# "Climate DNA"

*Teaching modules designed for upper secondary education programmes, which support participation in Klimatorium's youth climate conference, the 'Global Youth Climate Summit'.*

2–3 modules
physics/chemistry
(possible links to design and economics)

**Purpose:**

Bring climate education to life. This material bridges the gap between complex theory and concrete action, helping students experience that their knowledge has the power to change the world. Throughout the programme, they are equipped with strong academic tools and insights that they can take directly into the Global Youth Climate Summit — a platform where young people's own voices shape the agenda and make climate action tangible, relevant, and timely.

Through the Global Youth Climate Summit, we aim to create the eye-opening realisation that **"we are nature."** By connecting photosynthesis and respiration as one interconnected cycle, students see how humans are chemically dependent on — and fundamentally part of — the living world.

## Structure

**Module 1**

- Activity: Explore the biological vs. fossil cycles. Using a concrete object, identify which materials come from the fast cycle and which come from the underground.
- Outcome: A completed chart categorising the object's materials by cycle type.

**Module 2**

- Activity: Complete a manifesto template based on the analysis from Module 1.
- Outcome: A draft of climate demands based on the template.

**Module 3**

- Activity: Create the visual contribution for the Global Youth Climate Summit.
- Outcome: Class presentation of climate demands + a 30-second video.

*Module 1 is divided into three cases. Choose the case that best suits your class and follow its colour throughout the first module.*

# MODULE 1

Duration:
90 minutes

“The Chemical Mirror and Linear Consumption”

**Purpose**
To illustrate how distinguishing between “me,” “nature,” and “my things” is a chemical illusion. We use the exact same building blocks, but the way we organise them creates either life and balance (photosynthesis/nature) or waste and imbalance (linear consumption / Earth Overshoot Day).

**Academic focus**
Atomic building blocks (C, H, O, N), conservation of elements, closed cycles, and linear consumption.

## Class Introduction (20 minutes)

The teacher introduces the concept of **the closed cycle.**
Plants build all living matter from six primary elements: Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P), and Sulfur (S). In biology, these are known as CHNOPS. The human body is made up of exactly the same six elements.

Every oxygen molecule ($O_2$) you breathe right now is “waste” from a plant’s photosynthesis. Every carbon atom in your body — in your muscles, DNA, and fat — was once floating in the air as $CO_2$ and was captured by a leaf. We eat and breathe solar energy that plants have packaged for us. Chemically, there is no separation between us and the forest.

**The Two Key Differences: The Biological and Fossil Cycles**

- **Biological cycles (fast)**: The cycle is in balance. The $CO_2$ released through respiration or decomposition is the same carbon that was recently absorbed by plants through photosynthesis.
- **Fossil cycles (locked):** The cycle is out of balance. Carbon has been locked underground for millions of years. When we extract it and either burn it or allow it to accumulate as non-degradable plastic, we add new net carbon to the cycle.

### The Three Key Chemical Reactions

Photosynthesis
$6CO_2 + 6H_2O$ + solar energy → $C_6H_{12}O_6 + 6O_2$

Respiration (the biological cycle)
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy (ATP)

Combustion of plastic (the fossil cycle)
$(H_4)n + 3nO_2 \rightarrow 2nCO_2 + 2nH_2O$ + heat

**Eye-Opener**

- Glucose, the product of photosynthesis and a building block of everything from our muscles to trees:
  - $C_6H_{12}O_6$
- Polyester / PET plastic:
  - $(C_{10}H_8O_4)n$

Both are simply chains of carbon, hydrogen, and oxygen. But while nature has designed glucose to be broken down and recycled in an endless cycle, humans have bonded the atoms in plastic so tightly that they are locked out of the cycle. This is linear consumption.

