DESIGN x SCIENCE ACCELERATOR

Imperial College London

Design x Science cards

Version 1.2 October 2022

Design x Science cards can be used in collaborative settings where the aim is to generate innovative ideas. The cards present a general definition, selected advantages and disadvantages in addition to an application of the method in a specific context.

Design x Science cards are available in three themes: Bionic Materials (blue), Synthetic Biology (grey) and Bio Engineering (black).

DESIGN X SCIENCE CARDS ARE CREATED BY:

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Imperial College London, 2021
www.designxscience.com

Design x Science cards

There is a growing need for more sustainable, innovative, biological, inclusive and ethical products, services and experiences. Bioscience and Design collaborations can effectively address these needs, however, meaningful and impactful entanglement are rare and challenging to take part in. Bridging Bioscience and Design is difficult, but appropriate tools, methods and mindsets can lead to novel and creative solutions.

Design and Science cards build shared understanding, identify problems and help discovery of opportunities in bio-design. Each card represents a scientific method or concept in a way that supports collaboration and idea generation.

Further reading

• Välk, S., Chen, Y., Dieckmann, E. & Mougenot, C. (2022). Supporting collaborative biodesign ideation with contextualised knowledge from bioscience. https://doi.org/10.1080/15710882.2022.2138447. CoDesign.

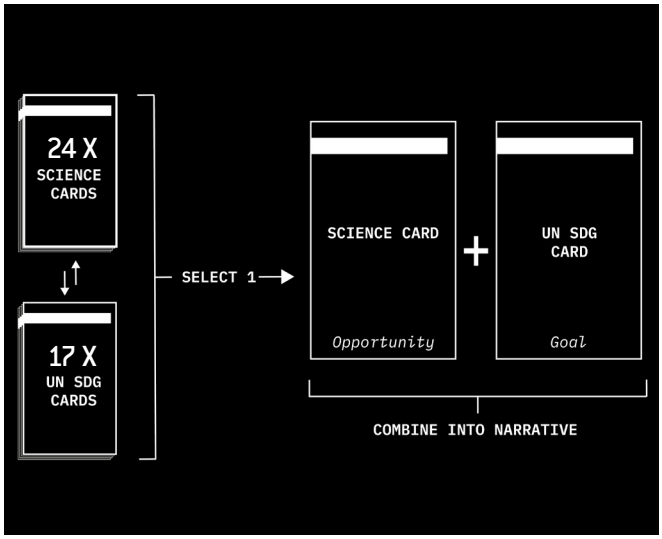
Share your experience

We kindly ask you to share with us how you used the card-set in your design, innovation or education project. Your insights will be helpful for us to improve the design of the cards and their usage: sander.valk@imperial.ac.uk or on Twitter @sandervaelk

How to use Design x Science cards

Design x Science cards can be used in collaborative settings where the aim is to generate innovative ideas. We recommend using the cards on a virtual whiteboard (e.g. Miro).

1. Exploration of cards
2. Group discussion or reflection (if working alone)
3. Pre-selection of 2-3 cards that provide most interesting / relevant opportunities for designing
4. Frame a problem for solving (from your personal brief or from UN SDGs)
5. Create a narrative – *How Might We use Science card X to solve Problem Y ?*
6. Idea generation and sketching



Integrating United Nations Sustainable Development Goals (UN SDGs)

United Nations Sustainable Development Goals provide effective building blocks for creative idea generation and act as connectors in interdisciplinary collaboration. Combining Scientific opportunities and UN Goals helps to build a fruitful narrative for idea generation.

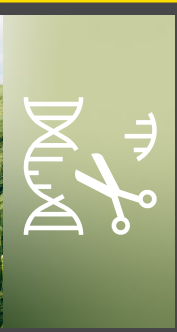
CRISPR - CAS9

- gene editing involving precise cutting and pasting of DNA by specialised proteins. Its applications include correcting genetic defects, treating & preventing the spread of diseases.

+ quick and easy
affordable

− ethics
unknown effects

example



A new high-resolution sequence of barley genome paves the way for improved malt. Improving malt can help meet the needs of beer brewers and whisky distillers and ultimately lead to new taste experiences for drinkers.

https://www.wired.com/story/what-is-crispr-gene-editing/

DISEASE DETECTING BIOSENSORS

- are devices used to detect the presence or concentration of a biological analyte, such as a biomolecule, a biological structure or a microorganism.

