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Cell and Tissue Engineering

Types of Biomaterials

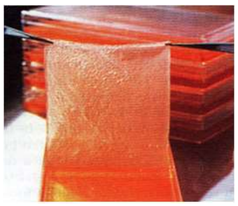
Types of Biomaterials

Natural or biological materials

ECM and cells

Synthetic materials

metals, ceramics, composites and synthetic polymers



Collagen skin substitute

Finger joint

Intraocular lens

Heart valve

Hip joint

http://www.kokenmpc.co.jp; http://www.uweb.engr.washington.edu/research/tutorials/introbiomat.html

Ok so we've got biomaterial properties under our belts. Let's shift gears and talk about some types of biomaterials.

Biomaterials are divided into two categories – **natural** or biological materials like **collaged – this has been** used in skin grafts -- and **synthetic** materials – like metal found in this hip joint.

Here are some other common medical devices which use biomaterials – including a finger joint, ocular lens, and heart valve.

Natural or Biological Materials – ECM and Cells (1)

Proteins

- Collagen
- Fibrin
- Silk

Polysaccharides

- Agarose
- Alginate
- Hyaluronic Acid
- Chitosan

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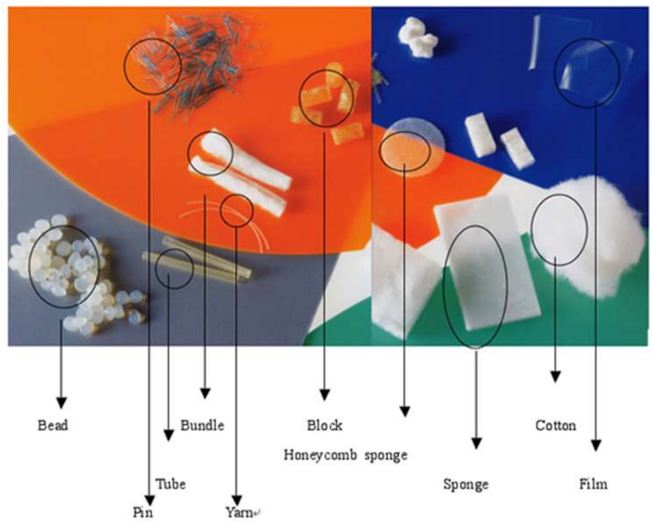
The advantage to natural biomaterial is that they mostly come from an in vivo source – this translates to low price and fairly consistent availability.

Natural biomaterial are typically broken down into two subcategories – **proteins** and **polysaccharides**. READ THE LISTs

Natural or Biological Materials – Collagen

Proteins
- Collagen
- Fibrin
- Silk



RGD: arginine - glycine – aspartic acid

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http://www.tankonyvtar.hu/en/tartalom/tamop425/0011_1A_3D_en_book/ch01s04.html

Under the protein subcategory you see collagen – this is the most frequently used and studied biomaterial.

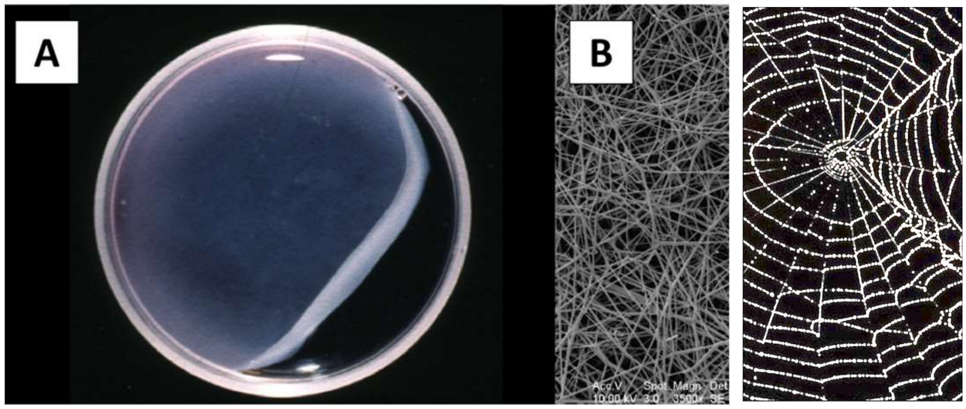
It is accessible from the connective tissues of animals – bovine, porcine, and murine being the most common sources.

One of the great features of collagen is that it has superior biocompatibility – it is a highly conserved protein across species, a patient will easily accept collagen from another source without immune issues.

Additionally it supports the adhesion and growth of many cell types – utilizing the integrin binding RGD sequence – and can be molded into many forms as shown in this image. These include Beads, sponges, films etc.

