Oct. 6, 2021

Bio-integrated Materials Science (Online Lectures)

Overview of the Lecture
Lecture 1-1

Prof. Jung Heon Lee

Course objectives

- To provide basic knowledge of bio-integrated materials to the students in the College of Biological and Agricultural Engineering at Jilin University.

- To give an overview of recent contribution of science and engineering in biological systems and medicine with emphasis on materials.

- To provide broader scope in the bio-materials field.

Grading scheme

Attendance (20%)

+

Homework (50%)

+

Final Exam (30%)

*Grades will initially be offered as A, B, C, D, etc, and will later be converted to official grades of Jilin University.

Contact Information

Prof. Jung Heon Lee (李政憲/李政宪)
(Email: jhlee7@skku.edu)

- Associate Professor, Adv. Mater. Sci. & Eng., Sungkyunkwan University (2012 ~ Present)
- Postdoctoral Researcher, Northwestern University
- Ph.D: Materials Science & Engineering, UIUC (Major: nanobiotechnology, biomaterials)
- M.S: Materials Science & Engineering, SNU (Major: electronic materials)
- B.S: Materials Science & Engineering, Yonsei University

Research topics
- Bioinspired materials
- Nanobiotechnology
- Surface/interface of materials
- Biomedical and environmental sensors
- Cell & tissue engineering
- Computer assisted nanomaterial synthesis and analysis

https://www.bionanomaterials.org

Biological & Nanoscale Materials Lab
Advanced Materials Science & Engineering
Sungkyunkwan University (SKKU)

Home | Research | Group | Publications | Teaching | Gallery | News

Welcome!

The research interest of our laboratory lies at the interface between Materials Science, Biology, Chemistry, and Nanotechnology. We are developing nanoscale materials or devices which can be applied to diverse levels of biological systems for diagnostics or therapeutics. We are also investigating opportunities to adapt programmable and readily modifiable properties of biomolecules in the fabrication of smart materials or advanced nanoscale devices.

Biological & Nanoscale Materials Lab., School of Advanced Materials Science & Engineering,
Sungkyunkwan University (SKKU), Suwon 16419, Korea

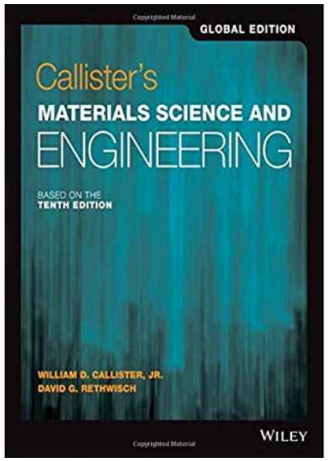
Lecture schedule, Zoom links

No.	Dates / Time (CST)	Contents
1	Oct. 6 (Wed), 1:00-3:00 PM	Bio-integrated materials science introduction, Atomic bonding
	Zoom Link: https://us02web.zoom.us/j/88596826357?pwd=UjRaOUpjK3M4Mm9Qb0F0TnhUcHZRZz09 Zoom ID: 885 9682 6357 / Password: Ju1234	
2	Oct. 8 (Fri), 1:00-3:00 PM	Metals and ceramics
	https://us02web.zoom.us/j/87578671156?pwd=R3VrMnl0YzBzdHBHNzJpNDgyWnp1QT09 ID: 875 7867 1156 / Password: Ju1234	
3	Oct. 11 (Mon), 9:00-11:00 AM	Crystal systems of materials, polymers
	https://us02web.zoom.us/j/89791357693?pwd=TWZHRFUyeDE3RVZubVFJNllUSXZUQT09 ID: 897 9135 7693 / Password: Ju1234	
4	Oct. 13 (Wed), 1:00-3:00 PM	Properties of materials
	https://us02web.zoom.us/j/84747461023?pwd=eTRNa0pWanhYMnk1NzJXUXphNlc0dz09 ID: 847 4746 1023 / Password: Ju1234	
5	Oct. 15 (Fri), 1:00-3:00 PM	Biomolecules
	https://us02web.zoom.us/j/82064688452?pwd=N0VwWGE0cGlvYW5zOXF3VGpMYVdMQT09 ID: 820 6468 8452 / Password: Ju1234	