\+ quick test results (1h)
easy customisation

− difficult to apply in some field compatible formats

example

Biosensor can be used effectively for urinary tract infection detection. Results can be derived withing a fracition of time it takes with conventional methods used by the NHS. Detection is also possible for patients not showing symptoms.

https://dx.doi.org/10.1126/science.aaq0179

POLLUTION DETECTING BIOSENSORS

- are devices used to monitor and detect contaminants in the natural environment. Pollutants can be detected from air, water and soil, even at low concentrations.

\+ easy to use
non-toxic

− detects a single analyte
commercial availability

example

Affordable and easy-to-use biosensor reducing the chance of being poisoned by arsenic – a common contaminant of wells in parts of Asia. The modified bacteria will turn green when arsenic levels are safe, and purple when arsenic levels are unsafe.

https://bit.ly/3n3YoV5

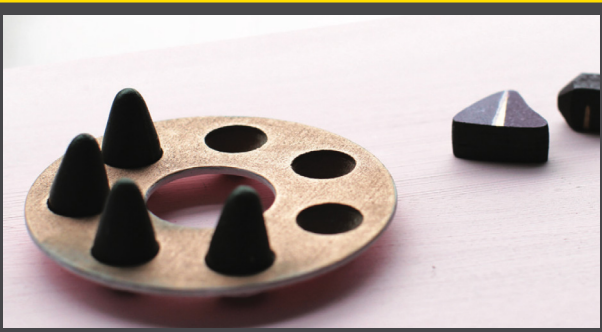
PROBIOTICS

- live bacteria and yeasts promoted as having various health benefits. They're usually added to yoghurts or taken as supplements, and are described as "good" or "friendly" bacteria.

+ affordable
established

− limited evidence
may disrupt gut

example



Biobons developed to address gut's needs. These chocolates are infused with bacteria to improve the balance in the gut, based on the needs of each individual.

www.rca.ac.uk/students/maria-apud-bell/

DNA ISOLATION (AND SEQUENCING)

- technique used to determine the nucleotide sequence of DNA (deoxyribonucleic acid). It is the essential blueprint containing the instructions for building an organism

\+ detects precise genetic material

\− requires high purity
requires a lot of material

example

Selfmade is a collaboration between synthetic biologists, designers, artists, and social scientists exploring human – bacteria relationships. The result is a cheese with starter cultures from human body (swabs from hands, feet, noses & armpits).

https://www.agapakis.com/work/selfmade

GENOME EDITING (AND FERMENTATION)

- rapidly evolving area for producers of life sciences. Genome editing provides the ability to knock-in, knockout, modify, or correct genes.

\+ generation of new biological systems

− ethically sensitive host organism rejection

example

Perfect Day uses cow genes in fungi to make 'real milk' proteins (bulding new biological systems for food production). These proteins are the basis for a vegan alternative of cow's milk and lack any lactose, cholesterol, hormones, and antibiotics.

https://perfectdayfoods.com

GENETIC ENGINEERING

- direct manipulation of an organism's genes to optimise the organism for specific purposes

\+ commercial potential
enhance organisms

− GMO not widely accepted
unknown hazards

example

Genetically encoded autoluminescent plants can be engineered by inserting genes from a bioluminescent mushroom (Neonothopanus nambi) into the DNA of tobacco plants.

https://doi.org/10.1038/s41587-020-0500-9

CELL - FREE SYSTEMS

- technology that can engineer biological parts without using living cells. It provides simple and fast engineering solutions, mainly in environmental and biomedical applications

+ easy optimisation
affordable

− not a robust system
can't be reused

example

Biobits manufactures low-cost and easy-to-use kits that teach molecular biology and synthetic biology. Instead of using live cells to turn DNA into proteins, BioBits uses a cell-free extract instead. Additional water is required to run experiments.

