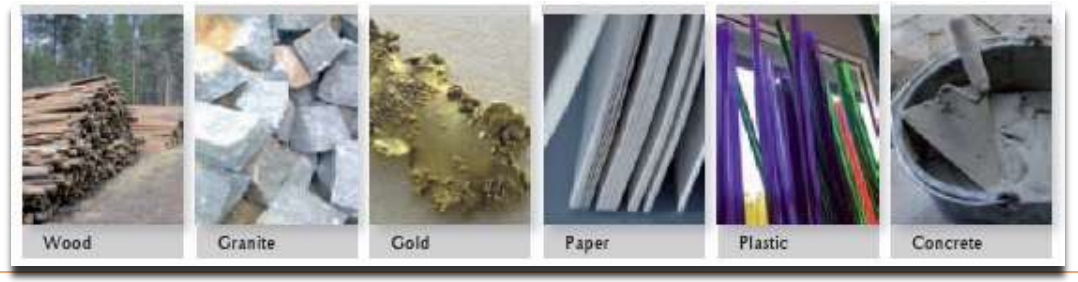
BIRZEIT UNIVERSITY

# Materials for Design

DSGN3240

Lecture 3

## MATERIALS' PROPERTIES

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# How to decide?

# Material

More than 50,000 materials

Sumerian headdress from a royal tomb in Ur, lapis lazuli and carnelian beads and gold leaves, *c.* 2600–2500 BCE; in the Metropolitan Museum of Art, New York City.

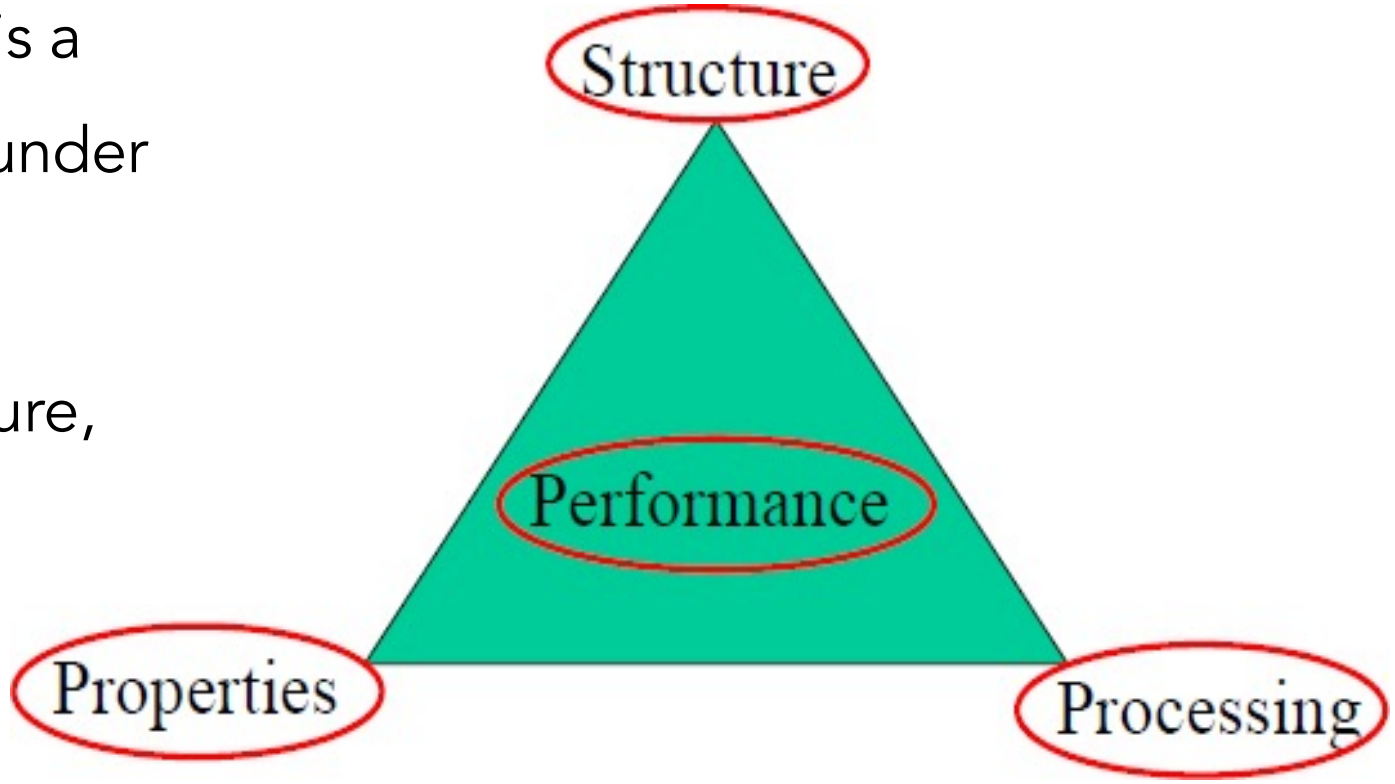
**Since there are thousands of materials available it is almost impossible to select a material for a specific task unless otherwise its properties are known.**