Lecture schedule, Zoom links

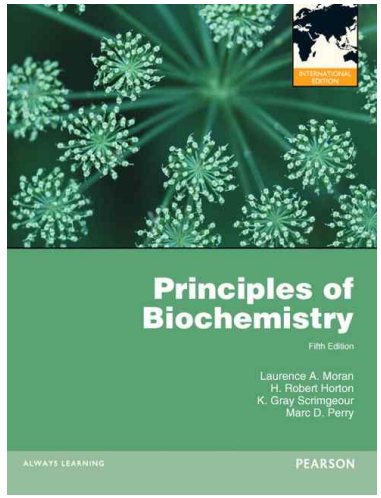
No.	Dates / Time (CST)	Contents
6	Oct. 20 (Wed), 1:00-3:00 PM	Nanobiotechnology
	https://us02web.zoom.us/j/85427623138?pwd=OEx6WlNnelhjWGM1b05BVTZZZU1MUT09 ID: 854 2762 3138 / Password: Ju1234	
7	Oct. 22 (Fri), 1:00-3:00 PM	Nanomaterials for biological applications
	https://us02web.zoom.us/j/87939423128?pwd=RTdKR2tVR3dBYmxNYVRsOWdya085dz09 ID: 879 3942 3128 / Password: Ju1234	
8	Oct. 27 (Wed), 9:00-11:00 AM	Materials for tissue engineering
	https://us02web.zoom.us/j/85930829727?pwd=WU44MFhPOWtrSHl4aXJvWmxqM0VaZz09 ID: 859 3082 9727 / Password: Ju1234	
9	Oct. 29 (Fri), 1:00-3:00 PM	Biomimetic materials
	https://us02web.zoom.us/j/86081299354?pwd=QVpnMWorNDB3SU1ZT3dWVFZuY0JqUT09 ID: 860 8129 9354 / Password: Ju1234	
10	Nov. 1 (Mon), 9:00-11:00 AM	Q & A section
		Final Exam
	https://us02web.zoom.us/j/85929873448?pwd=bkFKL1Z1eG9mZEpOWTBHWEZLNjJJUT09 ID: 859 2987 3448 / Password: Ju1234	

Reference books



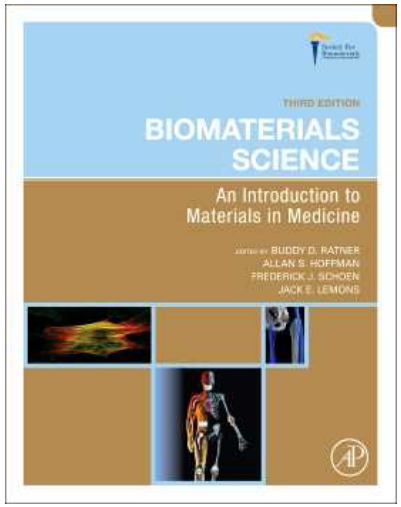
Callister's Materials Science and Engineering (10th ed.)

Authors: William D. Callister Jr., David G. Rethwisch
ISBN: 978-1-119-45520-2

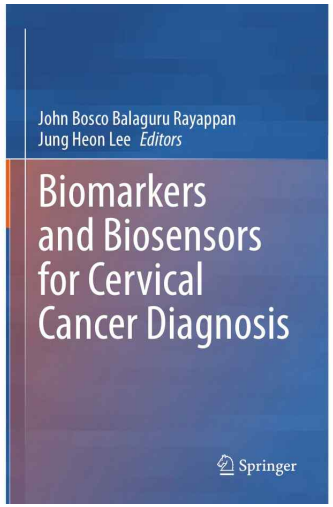


Principles of Biochemistry (5th ed.)

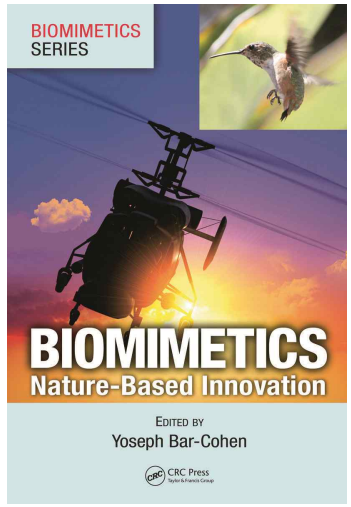
Authors: Morgan *et al.*
Pearson
ISBN: 9780321795793



Biomaterials Science (3rd Ed.)
An Introduction to Materials in Medicine
Authors: B. D. Ratner *et al.*
2012 Academic Press
ISBN: 9780123746269