https://www.mybiobits.org

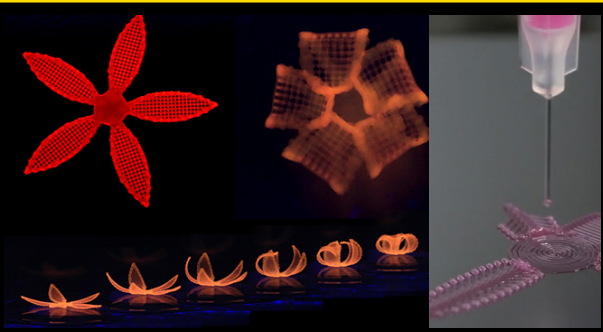
3D / 4D PRINTING

- allows programmable materials assemblies that transform in time as a result of changes in the environment (e.g. humidity, temperature)

\+ applied in soft robotics & drug delivery

− limited design variations cost

example



This microscale printing process uses hydrogel–cellulose fibril ink that allows the final print to change its shape. The technology's uses are in smart textiles, soft electronics, biomedical devices, and tissue engineering.

https://www.nature.com/articles/nmat4544

CELLULAR AGRICULTURE

- utilisation of cell cultures of the whole variety of host organisms for the production of agricultural commodities rather than production by farmed animals or crops.

\+ climate- independent
scalable

− consumer acceptance
costly

example

Eat Just (food startup in San Francisco) has started selling lab-grown chicken meat in Singapore. Meat grown in bioreactors avoids bacterial contamination from animal waste & overuse of antibiotics and hormones

https://doi.org/10.1016/j.copbio.2019.12.003
https://www.bbc.co.uk/news/business-55155741

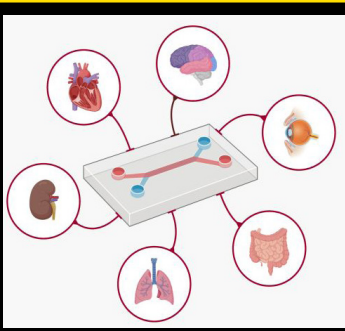
ORGAN ON A CHIP

- microfluidic chambers for cells and tissues in which chemical and physical stimuli are controlled to mimic the physiological conditions. Applicable from cell to organ scale.

\+ accelerates drug development

− labour intensive artificial environment

example



Bi/ond's Organoids are miniature versions of organs offering a platform for visual and chemical inspection of changes in organs when subjected to different treatments.

https://doi.org/10.1016/B978-0-12-420145-3.00020-1

https://www.gobiond.com

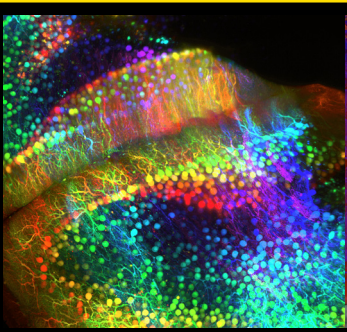
3D / 4D IMAGING

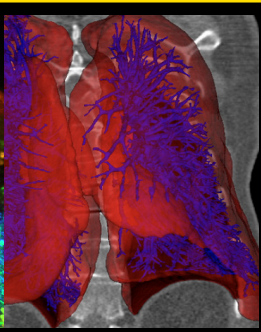
- capturing of morphology and molecular structure and dynamics, often with living samples. 3D imaging reveals how body & disease work from molecular to organism scale.

+ precise / detailed
accurate / dynamic

− limited specimen size
labour intensive, costly

example





Aether is developing a medical imaging software, which majorly advances organ 3D printing. This helps doctors & researchers increase productivity by making automatic segmentation of organs and tissues possible.

https://bit.ly/3oJsoH2
https://bit.ly/2LtU0Bj

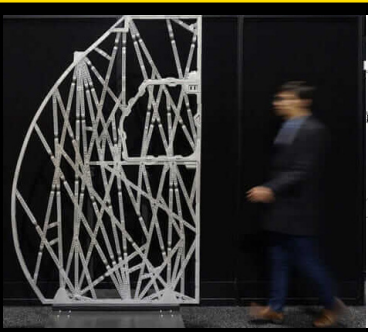
BIOMIMETIC ENGINEERING

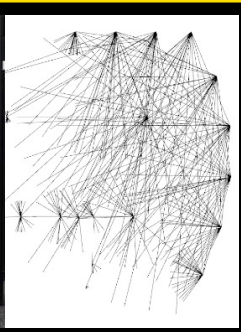
- development of new technology and innovation inspired by the natural design (often structural, but not limited to).

