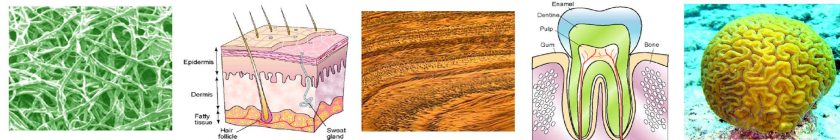


Resources to Support Bio-engineering and Biological Materials Education

L. Brown and A. G. Pereira-Medrano
Granta Design Ltd, Cambridge, United Kingdom



Background

At present, the potential contribution of Engineering and Materials Sciences to the Bio-sciences are of particular interest. These contributions can be on new experimental techniques, simulation methods of the physical sciences that contribute to bio-engineering, and development of new procedures and more effective treatments for the health industry, while nature can suggest ways to make new materials to engineers and material scientists.

A bio-materials database aimed at engineering students should aim to:

- Capture the mechanical and thermal properties of biological materials (i.e. stiffness, strength, elasticity, resilience, toughness and thermal protection)
- Allow comparison of these with the equivalent properties of biomaterials and other materials.

Description of Databases


The CES EduPack Bioengineering (Level 1&2, Level 3) databases contain records of natural and bio-materials (man-made materials designed to replace natural materials). Rather than storing many records for each variant, representative data are presented, usually as a single record. These databases enable:

- Retrieval and comparison of properties of natural and man-made biomaterials, in a consistent framework
- The construction of material property charts for natural materials
- Exploration of basic structural building blocks (minerals, polysaccharides and proteins) that give the great diversity found in bio-materials
- Substitution studies exploring the potential for one to substitute for another, suggesting where manmade Materials might best be used for implants and organ replacement
- Bio-mimicry: designing man-made composites and structures that mimic those of the natural world

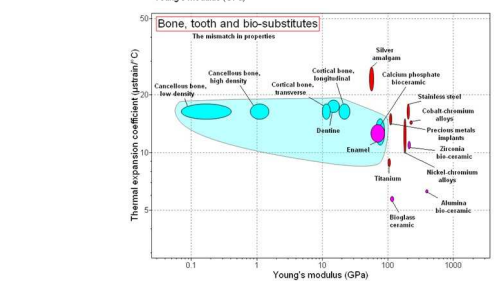
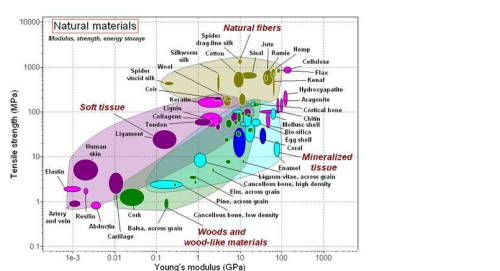
GRANTA CES 2012 EDUPACK

Introductory Teaching Level 1&2

It contains 85 natural materials and bio-materials records and for 94 standard metals, polymers, ceramics and composites of engineering.

Description		General properties	
The material		Density	1.960 - 2.0640 g/cm ³
Bone, the principal structural material of the animal kingdom, is a composite of the organic hydroxyapatite and the collagen skeleton. It performs a number of functions, among them that of carrying the weight loads of the body. The bones of the skull and ribs generally take the form of an architectural shell or tubes with an outer layer of dense, cortical or compact bone surrounding a foam-like structure of cancellous (trabecular or spongy) bone.		Young's modulus	18 - 26 GPa
Composition (summary)		Yield strength (average limit)	60 - 144 MPa
Hydroxyapatite - collagen composite (see the records for both of these).		Tensile strength	136 - 197 MPa
Image		Elongation	0.5 - 1.4 % strain
		Hardness - Vickers	20 - 80 HV
		Fracture strength at 107 cycles	21 - 80 MPa
		Fracture toughness	3.5 - 6.1 MPa.m ^{0.5}
Thermal properties		Electrical properties	
Maximum service temperature		Electrical conductor or insulator?	
Thermal conductor or insulator?		Thermal conductivity	
Thermal conductivity		Specific heat capacity	
Specific heat capacity		Thermal expansion coefficient	
Thermal expansion coefficient		Optical properties	
Electrical conductivity		Transparency	
Thermal conductivity		Floor insulator	
Specific heat capacity		Thermocouple	
Thermal expansion coefficient			

Caption: Cortical (dense) and cancellous (spongy) bone. The data in this record refer to cortical bone.