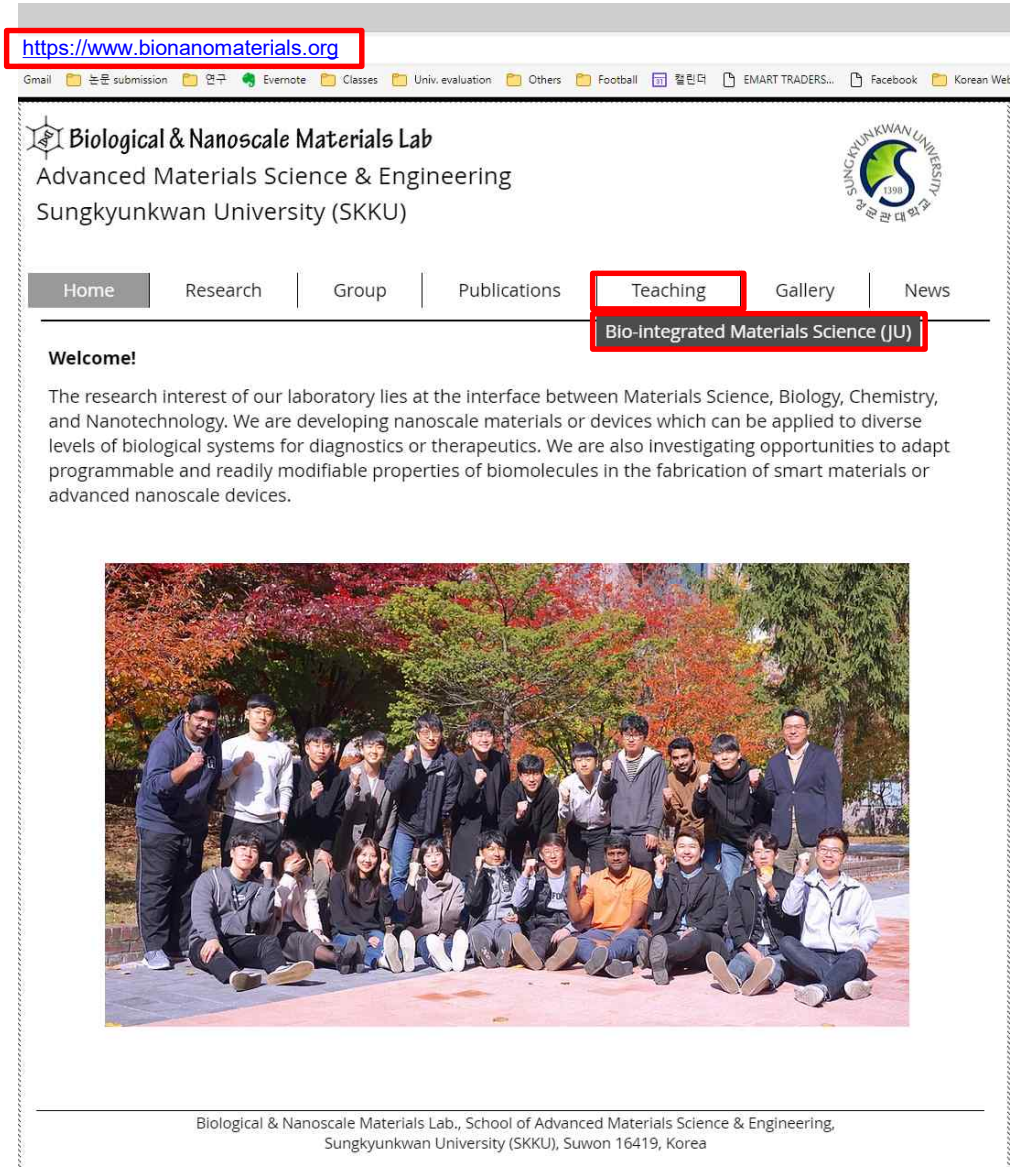


Biomarkers & Biosensors for Cervical Cancer Diagnosis
Authors: Rayappan & Lee
2021, Springer