How to decide?
Design **requirements**
Design-limiting **properties**
**Processes** for shaping, joining, and finishing

# Material properties

# **Materials Science** Investigating the relationship between **structure and properties** of the materials

- Materials are characterized by their properties.
- Engineering use of a material is a reflection of these properties under conditions of use.
- Each material possess a structure, relevant properties, which is dependent on processing and determines the performance.



Properties are the way the material responds to the environment and external forces.

**Physical**
- Mechanical
- Electrical
- Optical
- Acoustics
- Thermal
- Magnetism

**Chemical**
- Oxidation
- Corrosion

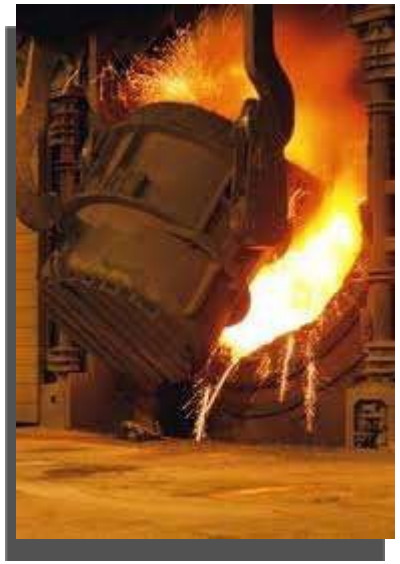
**Ecological**
- Toxicity
- Recyclability
- Renewable
- Biodegradable

# Raw materials

Those materials that exist in nature and we use as they are. Examples?