\+ often energy efficient
environment conscious

− lack of knowledge on
application areas

example





Airbus developed a 45% lighter aircraft partition wall, to be fabricated using metal additive manufacturing. Its design is based on a single-celled organism: slime mould.

https://redshift.autodesk.com/bionic-design/

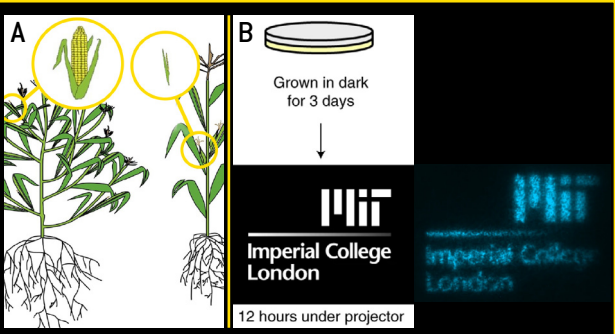
SYNTHETIC MORPHOLOGY

- designed genetic modulation of biological forms, allowing to adjust and regulate the shape and/or formation.

\+ natural cell & organ making outside body

− unknown effects caused by environment

example



(A) Domestication of teosinte to modern maize. (B) ICL researchers developed an engineered yeast that can respond (glow) to chemical & optical stimuli, with applications in biosensing.

https://doi.org/10.1016/j.semcdb.2017.08.051
https://doi.org/10.1038/s41563-020-00857-5

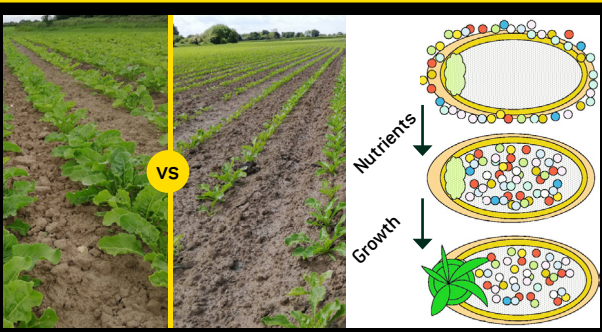
BIOLOGICAL PRIMING

- a mild treatment of a stressor that conditions the organisms' resistance to the stressor. The aim is to guard the host organism and regulate its functions (e.g. vaccines).

\+ boosts biological systems' resilience

− enhancement may not be strong / consistent

example



Germains has developed a range of biologically primed seeds to increase the quality of crops by providing faster emergence, faster & stronger plant development, root uniformity and overall yield potential.

https://doi.org/10.1038/s41522-020-00157-5

https://germains.com

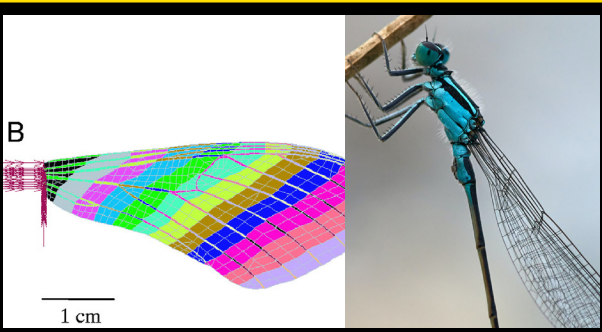
ARCHITECTURAL MODELLING

- computational simulation and test of the structural performances (e.g. strength, stability)

\+ estimates structural functioning

− potentially inaccurate requires a lot of data

example



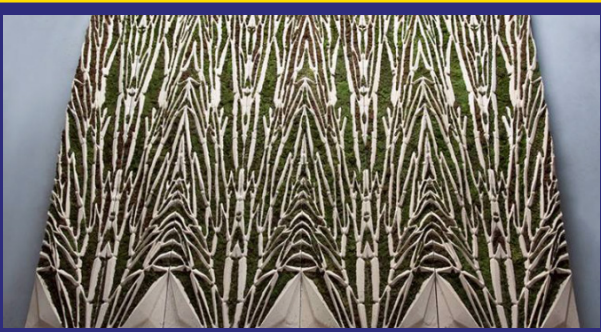
Researchers at UC Davies found that dynamic 3D shape of flapping insect wing influences flight performance. Finite Element Modelling shows that stiffness declines sharply from the wing base to the tip & from leading edge to the trailing edge.