Biomimetics
Nature-Based Innovation
Authors: Bar-Cohen
2012, CRC Press

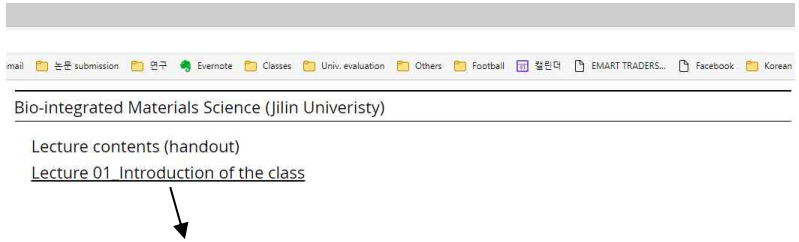
Handouts for the lecture



https://www.bionanomaterials.org

Teaching → Bio-integrated Materials Science

Password: Ju1234



Handouts for the class can be downloaded

Questions

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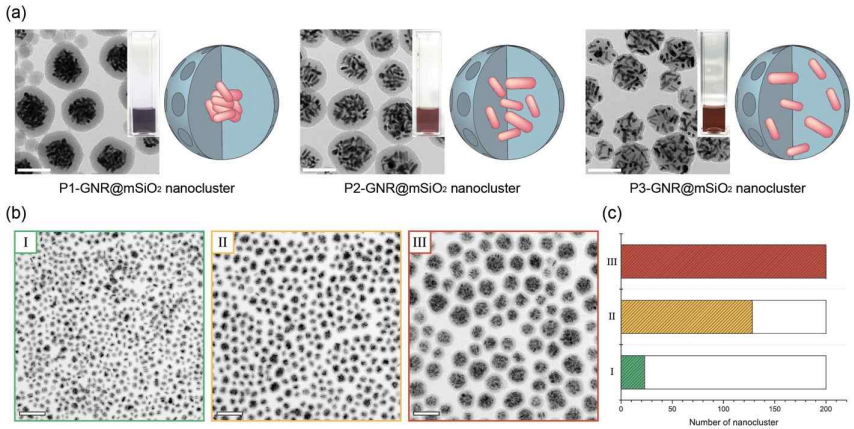
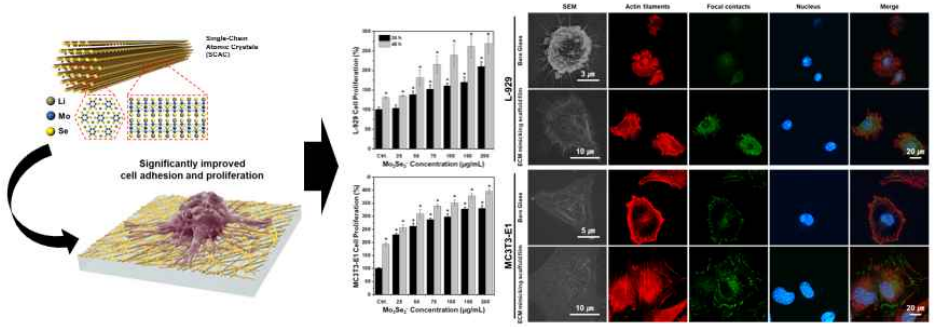
Research in bnml at SKKU

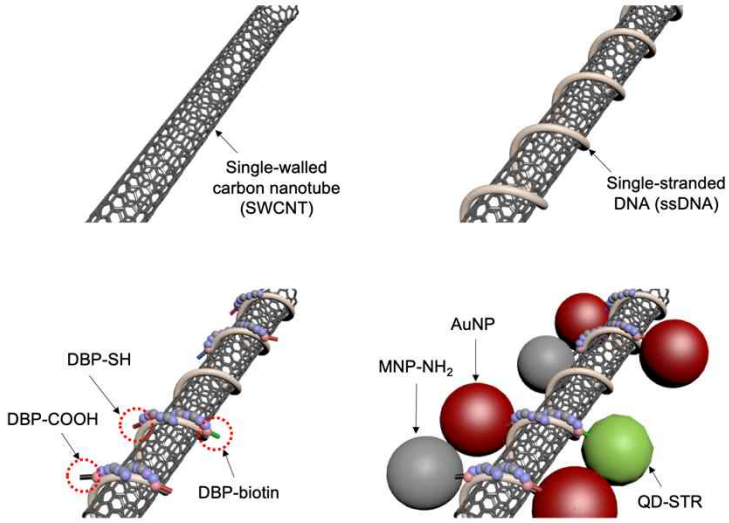
Part 1. Nanomaterials for Biomedical Diagnosis & Treatment



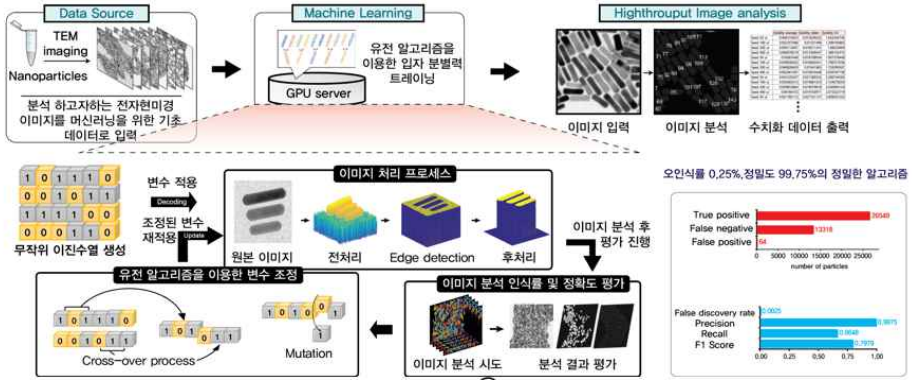
Part 2. Materials for Tissue Engineering



Part 3. Biomimetic Materials



Part 4. AI based Material Design & Characterization



SUNG KYUN KWAN UNIVERSITY

(SKKU)