# Investigating Biological Building Blocks

*Choose your study programme — or the case that best suits your class (60 minutes).*

The Biochemical and Technical Track: A-level Chemistry/Biology/Biotechnology

The Ecological and General Education Track: B-level Biology, Chemistry, or Geography)

The Green Business Track: Business Economics, International Economics combined with a Science elective

# The Biochemical and Technical Track

**Object for Dissection:** A smartphone or a piece of advanced electronic equipment.

**Academic Task:**

- Students explore the periodic table and the role of heavy and rare elements (e.g. lithium, copper, cobalt, neodymium).
- They investigate the chemical bonds in a lithium-ion battery or the rare earth elements used in screens.
- They contrast this with how biology transports electrons, e.g. iron in haemoglobin or magnesium in plant chlorophyll.

**The Linear Problem:**

Why is it chemically so difficult to recycle a smartphone compared with a biological cycle? Students examine how materials are alloyed and mixed at the microscale, increasing entropy and making the separation of individual elements extremely energy-intensive.

**Ideas for Extending the Academic Task:**

- Conduct laboratory experiments building simple galvanic cells (e.g. copper/zinc) and measuring open-circuit voltage.
- Explore why the position of elements in the periodic table is crucial to their properties.
- Analyse chlorophyll extracts or haemoglobin using spectrophotometry (absorption spectra).
- Create a comparison chart of energy density, efficiency, and the fate of electrons in a lithium battery versus the thylakoid membrane of a chloroplast.
- Develop a mini-project exploring how to build "greener" batteries by learning from biology (e.g. organic flow batteries or artificial photosynthesis).

**Key Terms**

**Haemoglobin:** An essential iron-containing protein found in the body's red blood cells that binds and transports oxygen.

**Chlorophyll:** The green pigment found in plants, algae, and some bacteria. It absorbs blue and red light but reflects green light, which is why plants appear green.

**Entropy:** The degree of disorder, randomness, or uncertainty in a system.

**Reflection**

When you charge your phone, you move electrons in lithium. When a tree captures sunlight, it moves electrons in magnesium. The principle is the same — but why does technology fail where biology has worked for billions of years?

## Chemical Design for Disassembly Requirements

*Preparation for the Global Youth Climate Summit*

Students formulate a technical requirement for Chemical Design for Disassembly. The requirement should be clear and understandable to a non-expert — for example, their grandmother.

Template for the requirement specification:

- Technical requirement = What (goal)
- How (chemical means)
- Why (broader impact)

Example:
"Chemistry should function as a 'liquid seal' (goal) by using a low-viscosity polymer that penetrates all micro-cracks (means), making the battery completely airtight without the need for heavy mechanical screws (impact)."

## The Ecological and General Education Track

**Object for Dissection:** A running shoe (sneaker) — alternatively, a plastic water bottle.

**Academic Task:**

- Students take apart a running shoe to understand why current product design creates waste problems. The goal is to identify which materials need to be replaced when designing biodegradable shoes in the future.
- They trace how crude oil (ancient fossilised plants and algae) is transformed through chemical processes such as polymerisation into the plastic fibres used in the shoe. They complete the accompanying chart of the shoe's components and assess its circularity.
- They compare the shoe's lifespan and chemical inertness (its resistance to decomposition) with a leaf from a tree (cellulose), which enters the carbon cycle within a few months through microbial respiration. They explore what future shoes could look like if designed for circularity.

### Key Terms

**Polymer:** A plastic material made up of long chemical chains.

**Polymerisation:** The process of transforming oil into strong plastic.

**Linear economy:** Extract – produce – consume – discard. We take carbon from underground and lock it above ground as waste and $CO_2$.

**Circular economy:** A closed cycle based on reuse and recycling. Products are designed to be reused and kept within a circular cycle.