Advanced Teaching Level 3 (under development)

The development of level 3 has been driven by the need to provide a bridge between the basic information of levels 1 & 2 and the detailed data provided by the medical reference database that are available.

As a result, some detailed information from the Medical Materials and the Human Biological Materials (HBM) databases is incorporated into this new bioengineering module.

The focus is on increasing the number of materials that are being used in bioengineering applications and the materials that they interact within the human body.

The database contains > 1500 records biomaterials, metals, polymers, ceramics and composites of engineering.

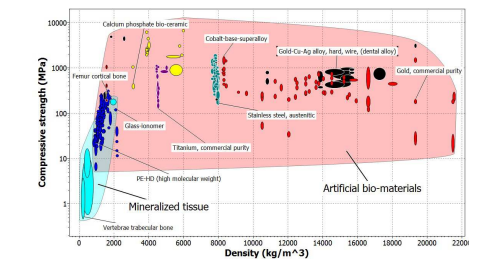
Identification
The femur (upper bone) is the longer and stouter bone in the human body. Cortical (or compact) bone is the outer layer of bone that is dense and contains the majority of the bone's mass. It is composed of collagen fibers and mineral salts. The inner layer is cancellous (or spongy) bone, which is lighter and contains a network of trabeculae.

Mechanical properties
Density: 19.3 - 19.4 g/cm³
Young's modulus: 18 - 26 GPa
Yield strength: 60 - 144 MPa
Tensile strength: 136 - 197 MPa
Elongation: 0.5 - 1.4 % strain
Hardness - Vickers: 20 - 80 HV
Fracture strength at 107 cycles: 21 - 80 MPa
Fracture toughness: 3.5 - 6.1 MPa.m^{0.5}

Thermal properties
Maximum service temperature: 127 - 227 °C
Thermal conductor or insulator?: Floor insulator
Thermal conductivity: 0.41 - 0.53 W/m.K
Specific heat capacity: 1.343 - 1.3640 J/kg.K
Thermal expansion coefficient: 15 - 18 ppm/K

Electrical properties
Electrical conductor or insulator?: Floor insulator

Optical properties
Transparency: Translucent



Future Developments

The **bioengineering level 3 database** is currently within development and will aim to combine the introductory information presented within the EduPack software with a selection of data from the more advanced Granta medical databases.

Both the Medical Materials and the Human Biological Materials databases will provide bio-engineering specific information aimed at final year undergraduate and postgraduate taught students. It includes a selection of biomaterials used in bio-engineering applications and a greater range of human bone data, enabling comparisons between the two.

The **Human Biological Materials database** is undergoing development with the aim to provide a comprehensive data source. The number of materials is increased, the quality of the data presented is enhanced and made as relevant as possible for researchers. Users should be able to identify specific information related to their research area, which can then be easily extracted for further analysis and the original source material can be accessed for greater detail.

Interested? If you are interested in potentially using these developments, please contact: Dr. Ana Pereira - ana.pereira@grantadesign.com

GRANTAMI MATERIAL INTELLIGENCE

Advanced Teaching and Research Human Biological Materials (HBM)

The HBM database provides a single location of mechanical property data related to the human body, which is fully referenced to the original source material.

The database focuses on the properties of the skeletal tissues and presents information from the cortical and trabecular structures of the different bones, such as the femur, humerus and vertebrae.

Where possible, dependencies such as age are presented in graphical form, enabling the user to visually see how different properties are affected.

The database is primarily a reference resource that enables users to quickly extract the relevant information from for further analysis and fully supports Finite Element Analysis (FEA).

General properties

Density	1700 to 2100 g/cm ³
Analyzed data values	10
Analysis with age	View Graph
Bone mineral density (BMD), volumetric	0.030 to 0.47 g/cm ³
Analyzed data values	1
Bone mineral density (BMD), volumetric with age	View Graph

Compressive modulus

Analyzed data values	0.51 to 3.0 GPa
Compressive modulus with age	Hide Graph

Compressive strength with age

Tibia cortical bone	Mean
Tibia cortical bone	Burstein et al. 1979
Femur cortical bone	Mean
Femur cortical bone	Reid et al. 1974
Femur trabecular bone	Mean
Femur trabecular bone	Matterns et al. 1983 - Femoral neck
Tibia trabecular bone	Mean
Tibia trabecular bone	Ding et al. 1997 - Tibia
Vertebrae trabecular bone	Mean
Vertebrae trabecular bone	Tanaka 1975 - Lumbar vertebrae