transformed into

## Processed materials

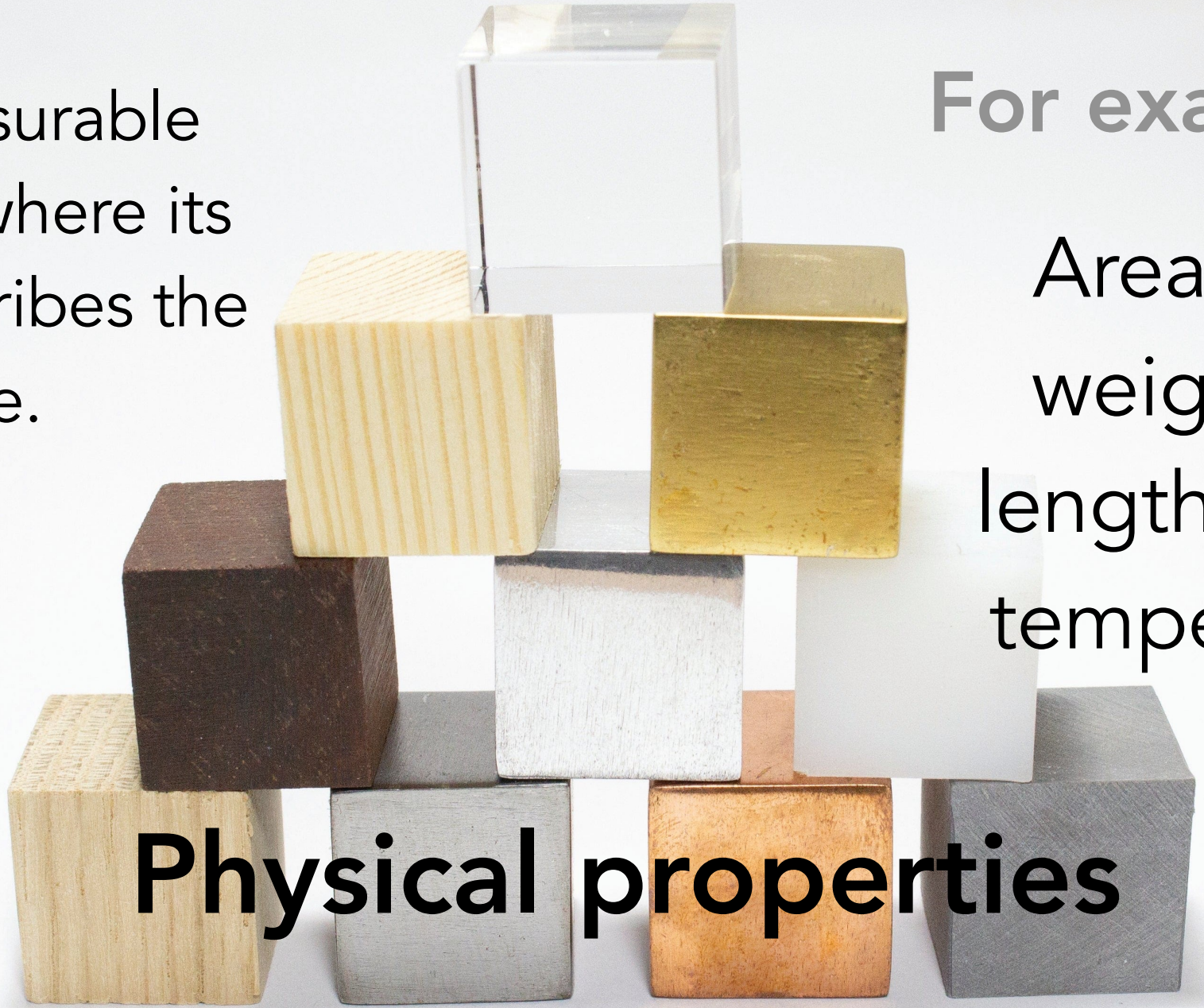


… with different properties…

used to create

## Technological objects

Any measurable property where its value describes the state.