https://doi.org/10.1242/jeb.00524

BIORECEPTIVE DESIGN

used to create materials with certain characteristics (e.g. porosity, pH) that enhance attachment and proliferation of living organisms.

example



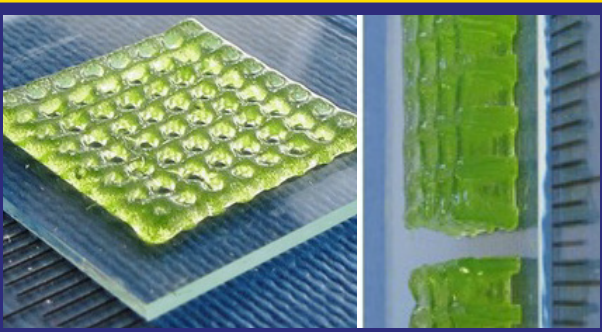
These panels are made of a novel type of concrete which enhances attachment and proliferation of algae, lichens and mosses. It investigates the potential for biologically augmenting architecture.

www.richard-beckett.com

BIO PRINTING WITH ALGAE

Using 3D printing processes and natural materials to create specific algae laden constructs

example



3D plotted algae laden alginate scaffolds utilise photosynthetic oxygen production of microalgae for the development of new therapeutic concepts.

https://doi.org/10.1002/elsc.201400205

BIOMIMICRY

Biomimicry uses features and strategies found in nature and applies them to man-made objects

example

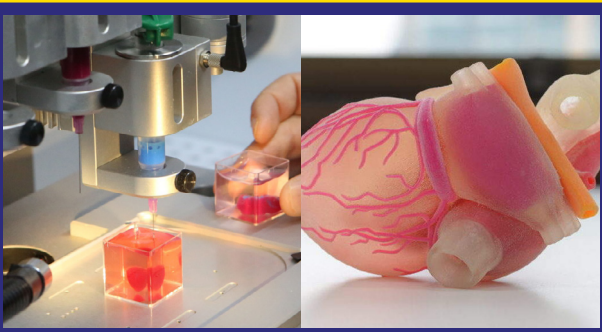
Airbus a320 sharklets developed with riblet sheets modelled on shark skin.
Placing sharklets on the wings and fuselage cuts fuel burn by up to 4% and lengthens aircraft in-service life.

https://bit.ly/360xyeC

ORGAN PRINTING WITH SOFT MATERIALS

3D printing to deposit cells and gels to create structures. This technique enables anatomical cell arrangement with predefined growth factors and locations in hydrogel scaffolds. Such 3D biological structures mimic native tissues

example



Cells in the 3D printed heart can contract, but don't yet have the ability to pump. 3D printed heart may be able to bypass one of the most serious problems with transplants: rejection of the new organ by the patient.

DOI: 10.1089/ten.2006.0175
https://bit.ly/360xyeC

UPPRINTING FOOD WITH SOFT MATERIALS

Soft materials can be created or used to make data driven recipes. These allow for customised flavour and nutrition, and printing processes allow for the production of unique textures

example

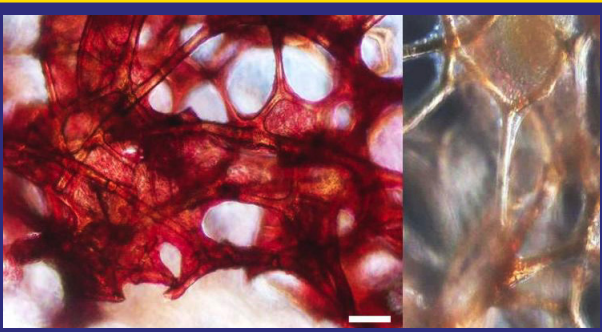
Spicy sweet potato (with rice, cumin and coriander) – blending and combining different ingredients from residual food flows, purees are created, which then are being 3D printed by a food printer.