### The Shoe's Components

| Component | Material | Polymer from Crude Oil? |
|---|---|---|
| Sole | Foam / rubber | YES |
| Upper part | Synthetic textiles (polyester) | YES |
| Shoelaces | Synthetic fibres | YES |
| | | |
| | | |

**Where Does the Shoe Come From?**

Almost the entire shoe is made from crude oil (fossil carbon from ancient algae and plants). Students arrange the words below in the correct order to show the shoe's journey:

- Fossil carbon (crude oil)
- Chemical process (polymerisation)
- Plastic fibres
- Running shoe

## The New Product Design

*Preparation for the Global Youth Climate Summit*

Students use this knowledge to design the shoes of the future. They write three concrete principles for new, sustainable running shoes by completing the following sentences:

- *Our new shoes should not be made from crude oil, but from... (e.g. biodegradable biological polymers)*
- *When the shoes reach the end of their life, they should be able to decompose through... (e.g. composting / microorganisms)*
- *By changing the materials, we help slow climate change because... (we avoid extracting new fossil carbon from the ground)*

# The Green Business Track

**Object for Dissection:** A piece of fast-fashion clothing (e.g. a T-shirt made from 50% cotton / 50% polyester).

**Background:**

- Cotton is produced through photosynthesis in a field (renewable resource, biological cycle).
- Polyester is produced in a factory from petrochemicals (non-renewable resource, technical cycle).

**Academic Task:**

- Students analyse the economic incentives: Why is it cheaper for a company to use virgin polyester (oil) rather than recycle the atoms already contained in the T-shirt?

**Reflection:**

- Entropy and the separation dilemma: It is chemically easy to blend cotton and polyester into one textile, but extremely difficult to separate them again. Blended textiles create high entropy and require large amounts of chemical energy and solvents to return the materials to pure cycles.
- Externalisation of costs: If a T-shirt costs DKK 100, this price mainly reflects the cost of extracting oil and harvesting cotton. The costs of microplastic pollution, $CO_2$ emissions, and waste disposal are passed on to society.
- Virgin resources vs. recycling: It requires less energy and money to extract crude oil and refine it into pure PET/polyester than to collect, sort, chemically break down (depolymerise), and purify used fast-fashion textiles.

**Examples:**

- The hybrid problem: A standard T-shirt may consist of a blended material (e.g. 50% cotton, 50% polyester). Cotton can be broken down by enzymes and bacteria, while polyester requires high temperatures and chemical solvents. When woven together, they interfere with each other's natural pathways for decomposition and recycling.
- PET bottle vs. T-shirt: Clothing brands advertise "recycled polyester from plastic bottles." While consumers may perceive this as a better product, it takes plastic bottles out of a closed bottle-to-bottle recycling loop. Once the plastic is turned into a T-shirt blended with cotton, it is effectively locked into a dead-end cycle and will eventually end up being incinerated.
- EPR (Extended Producer Responsibility) in practice: Extended Producer Responsibility requires producers to pay a waste fee proportional to how difficult a product is to chemically separate. If applied to T-shirts, for example, a shirt made from 100% pure cotton or 100% pure polyester would be cheaper to produce than a 50/50 cotton-polyester blend.

**The Linear Problem:**
Linear business models work against the principles of thermodynamics and biology, which favour closed cycles, because the price of raw materials does not reflect the cost of dealing with the atoms afterwards.

## Demands for Business Owners

*Preparation for the Global Youth Climate Summit*

Students formulate an economic/chemical demand for business owners to introduce Extended Producer Responsibility (EPR), where the company remains responsible for the atoms in its product throughout its entire lifecycle.

What might future design requirements look like?

## Shared Conclusion

**The teacher summarises the main message from Module 1 on the board:**
Whether we look at a smartphone, a sneaker, or a T-shirt, we see that the problem is not the atoms themselves. The problem is that humans have created a linear dead end for them. Nature knows no waste — everything produced through photosynthesis becomes part of something else.

Through the Global Youth Climate Summit, young people's demands come together around the idea that our systems should learn from the laws of chemistry and biology.

**Eye-Opener**
The teacher guides students to realise that atoms do not disappear.
We do not destroy matter; we simply spread it out so that it can no longer be reused (entropy).

Duration:
90 minutes

# MODULE 2

## "Earth Overshoot Day and the Hidden Cycle"

**Academic Focus**

Mass input, energy balances, and resource cycles.

**Activity**

Students connect their object directly to the concept behind Earth Overshoot Day. How much energy and material does it take to keep this object in circulation? Students are introduced to the idea that Earth has a limited supply of renewable resources, and that our behaviour and consumption must change if we are to restore balance.