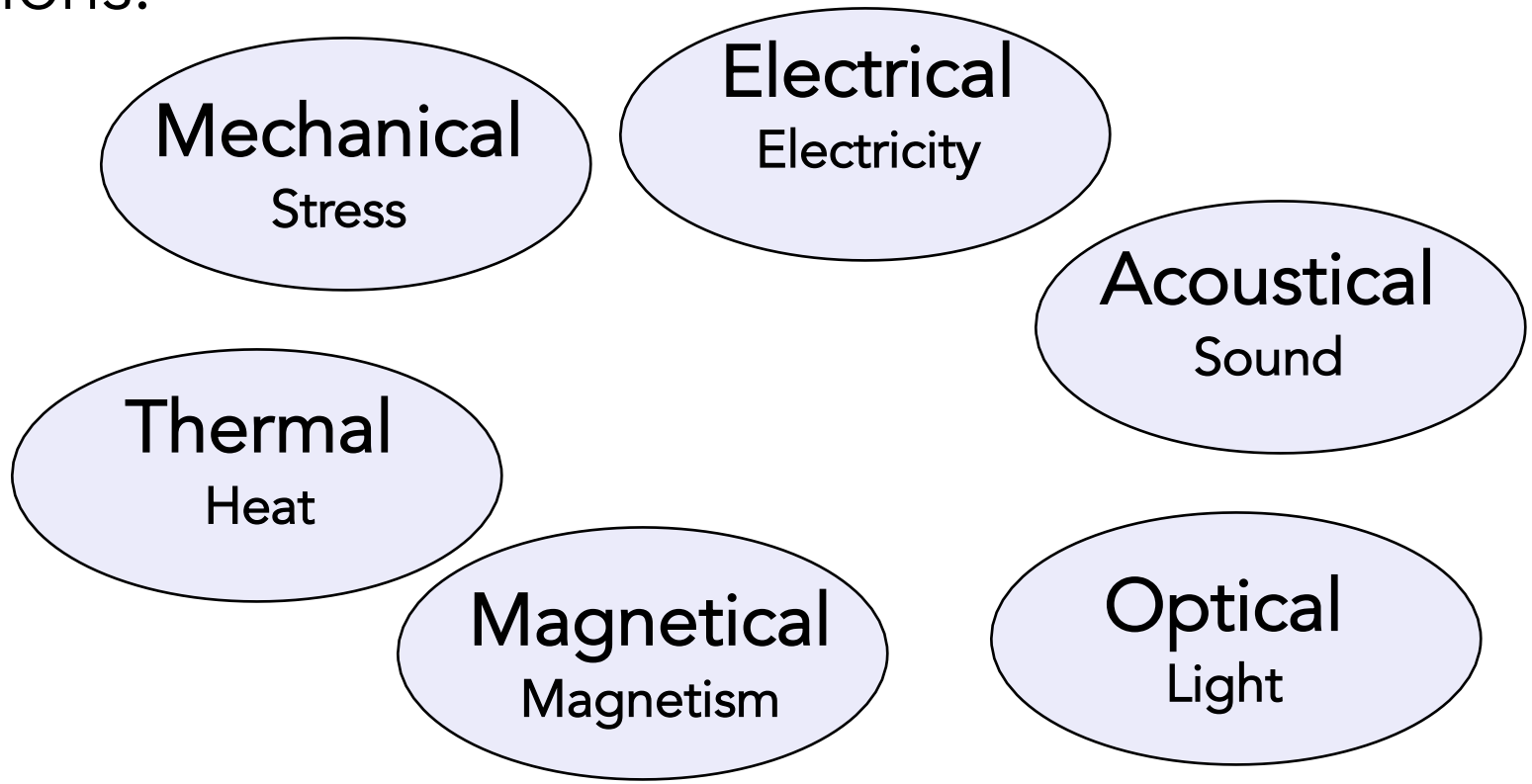
For example …

Area, density, weight, mass, length, pressure, temperature, …

# Physical properties

# Physical properties.

They describe the behavior of a material under different conditions.




* When any given force acts on an object, we can say that it undergoes **stress.**

# Mechanical properties

Mechanical properties are physical properties that a material exhibits upon the application of forces.

# Mechanical properties.

**Elasticity**:

A material's capacity to deform when a force is applied, and then return to its original shape when the force is withdrawn.

# Mechanical properties.

**Plasticity**

Material's capacity to maintain the deformations that have been produced on it after the force is withdrawn.

# Mechanical properties.

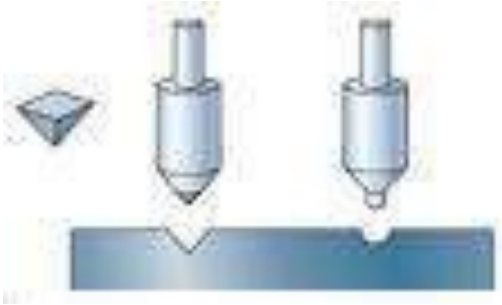
**Malleability.**
This is a material's ability to deform permanently (usually in **thin sheets)** under the force of compression.

**Ductility.**
This is a material's capacity to deform permanently when stretched (usually into **rods or wires**).

# Mechanical properties.

**Resistance.**
Capacity to undergo stress without breaking.

Whatever the material is and the stress applied, the material will eventually break.



# Mechanical properties.

## Hardness.

Material's resistance to being scratched or dented.

## Toughness.

Material's resistance to breaking when hit. When a material is not tough, meaning it **breaks easily**, it is referred to as **brittle**.

Note: The response of materials when stresses are suddenly applied is different from that when they are applied slowly.

- Conductor
- Semiconducor
- Insulator

Electrical properties.

# Electrical properties.

Electrical Conductivity.

Material's capacity to conduct an electrical current.
The greater the electrical conductivity of a material, the more easily electricity

is conducted through it.

The properties related to conductivity of heat.

# Thermal properties

# Thermal properties.

Thermal Conductivity.

Material's capacity to conduct heat.
The greater the thermal conductivity of a material, the more easily heat is conducted through it.