www.upprintingfood.com

BIONIC MATERIALS – TISSUE BIONICS

A bionic material is a combination of a living organism with a non-living object to augment and/or introduce certain features

example



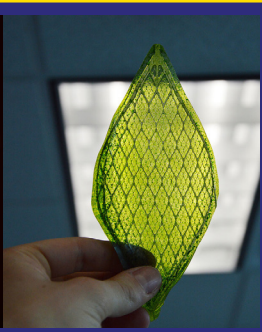
Functional growth factor delivery from collagenous marine sponge – exploiting natural biomatrices such as the marine sponge to enhance human cell responses and promote the initial stages of bone tissue regeneration.

doi:10.1088/1748-6041/3/3/034010

BIONIC MATERIALS – GLASS + ALGAE

Bionic materials combine living organism with a non-living objects. Algae can be populated in glass structures and kept alive by daylight

example



Exhale – bionic chandelier which purifies indoor air. The air is purified through photosynthesis performed by living photosynthetic micro-organisms enclosed into leaf modules.

www.designwanted.com/design/exhale

DESIGN FOR CELLULAR BIONICS

Cellular bionics explores how far the boundaries between the living and non-living can be blurred. It considers which properties to leverage, methods of data abstraction, mathematical models and interaction characteristics

example

Neuralink: brain - machine interface. The in-brain device could enable humans with neurological conditions to control technology, such as phones, with their thoughts. It may also solve neurological disorders, hearing loss, blindness, paralysis and depression.

https://neuralink.com

GOOD HEALTH AND WELL - BEING

Ensuring healthy lives and promoting well-being at all ages is essential to sustainable development. Currently, the world is facing a global health crisis unlike any other — Covid-19 is spreading human suffering, destabilizing the global economy and upending the lives of billions of people around the globe

SUSTAINABLE DEVELOPMENT GOALS

3 GOOD HEALTH AND WELL-BEING

AFFORDABLE AND CLEAN ENERGY

Access to electricity in poorer countries has begun to accelerate, energy efficiency continues to improve, and renewable energy is making. Nevertheless, attention is needed to improve access to clean & safe cooking fuels and technologies for 3 billion people.

SUSTAINABLE DEVELOPMENT GOALS

7 AFFORDABLE AND CLEAN ENERGY

CLEAN WATER AND SANITATION

Progress has been made in increasing access to clean drinking water and sanitation, billions of people still lack these basic services. World-wide, 1/3 people do not have access to safe drinking water, 2/5 do not have hand-washing facility with soap and water, more than 673 million people still practice open defecation.

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

INDUSTRY, INNOVATION & INFRASTRUCTURE

Inclusive and sustainable industrialisation, plus innovation and infrastructure, can unleash dynamic and competitive economic forces that generate employment and income. They play a key role in introducing and promoting new technologies. The world still has a long way to go to fully tap this potential.

SUSTAINABLE DEVELOPMENT GOALS

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

REDUCED INEQUALITIES

Ensuring no one is left behind is integral to achieving the Goals. Inequality within and among countries is a persistent cause for concern. Despite some positive signs in some dimensions, inequality still persists. Inequalities are deepening for vulnerable populations and countries with weaker health systems.

SUSTAINABLE DEVELOPMENT GOALS

10 REDUCED INEQUALITIES

SUSTAINABLE CITIES AND COMMUNITIES

The world is increasingly urbanised. More than 60% will live in cities by 2030. Rapid urbanisation is resulting in a growing number of slum dwellers, inadequate and overburdened infrastructure and services (waste collection, sanitation systems & transport), worsening air pollution & unplanned urban sprawl.

SUSTAINABLE DEVELOPMENT GOALS

11 SUSTAINABLE CITIES AND COMMUNITIES

RESPONSIBLE CONSUMPTION & PRODUCTION

Responsibility is about doing more and better with less, but also about decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles. Responsible methods and technologies will contribute substantially towards low-carbon and green economies.

SUSTAINABLE DEVELOPMENT GOALS

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

CLIMATE ACTION

2019 was the second warmest year ever recorded. Climate change is affecting every country on every continent. It is disrupting national economies and affecting lives. Weather patterns are changing, sea levels are rising, and weather is becoming more extreme. Saving lives requires urgent action .