Overview

History

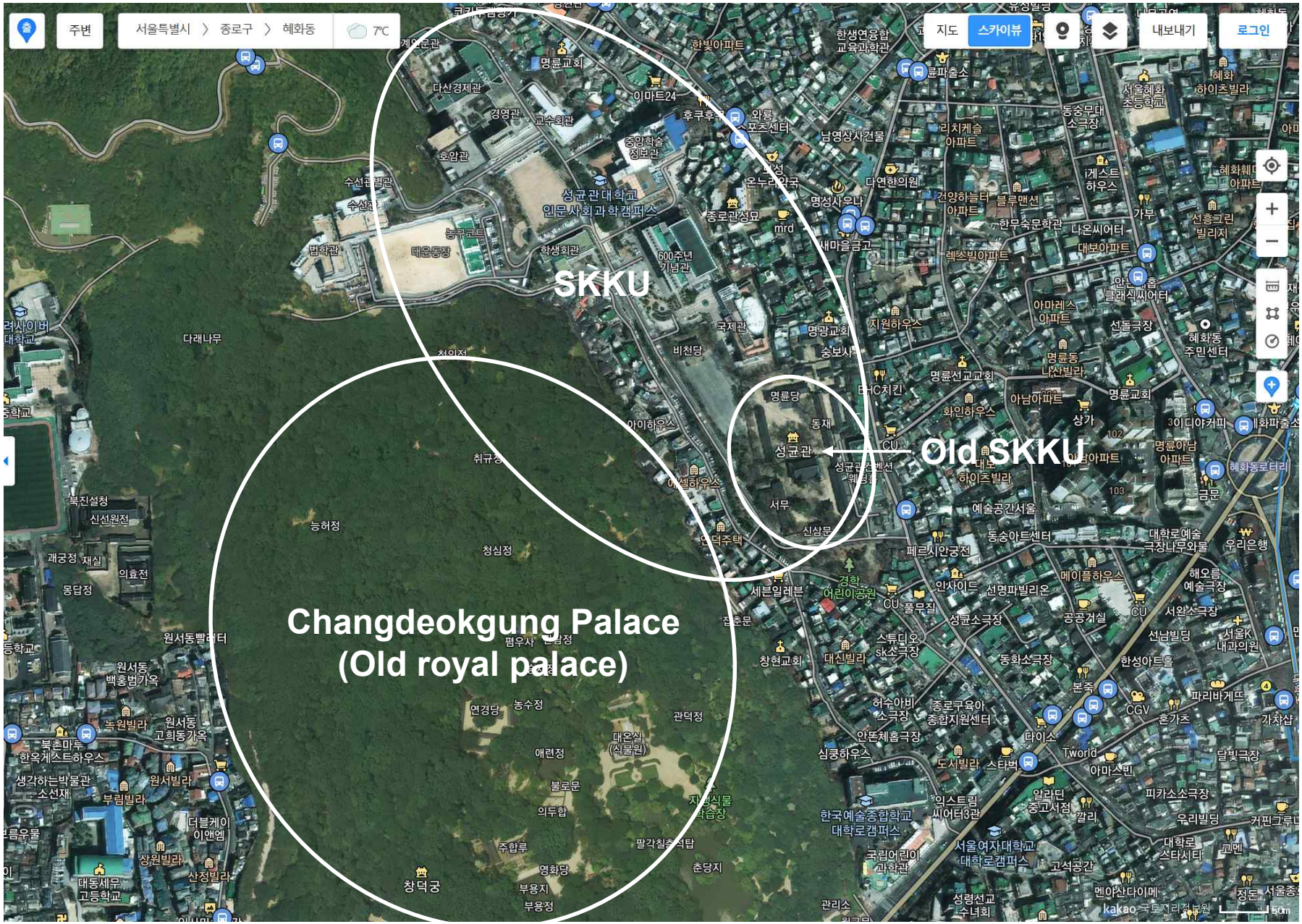
Venerable Heritage

- Sungkyunkwan was founded in 1398 as a royal Confucian academy
- Jongyeonggak, the first library, established in 1475
- Became modern university in 1895

Modern Advancements

- Became comprehensive university 1953
- Natural Sciences campus opened in 1978
- Partnered with Samsung since 1996