# Thermal properties.

**Expansion.**
Variation in the size of a material when subject to changes in temperature.

**Melting point.**
The temperature at which a solid material becomes liquid.

**Fusibility**.
Property of materials that refers to the amount of heat they require so they can melt.

# Acoustical properties.

**Sound Conductivity.**

Material's capacity to conduct sound. The greater the sound conductivity of a material, the more easily sound waves travel through it.

# Optical properties.

Transparency

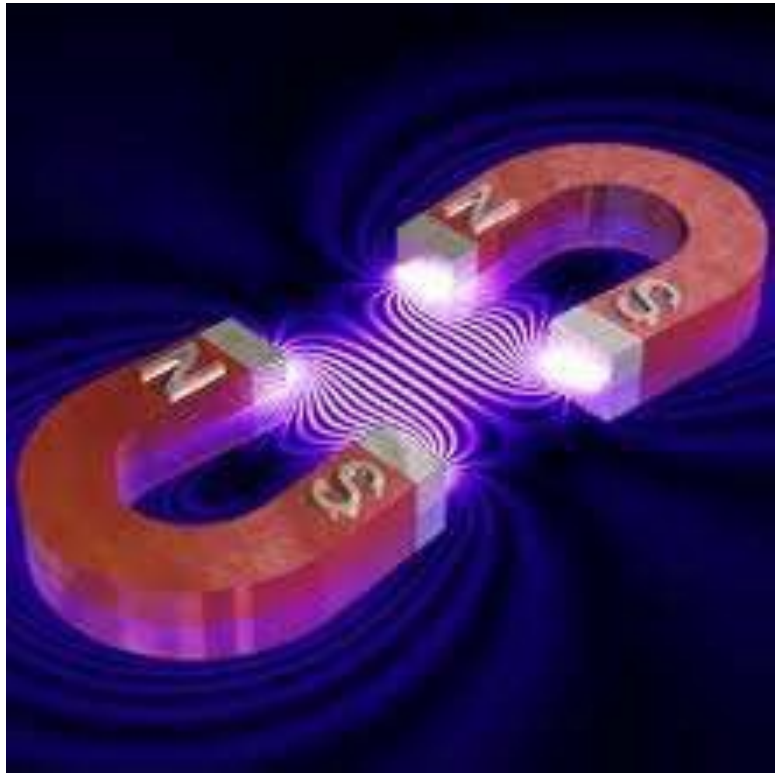
Opacity

Translucency


Magnetic response

# Magnetic properties.

## Magnetism



# Chemical properties

The ability of a matter to change \ or not to change into another matter.

# Chemical properties:

They describe the behavior of materials in contact with other substances.

Oxidation

Solubility

Corrosion

Permeability


Combustibility

# Chemical properties:

## Oxidation.

Reaction of a material with the oxigen in air.

## Corrosion.

Process of disintegration of material due to chemical reaction with substances in the environment.

## Permeability.

Capacity to absorb water or other fluids.

