Aalto University

Sustainable design S8
Group work on Biomaterials

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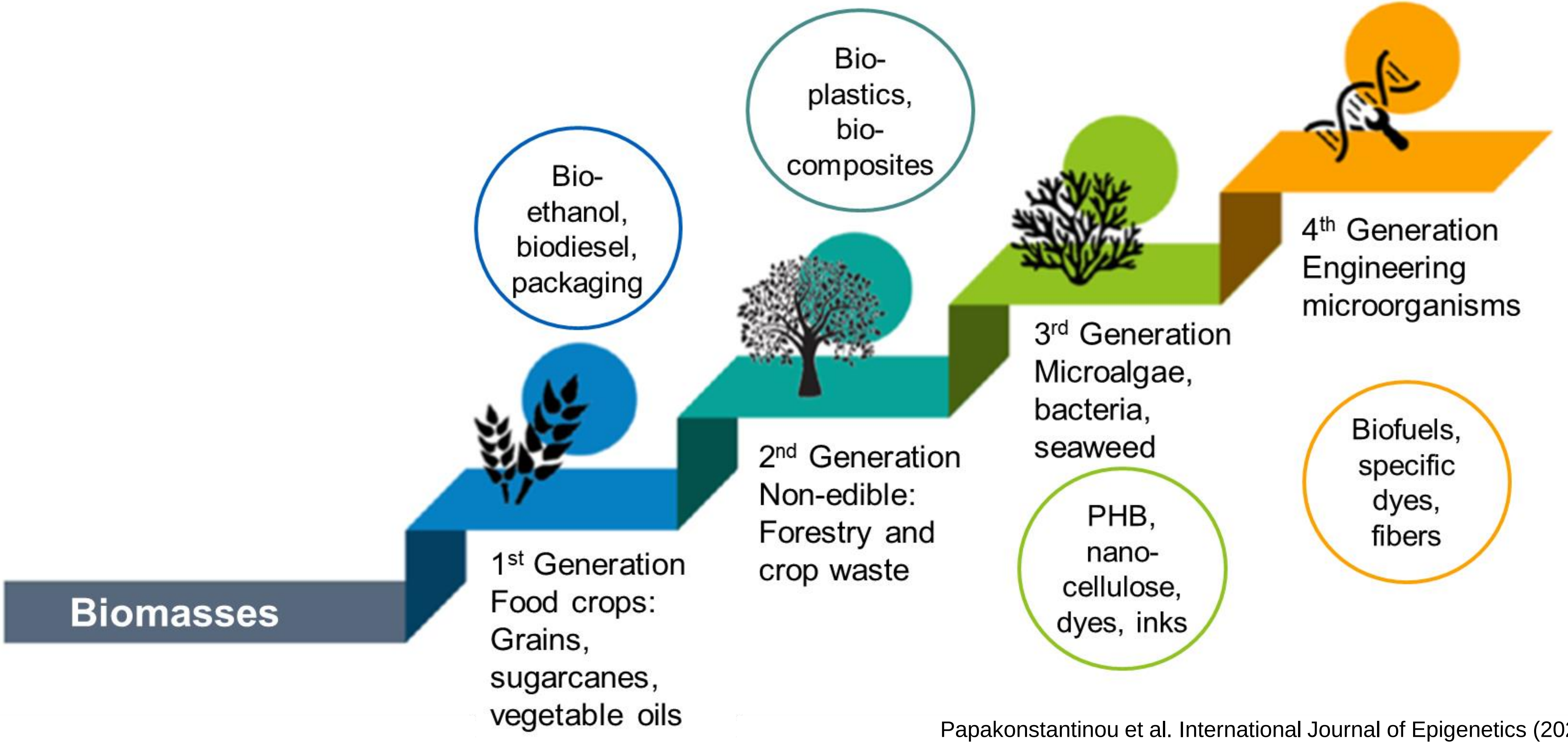
Biomaterials: A definition for this group work

Materials derived from renewable resources, such as plants, animals, or microorganisms, that are intended to have a reduced environment impact compared to traditional materials.