SKKU Seoul Campus



Overview

Historic Legacy

Yi Hwang (이황,李滉)
1501 – 1570

- President
- Alumnus
- Confucian Scholar
- Statesman

Yi I (이이, 李珥)
1536 – 1584

- Alumnus
- Confucian Scholar
- Statesman
- Philosopher

(세종대왕, 世宗大王)
King Sejong
1397 – 1450

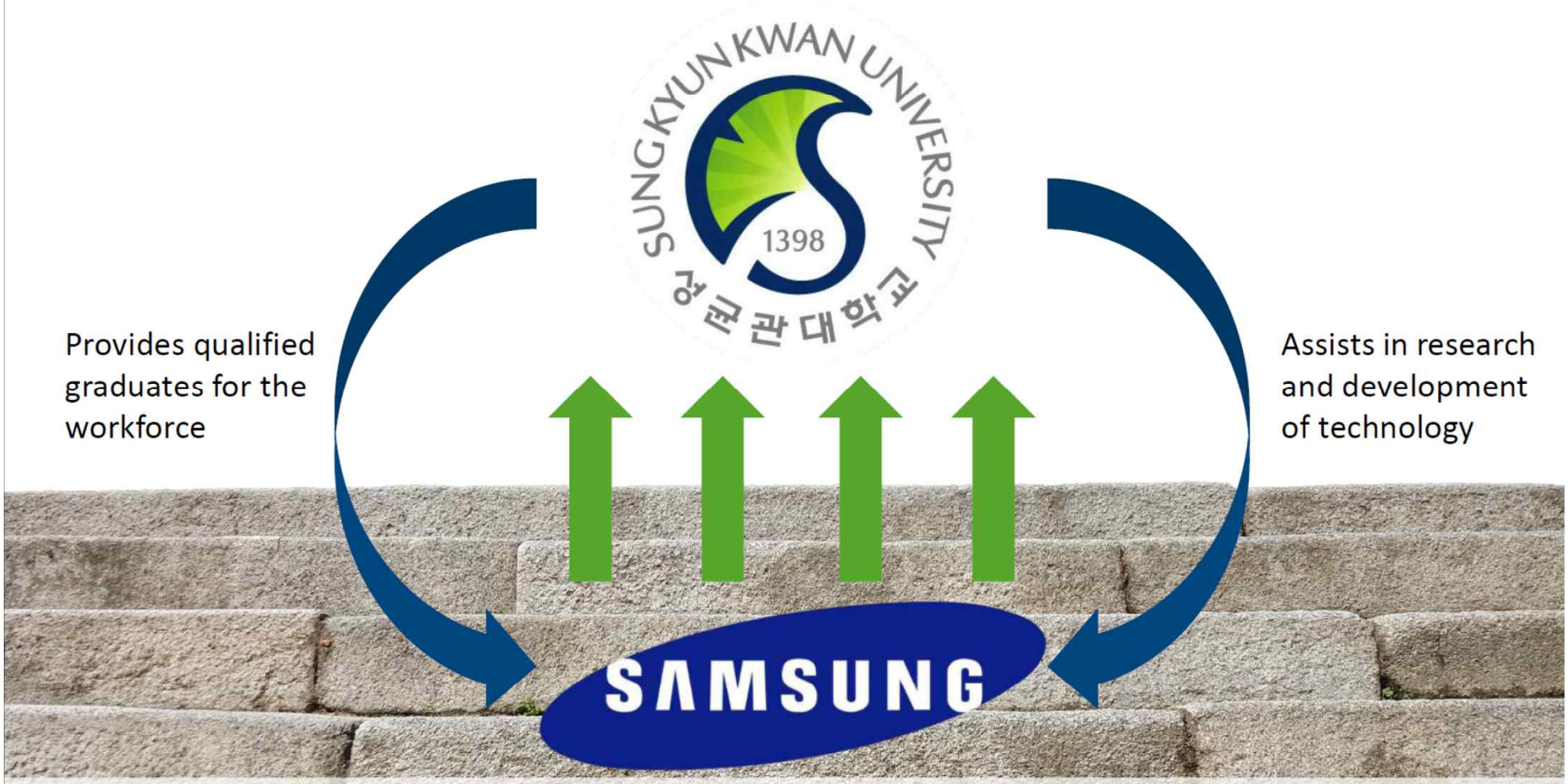
- Chairman of Board of Trustees
- Invented Korean Alphabet (Hangul)