SUSTAINABLE DEVELOPMENT GOALS

13 CLIMATE ACTION

NO POVERTY

The pandemic could increase global poverty by as much as half a billion people, or 8% of the total population. This would be the first time that poverty has increased globally since 1990. More than 700 million people (10% of population) live in extreme poverty struggling to fulfil the most basic needs.

SUSTAINABLE DEVELOPMENT GOALS

1 NO POVERTY

ZERO HUNGER

After decades of decline, the number of people who suffer from hunger – as measured by the prevalence of undernourishment – began to slowly increase again in 2015. Current estimates show that nearly 690 million people are hungry (8.9% of world population)– up by 10 million people in one year.

SUSTAINABLE DEVELOPMENT GOALS

2 ZERO HUNGER

QUALITY EDUCATION

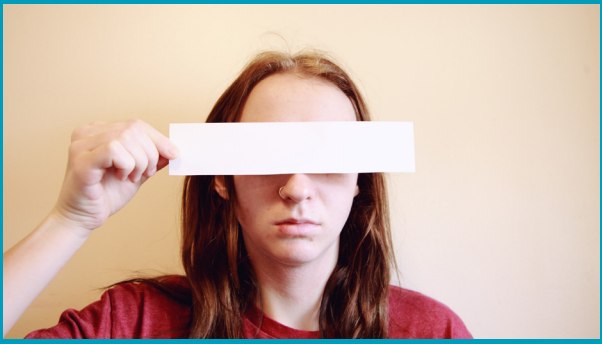
Education enables upward socioeconomic mobility and is a key to escaping poverty. About 260 million children were out of school in 2018 (nearly 1/5 of the global population in that age group). More than half of all children and adolescents don't meet minimum proficiency standards in reading and mathematics.

SUSTAINABLE DEVELOPMENT GOALS

4 QUALITY EDUCATION

GENDER EQUALITY

Discriminatory laws and social norms remain pervasive, women are underrepresented in politics, and 1/5 of women/girls (between 15 and 49)report experiencing physical or sexual violence within a year. Women play a disproportionate role in Covid-19 response, as front-line healthcare workers and carers at home.



SUSTAINABLE DEVELOPMENT GOALS

5 GENDER EQUALITY

DECENT WORK AND ECONOMIC GROWTH

Sustained and inclusive economic growth drives progress, creates jobs and improves living standards. Even before Covid-19, 20% of countries saw per capita incomes stagnate in 2020. We are likely to see disruptions to industrial production, falling commodity prices and financial market volatility.

SUSTAINABLE DEVELOPMENT GOALS

8 DECENT WORK AND ECONOMIC GROWTH

LIFE BELOW WATER

Careful management of seas and oceans is a key feature of sustainable future. Currently there is a continuous deterioration of coastal waters owing to pollution, and ocean acidification is having an adversarial effect on the functioning of ecosystems & biodiversity. This has negative effect on small scale fisheries.

SUSTAINABLE DEVELOPMENT GOALS

14 LIFE BELOW WATER

LIFE ON LAND

Human activity has altered almost 75% of the earth's surface, squeezing wildlife into an ever-smaller corner of the planet. This has implications for the emergence of zoonotic diseases (transmissible between animals & humans). Bringing humans into greater contact with wildlife amplifies disease emergence.

SUSTAINABLE DEVELOPMENT GOALS

15 LIFE ON LAND

PEACE, JUSTICE AND STRONG INSTITUTIONS

Conflict, insecurity, weak institutions and limited access to justice remain a great threat to sustainable development. In 2019, the United Nations tracked 357 killings and 30 enforced disappearances of human rights defenders, journalists and trade unionists in 47 countries.

SUSTAINABLE DEVELOPMENT GOALS

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

PARTNERSHIPS FOR THE GOALS

The SDGs can only be realised with strong global partnerships and cooperation. A successful development agenda requires inclusive partnerships - at global, regional, national and local levels - built upon principles and values, and upon a shared vision and shared goals placing people & the planet at the centre.

SUSTAINABLE DEVELOPMENT GOALS

17 PARTNERSHIPS FOR THE GOALS