Natural or Biological Materials – Fibrinogen, silk

Proteins
- Collagen
- Fibrin
- Silk



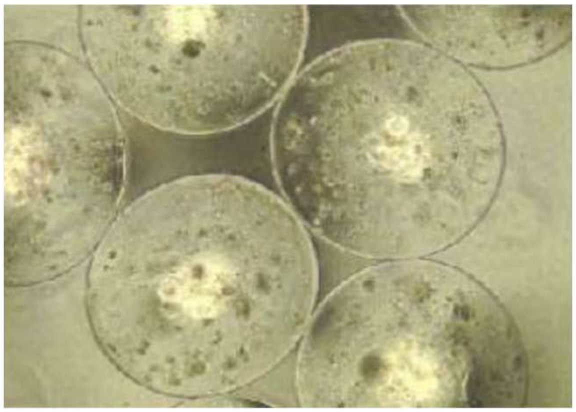
Bbc.co.uj; http://www.tankonyvtar.hu/en/tartalom/tamop425/0011_1A_3D_en_book/ch01s04.html

Fibrinogen is a soluble protein obtained from human plasma – and upon cleavage with **thrombin** will form fibrin forms solid gels – think of **clot** formation!

A benefit of this material is that you can polymerize it when cells are present, ensuring that you get cells throughout the thickness of the scaffold.

Silk we all know comes form arthropods – or spider.

Natural or Biological Materials – Agarose, Alginate



Polysaccharides
- Agarose
- Alginate
- Hyaluronic Acid
- Chitosan

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Bbc.co.uj; http://www.biomaterials.org/week/bio21.cfm; http://www.tankonyvtar.hu/en/tartalom/tamop425/0011_1A_3D_en_book/ch01s04.html

In the other subcategory we have **polysaccharides** – **sugar** polymers

These are commonly used in hydrogels and come from both plant and animal origin.

For example – **agarose** is commonly harvested from **algae** and seaweed. This material is immunologically **inert** and can be tailored to meet the **mechanical** needs of the tissue at hand. It is currently used in scaffolds for cartilage, heart, and nervous tissues.

Alginate is from the cell wall of brown algae – also biologically **inert --** this material is often used to encapsulate cells to <u>hide</u> them from the body and reduce rejection by the host.

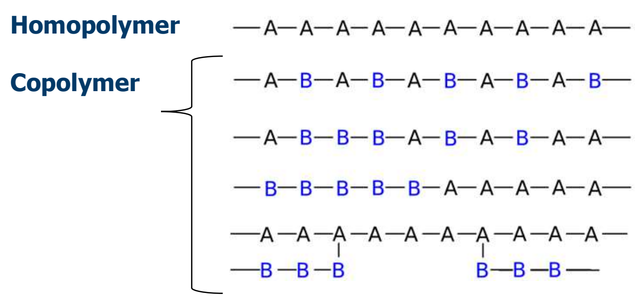
This has proven to be a successful strategy for transplanted pancreatic islet cells. This image shows you alginate microspheres encapsulating mammalian cells.

Synthetic Materials – Polymers

metals, ceramics, composites and synthetic polymers

Organic Polymers
- PGS, PLA, PLGA
- PEG
- Peptides

Inorganic
- Ceramic
- Metal
- Hydroxyapatite



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Choi et al 2012; Wikipedia.org

The second type of biomaterial is **synthetics**.

The main advantage here is that they are highly **reproducible** and available **on demand**. This translates to a material that is high quality and plentiful for industrial production needs.

With synthetic materials the engineer can easily **tailor** properties – be that **mechanical** properties, **degradation** rates, and **shape** to fit the cause. One aspect that typically must be tailored in are **cell adhesion** sites.

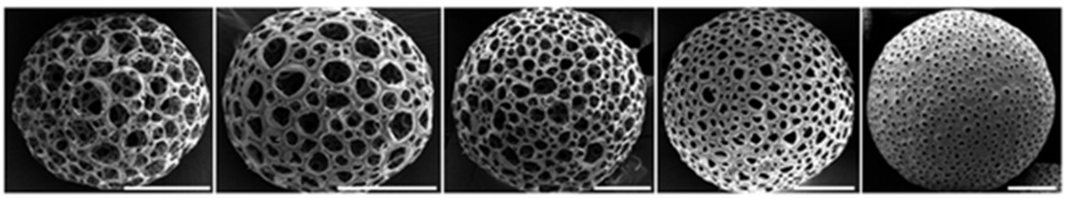
<u>Polymers</u> are are long chains of repeating units – if the repeating unit is the same it is a **homo-polymer** -- and if there are different units present then it is a **copolymer**. Copolymers can be arranged in different way as shown here **alternating**, in **blocks** or **branched**.

You'll read about polymer synthesis and degradation in the text this week.

Synthetic Materials – Organic Polymers

Organic Polymers

- PGS, PLA, PLGA
- PEG
- Peptides



Choi et al 2012

IN the **organic** subcategory – we begin with PLGA or poly lactic co glycolic acid.

This is a copolymer including monomers of both glycolic and lactic acid that is commonly used in resorbable sutures.