Uses: Packaging, textiles, construction, consumer goods, etc.

NOT INCLUDED are materials created to interact with biological systems for medical/therapeutic purposes or naturally occurring materials found within living organisms, such as bones, teeth, shells.

Biomaterials: 4 generations of feeds



Papakonstantinou et al. International Journal of Epigenetics (2021).

Biomaterials: Advantages

1. **Reduced Environmental Impact:** Replenished if derived from renewable resources
2. **Lower Carbon Footprint:** Plants used to produce bio-based materials absorb carbon dioxide from the atmosphere during their growth phase, making them "carbon neutral" or even "carbon negative" in some cases.
3. **Circular Economy:** If they are recyclable, they can be part of a closed-loop system without causing harm.
4. **Health and Safety Benefits:** Non-toxic bio-based materials with design applications, such as furniture, textiles, or packaging, can promote healthier living environments and reduce the exposure to potentially hazardous substances.
5. **Innovation and Market Opportunities:** The development and utilization of bio-based materials encourage innovation and opportunities for investment and development in this field.

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Examples of biomass-based material and design

Biomaterials for the future

Information sources:

1. Bio-based materials in architecture, design and interiors (↗)
2. How designers are taking up the challenge (↗)
3. Video links (↗)
4. ChemArts cookbook (↗)

Ideation for Biomaterials for the future

1. Hemp-based Sustainable Fashion Brand: Uses the eco-friendly properties of hemp, such as its durability, breathability, and low water usage. Ex: Patagonia Hemp jacket
2. Cork-based Sustainable Home Décor: Cork flooring, wall panels, furniture, and accessories made to showcase the unique texture and natural properties of cork, such as its sound insulation, thermal regulation, and renewable sourcing. Ex: Amorim
3. Mushroom Leather Sustainable Accessories: Explore the use of mycelium to create leather-like materials for accessories like bags, wallets, and phone cases. Ex: Mylo by Bolt Threads
4. Fruit Fiber Sustainable Textiles: Fruit fibers (pineapple leaves or orange peels) have natural strength, moisture-wicking properties, and biodegradability, and are waste materials from existing industry that can be used to make textiles. Ex: Piñatex by Ananas Amam

Biomaterials emerging from the design world: Nanocellulose

BioFaber

Aqueous culture enriched with sugars from food waste such as molasses and olive residues are used by the microorganisms to synthesize the nanostructured cellulose. [Link]

ModernSynthesis

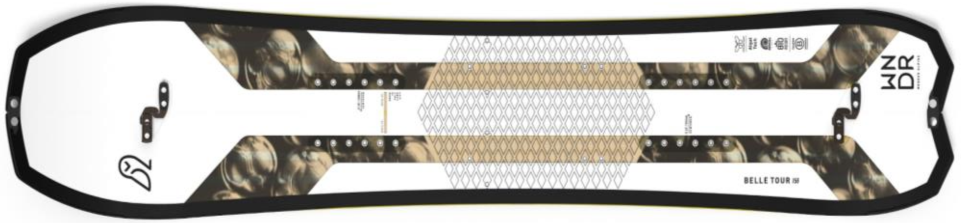
Microbial nanocellulose blended with natural textiles. [Link]

Biomaterials emerging from the design world: Algae-based

We design new molecules for better materials

Checkerspot WING

Algae-based polyurethane for oils for skis [Link]



FlexSea

Seaweed based packaging material [Link]

Biomaterials emerging from the design world: Direct air capture and microbial digestion

PANGAIA x AIR-INK®

Captures air pollution particles that are turned into different grades of safe, water-based inks, dispersions and coatings. [Link]

NEWLIGHT

Uses natural ocean microorganisms to make PHB (polymer) from air and greenhouse gas and call it AirCarbon. [Link]