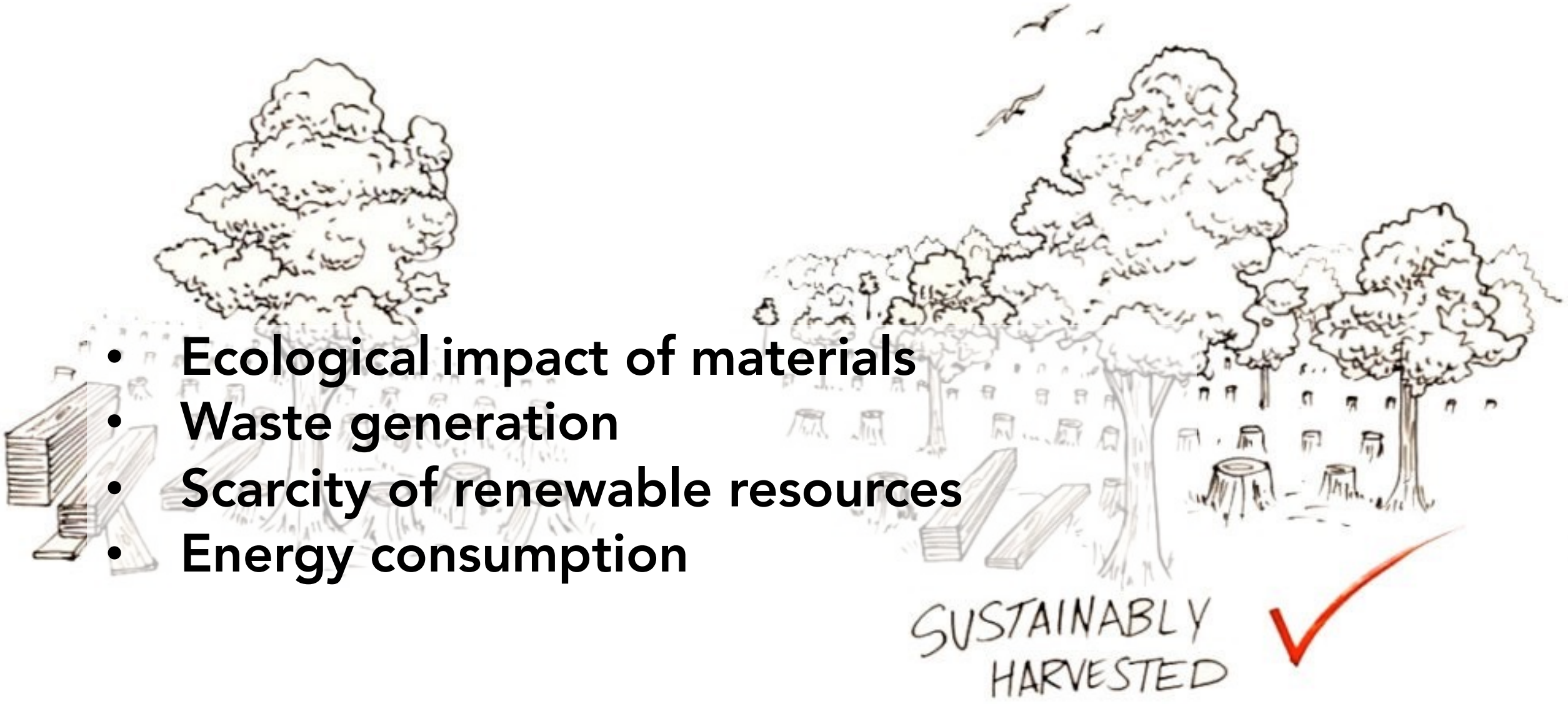
# Chemical properties:

**Solubility.**
Solubility is a material's capacity to mix with another substance, which acts as a solvent.

**Combustibility.**
Combustibility is a material's capacity to burn, giving off thermal energy.

# Environmental properties

- Ecological impact of materials
- Waste generation
- Scarcity of renewable resources
- Energy consumption



# Biological/Ecological properties:

They describe whether a material is damaging to the environment or living organisms.

Toxicity

Recyclability

Renewability

Biodegradability

# Ecological properties:

**Recyclability**

Recyclability is our ability to transform a material that has already been used into another product, with a new useful life.

Many materials that could not be recycled some years ago, are now recyclable.

# Ecological properties:

**Biodegradability**

Biodegradability is a material's capacity to deteriorate as a consequence of interacting with the environment.

It usually takes a long time for plastics to degrade. That's why recycling plastic is so important.

# Ecological properties:

**Toxicity**

Toxicity is the property of materials to cause negative effects on living organisms (by ingestion, inhalation or skin contact).

The greatest danger of the toxicity of plastics is when they are in contact with food and drinks, especially if these are heated up inside the same container.

# Ecological properties:

**Renewability**

Meaning that the material is replaceable by new growth.

# Examples

# Metal

## Bialetti Moka Cafe, 4 cups
## Source: Bialetti

**Material**
Aluminum alloy

**(Aesthetic properties)** the shiny, smooth surface of the cast aluminum matches

**(cost)** materials are relatively inexpensive; However, much energy is required in its extraction and processing

**(Sustainability)** Bauxite, the raw material for aluminum is a very energy intensive to mine and refine

However, aluminum is highly recyclable and uses just a fraction of the energy to


**(Physical properties)** Relatively lightweight makes it ideal for handheld use on a hot stove.

**(mechanical properties)** It can gain and lose heat quickly, making it ideal for quickly heating, brewing and serving a coffee

**(Material Properties)** aluminum is a relatively lightweight metal. It's thermal conductivity makes it ideal for heating liquid (water) on a stove.