Shin Saimdang (사임당 신씨, 師任堂申氏)
1504 – 1551

- Yi I's Mother
- Artist
- Calligraphist
- Poet

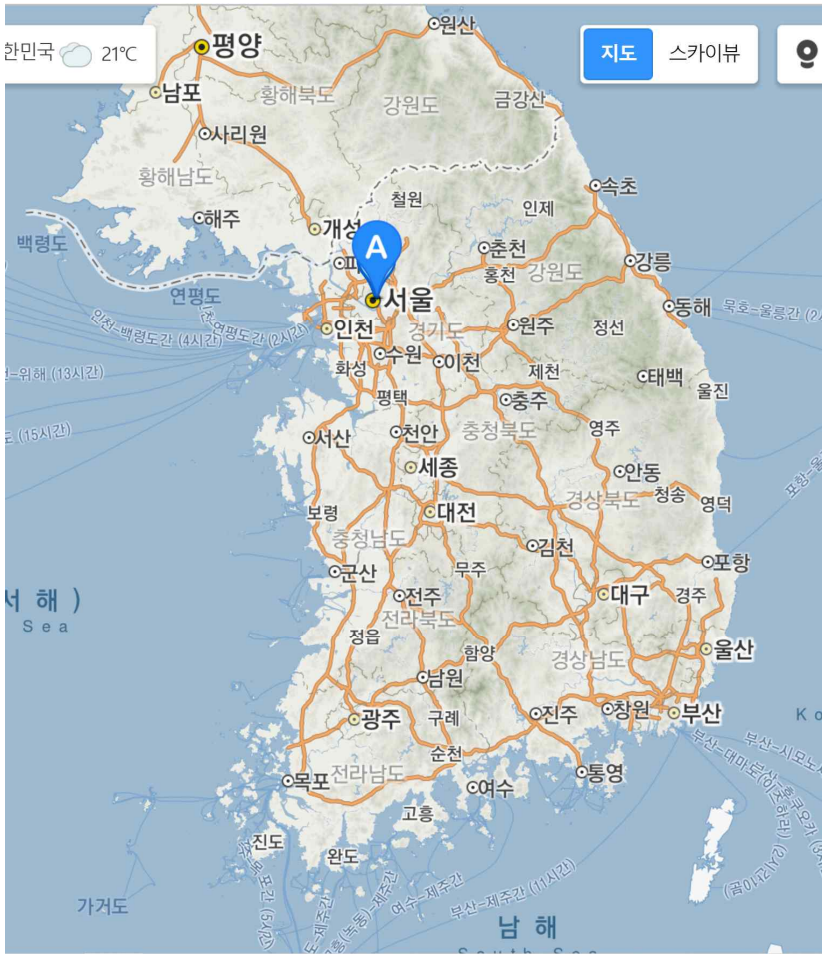
Overview

Samsung Foundation

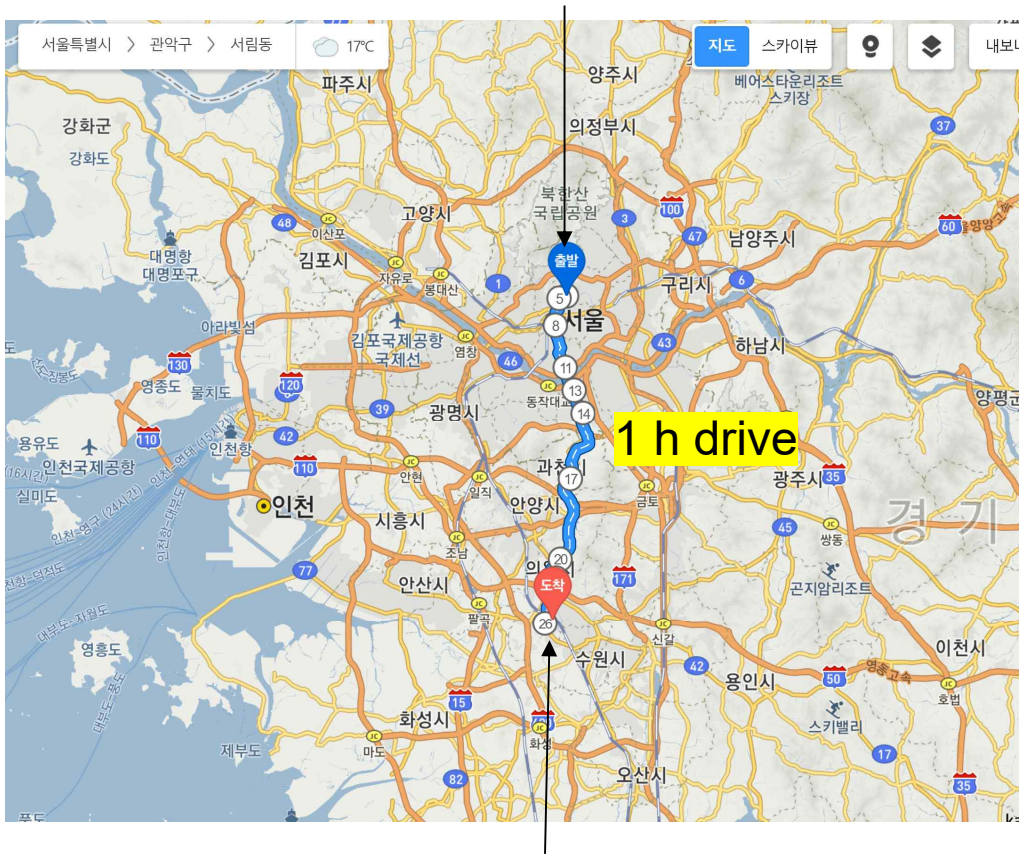


- Funds scholastic and research programs
- Invested in construction of new facilities
- Provides expertise through guest lecturers
- SKKU and Samsung manage 110 joint research projects with $10.7 million in annual funding

SKKU, Seoul Campus
Humanities and Social Sciences



Size of Korea: 100,210km²
(Jilin Province: 187,400km²)



SKKU, Suwon Campus
Natural Sciences

Overview

Seoul Campus

Humanities & Social Sciences

- University College
- College of Confucian Studies & Eastern Philosophy
- College of Liberal Arts
- College of Law
- College of Social Sciences
- College of Economics
- School of Business
- College of Education
- School of Art