This is an FDA approved material that's inert, supportive of cell growth, and degradable. However, the degradation products are acidic and must be taken into account. At the bottom of this slide you can see porous beads made of PLGA.

Porosity is one way to tailor a biomaterial for our application – this is what we'll be discussing in next section of this lecture.

PEG -- Poly ethylene glycol -- we heard about earlier in this lecture as being **protein resistant**. IT can be chemically modified however to enable specific protein interactions - for example **functionalization** with **heparin** will encourage interaction with **heparin-binding** growth factors. It is used not only for cell encapsulation, but also drug and molecule encapsulation and is heavily used in the pharmaceutical industry.

Peptides-based materials use short amino acid sequences which can be combined with other synthetic materials or with natural scaffolds. Common peptides include binding sequence from the ECM – for example the **RGD** sequence in collagen we saw earlier.

Synthetic Materials – Inorganic Polymers

Inorganic
- Ceramic
- Metal
- Hydroxyapatite

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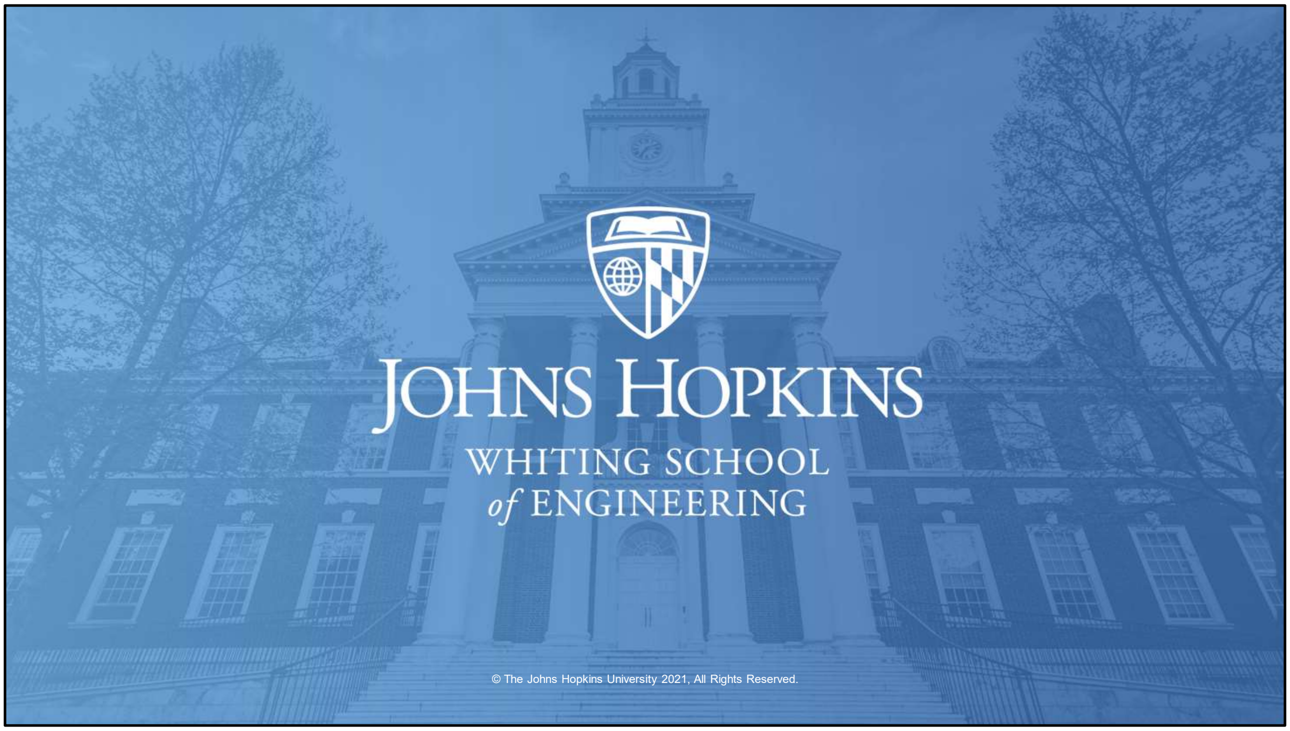
Choi et al 2012

On the inorganic side we have things like ceramics, metals and hydroxyapatite

Ceramics are almost exclusively used in bone tissue engineering. The work not just as the tissue replacement but also as fastener – here you can see some examples of bone screws which can be ceramic or metal.

Metals typically used in tissue engineering are **titanium** and **aluminum** alloys. These are **biocompatible** metals that are durable. These are in use clinically in prosthetics, dental implants, and heart valves. The flipside of being durable is, of course, that they are not **biodegradable** which means they can have **long term** effects on the body.

Hydroxyapatite is the inorganic calcium phosphate phase of bone – it is typically combined with polymers like PLGA or collagen to enhance bone formation.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