oxygen: Part of me stays in Norman to help him get energy in his cells. But most of me leaves Norman through his stomata. The good news is that I am then valuable to animals and humans. *(Oxygen walks away from Norman into the atmosphere)*

Narrator: As you can see, plants can make their own food through the process of photosynthesis. Thank you, Norman for demonstrating.

The End

ANNEX 1

Key Stage 4 Working Scientifically Statements

Through the content across all three disciplines, students should be taught so that they develop understanding and first-hand experience of:

1. THE DEVELOPMENT OF SCIENTIFIC THINKING	a. the ways in which scientific methods and theories develop over time b. using a variety of concepts and models to develop scientific explanations and understanding c. appreciating the power and limitations of science and considering ethical issues which may arise d. explaining everyday and technological applications of science; evaluating associated personal, social, economic and environmental implications; and making decisions based on the evaluation of evidence and arguments e. evaluating risks both in practical science and the wider societal context, including perception of risk f. recognising the importance of peer review of results and of communication of results to a range of audiences
2. EXPERIMENTAL SKILLS AND STRATEGIES	a. using scientific theories and explanations to develop hypotheses b. planning experiments to make observations, test hypotheses or explore phenomena c. applying a knowledge of a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments d. carrying out experiments appropriately, having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations e. recognising when to apply a knowledge of sampling techniques to ensure any samples collected are representative f. making and recording observations and measurements using a range of apparatus and methods g. evaluating methods and suggesting possible improvements and further investigations
3. ANALYSIS AND EVALUATION	a. applying the cycle of collecting, presenting and analysing data, including: i. presenting observations and other data using appropriate methods ii. translating data from one form to another iii. carrying out and representing mathematical and statistical analysis iv. representing distributions of results and making estimations of uncertainty v. interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions vi. presenting reasoned explanations, including relating data to hypotheses vii. being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error b. communicating the scientific rationale for investigations, including the methods used, the findings and reasoned conclusions, using paper-based and electronic reports and presentations

4. VOCABULARY, UNITS, SYMBOLS AND NOMENCLATURE	a. developing their use of scientific vocabulary and nomenclature b. recognising the importance of scientific quantities and understanding how they are determined c. using SI units and IUPAC chemical nomenclature unless inappropriate d. using prefixes and powers of ten for orders of magnitude (e.g. tera, giga, mega, kilo, centi, milli, micro and nano) e. interconverting units f. using an appropriate number of significant figures in calculations