Biomaterials emerging from the design world: From waste

RENEWCELL

Circulose® is a branded dissolving pulp that Renewcell makes from 100% textile waste with high cellulose content [Link]

Eggshell

Waste eggshells mixed with binders and water to create resins for biodegradable disposable cutlery [Link]

Conceptual design case around the sustainability aspects of Biomaterials

Design Concept: Biomaterial Lifestyle Store

Description: Promote sustainable living through the use of bamboo in products, educating customers about its environmental benefits, and provide resources for a sustainable lifestyle

Key Features and Services: Product collection, education, workshop/demonstration, resources, plant sales

Benefits and Outcomes: Sustainable material adoption, Community engagement, Environmental impact, Market development

Service Concept: Biomass-Based Sustainable Packaging Consultancy

Description: Consultancy services in the packaging industry, focusing on sustainably sourced biomass-based materials for packaging solutions

Key Features and Services: Sustainability assessment, biomass sourcing and material selection, design and optimization, supply chain integration, regulatory compliance and certifications, education and training, continuous improvement and monitoring

Understanding sustainability…

Biomass ≠ Sustainable (Dig deeper)

- **DO NOT correlate biobased & ‘green’/ ‘environmentally friendly/ benign/ bio-degradable**
- Examples:
  - ❑ Fossil-based biodegradable materials: Bioplastics (PLA, PHA), lubricants for Agri-machinery, LAS surfactants
  - ❑ Bio-based non-biodegradable materials: bio-PE and bio-PET, Treated wood, Biofibers with synthetic blends
- **REMEMBER!** No solution fits all *[places, people, situations, requirements]*

Questions for checking claims

- How to reach large-scale with these materials?
- Early-stage lifecycle assessments available for new technologies?
- Social impacts of altering supply chains: Known? Unknown?
- Impacts of the grown materials (algae, bacteria, hemp) on ecological balance?
- **Before bio-degradation, can it be reused?**

Checklist for sustainability of biomaterials

1. **Land Use and Competition:** Expansion of biomass crops or harvesting practices can result in land-use changes.
2. **Resource Intensity:** Resource requirements like water, energy, and fertilizers.
3. **Lifecycle Assessment:** Greenhouse gas emissions, energy consumption, water usage, and waste generation associated with the entire lifecycle, including cultivation, processing, transportation, use, and disposal should be assessed.
4. **Feedstock Availability and Sustainability:** Regional variation of biomass feedstocks [sustainably sourced wood]
5. **Chemical and Biological Interactions:** Biomass conversion to materials often involves the use of chemicals, solvents, or enzymes, so proper waste management and disposal practices are needed
6. **Market Demand and Infrastructure:** Expanding the use of biomass-based materials requires supportive market demand, investment in research and development, and appropriate infrastructure.

Questions?

Biomaterials: 4 generations of feeds

1. **First Generation Biomass-Based Materials:** Derived from edible crops, such as corn, wheat, sugarcane, and soybeans. Used in food and feed applications. Ex: bioethanol produced from corn, vegetable oils for cooking or biodiesel production, and starch-based packaging materials.
2. **Second Generation Biomass-Based Materials:** Derived from non-edible or waste biomass, such as agricultural residues (e.g., straw, husks), forestry residues (e.g., sawdust, wood chips), or dedicated energy crops (e.g., switchgrass, miscanthus). Ex: Cellulosic ethanol, bio-based polymers, and bio-based composites.
3. **Third Generation Biomass-Based Materials:** Derived from microorganisms, algae, or other non-plant-based sources and use photosynthetic microorganisms to produce bio-based products. Ex: PHB (bioplastics) from algae, nanocellulose from microbial fermentation.
4. **Fourth Generation Biomass-Based Materials:** Emerging materials based on synthetic biology, genetic engineering, and nanotechnology. Ex: Engineered microorganisms for targeted biofuel production, microbial dyes