**(Health)** there are some concerns that aluminum may migrate into food and drink, increasing the risk of some cancers

**(DfM)** cast in molds, the tapered form with chamfered edges allows for efficient and accurate mass production.

**(Manufacturing scale)** Its status as a classic design is due in part to the mass production over the decades. Because of the energy and specialize equipment (molds and metal casting) required for aluminum, it only becomes economical at a large scale



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# Plastic

## Nalgene Wide Mouth Water Bottle
## Source: Nagene

**(Aesthetic properties)** Can be colored; semi-transparency allows for easy identification of liquid and liquid levels

**(Sustainability)** Polycarbonate is a petroleum product. Though recyclable, quality degrades as it is recycled. Some polycarbonates contain BPA, which is cancer causing; Nalgene bottles do not contain BPA
The use refillable plastic water bottles reduces the use of single-use plastics


**(Manufacturing)** Thermoplastic is suited to manufacturing processes and economies of scale,

**(Cost)** materials are relatively inexpensive; most of the manufacturing cost of the final design is associate with production quality - this brand is known for its quality

**(Manufacturing scale)** Mass production allows bottles to be produced economically in large quantities

**(Mechanical properties)** Polycarbonate (brand name is *Tritan*) is a hard plastic, that is resistant to impact; This makes it ideal for a portable water container.

**(Manufacturing)** Blow molding for the body allows for accurate and consistent forms; suitable process for mass production

**(Physical properties)** Lightweight material contributes to the performance of the product - hikers want to carry as little weight as possible.

**(DfM)** Rounded form of the base allows for easy release from the mold.



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# Glass

## Lock and Lock Glass Container: LocknLock

**(Aesthetic properties)** smooth surface is clean to the touch; allows for easy cleaning; transparency makes it easy to identify the contents.

**(Material Properties)** Non-porous; ideal for food container as it won't absorb odors ror flavors

**(Manufacturing Scale)** Mass production is necessary because of the specialized machines and materials, as well as the significant energy costs associated with glass manufacturing.

**(Sustainability)**
Glass is energy intensive to produce; However, it is readily recyclable.
Crushed glass, cullet, is used in the manufacturing process - this reduces the energy required to manufacture.
Glass can be very durable

**(DfM)** Rounded form, edges, and corners allow for the design to be easily released from molds.

**(Physical properties)** Glass is quite hard, and will resist scratching and abrasion; This makes it a durable material to use in a kitchen

**(Cost)** relatively economical to product in large quantities (mass production)

**(Physical properties)** Transparency allows for the contents to be easily identified - this is helpful for users when storing removing food from the refrigerator.

**(mechanical properties)** Borosilicate glass, used here, is resistant to thermal shock means that hot foods can be placed in it without worrying about cracking. Also, food could be frozen in the freezer



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# Timber

## Slim Chair
## Source: opendesk.org

**(aesthetic properties)** light colored; layers in plywood are accents in the design

**(DfM)** available as large sheets, which is ideal for CAD/CAM subtractive manufacturing Plywood is uniform in thickness, making it idea for working with CAD machines

**(DfM)** DfM is evident through the use joints; simplifies and optimizes manufacture

**(Sustainability)**
18mm baltic birch plywood; Sustainably harvested; renewable resource; FSC (Forest Stewardship Council)

Glue in the plywood is not environmentally friendly; production is very energy intensive

**(DfM)** Screws and glue (adhesive) are used to assemble the chair -> Design for assembly

**(manufacturing)** CAD/CAM design allows for mass production; highly accurate manufacturing

**(manufacturing)** CAD/CAM allows for some customization of the design (changing height or dimensions)

**(Manufacturing)**
Subtractive manufacturing using CNC router

**(finish)** Clear polyurethane finish

**(Physical properties)**
relatively dense compared to other timbers

**(cost)** relatively affordable compared to hardwoods;

**(mechanical properties)** High strength to weight ratio; relatively strong in tension and compression -> this is ideal for its use as a chair; allows for the thin, light-weight looking design; Can support the weight of a person sitting on it



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# Why is it important?


The development of new materials allows designers to create new products, which solve old problems in new ways.