### The Reflective Task – Climate Demand

Students now examine their product more closely and dive deeper into the object using concrete data. This gives them a deeper understanding of our consumption and its impact on Earth's resources. The aim is to understand why we need to improve how we think about reuse and circular design.

**Exercise 1:**

Guess the weight of your object. How many kilograms of nature do you think had to be extracted and processed to create it? **Use the accompanying worksheet for this exercise if needed.**

**Smartphone: Worksheet | Answers** **Sneakers & T-shirt: Worksheet | Answers**

**Exercise 2:**

Reflection and Climate Demand

In groups, students discuss their reflections from the exercises and develop a climate demand to present to the class.

**Climate Demand Template**

1. *"Our object is a [e.g. running shoe] containing [e.g. polyester/foam] from the fossil carbon store."*
2. *"The problem is that this material is extracted from the ground and cannot re-enter the biological carbon cycle because…"*
3. *"We therefore demand that the manufacturer changes the material to [e.g. biodegradable polymers / recycled materials], so that it can…"*

**Key Terms**

**Earth Overshoot Day** is the date when humanity's consumption of resources exceeds Earth's ability to regenerate them that year.

**The Ecological Backpack (MIF: Material Input Factor)** is the amount of raw materials (water, soil, minerals, fuel) that must be extracted to produce 1 kg of a product.

**Embodied Energy** is the total amount of energy (measured in MJ or kWh) consumed from the extraction of raw materials to the finished product.

# MODULE 3

Duration:
90 minutes

## Developing and Pitching Climate Demands

*Product for use at the Global Youth Climate Summit*

**Activity**

As a class, students select their strongest and most compelling climate demand. They create a contribution to be submitted to Klimatorium before the Global Youth Climate Summit. The contribution can be in English or in the students' native language with a written English translation.

**Guidelines for Submitted Material**

- A photo of the class holding a large physical sign displaying the class's shared chemistry-based climate demand.
- A 30-second video pitch where one student presents the class's demand directly to the camera. (Hold the phone horizontally and upload in high resolution. A microphone is recommended for better audio.)
- A digital upload of the class's chemical autopsy (graphic or poster).

**Inspiration**

- What do you want to change or implement?
- The impact – What difference will it make, and why?
- The perspective – How can this be scaled up and inspire other countries at COP31?

### Jump Straight to Module 3

Are you participating in the Global Youth Climate Summit but haven't completed Modules 1 and 2? No problem! Get ready by completing Module 3 and submitting your climate demand to Klimatorium.

Modules 1 and 2 focus on our connection to nature and the production processes behind everyday products such as running shoes, smartphones, and T-shirts, without considering circular cycles. Students develop climate demands based on these topics, but no prior knowledge of these processes is required to create your own climate demands.

Get inspired by the questions below, create your own demand and submit it to Klimatorium.

### Inspiration:

- Dream about your future — what does it look like?
- What makes you proud of your generation?
- What message would you like to send to today's decision-makers?
- How would you like to see change?
- What matters most to you in the world you leave behind for your children and future generations?

**Upload your climate demand:**

Klimatorium
Danmarks internationale klimacenter

Global Youth Climate Summit

EUROPEAN CLIMATE PACT

# Inspiration – The Class's Digital Toolkit

## Earth Overshoot Day

Find your country's exact Overshoot Day — how many months are you living on borrowed time?

- www.overshootday.org
- www.footprintnetwork.org
- www.footprintcalculator.org

## Biomimicry

Find biological solutions. Explore how nature solves chemical challenges without plastic or toxic substances.

- www.asknature.org (the biomimicry institute)
- www.biomimicry.org

## Circular Economy

Understand the cycle and the difference between biological and technical atoms.

- www.ellenmacarthurfoundation.org search for 'resources' or 'education'
- The Butterfly Diagram
- Book: The Circular Economy: A Wealth of Flows by Ken Webster
- Youtube: Ken Webster Circular Economy