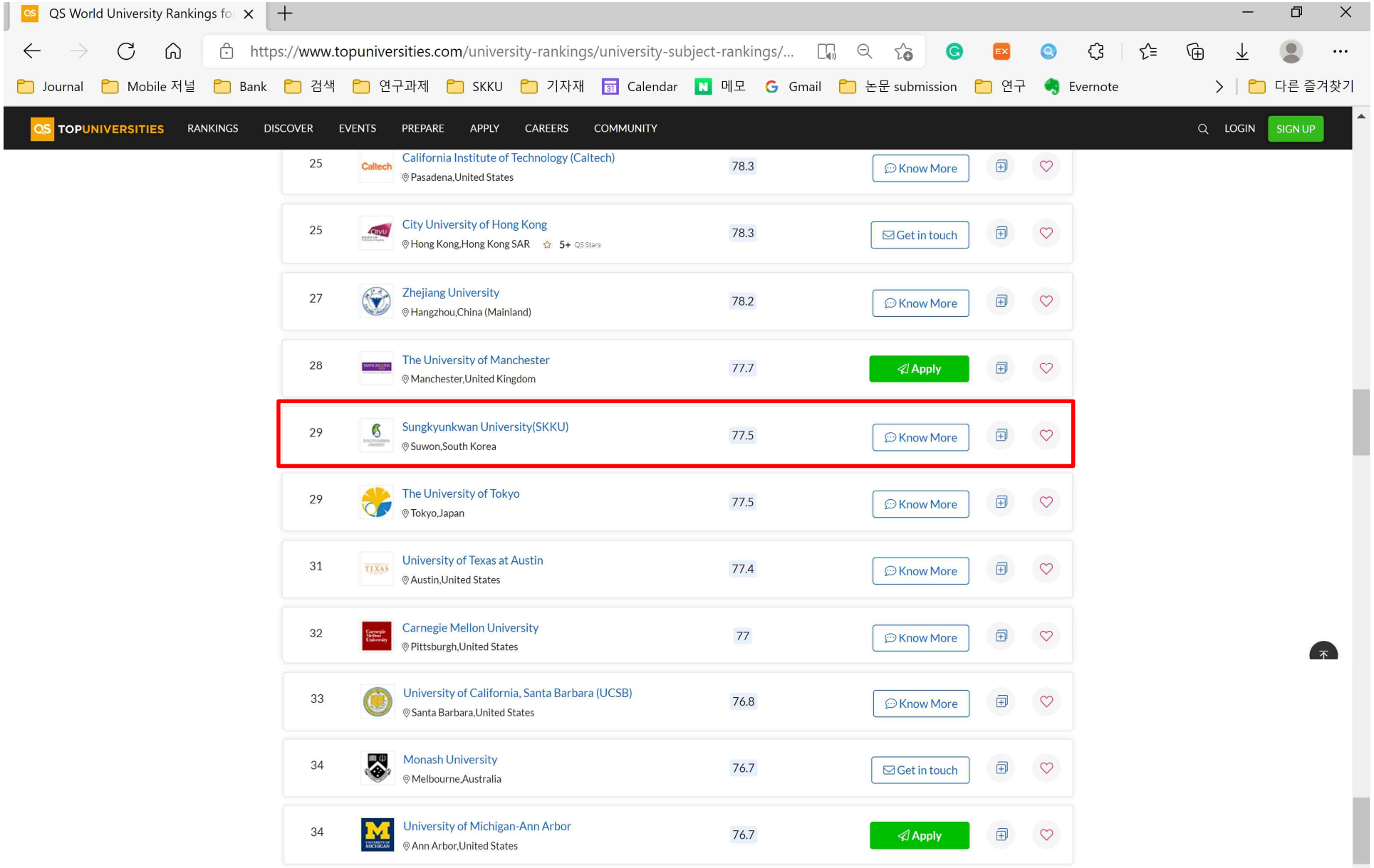
Overview

Suwon Campus

Natural Sciences

- College of Science
- College of Information & Communication Engineering
- College of Software
- College of Engineering
- School of Pharmacy
- College of Biotechnology & Bioengineering
- College of Sport Science
- School of Medicine
- SKKU Institute of Convergence

SKKU Materials Science Program



Introduction

- What is materials science?
- Why should we know about it?

History of Materials Science

- **Stone age**
  - People began to make tool from stone
  - Natural materials: stone, wood, clay, skins, etc.
- **Bronze age**
  - Bronze is an alloy (a metal made up of more than an element)
  - Bronze consists of Cu, about 12% Sn, and often other metals (such as Al, Mg, etc)
- **Iron age**
  - Use of iron and steel, a stronger and cheaper material

Advanced Materials Science

- **Silicon**
- **Polymer**

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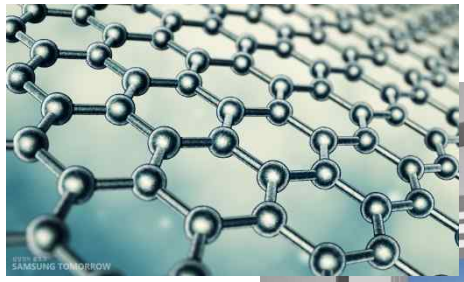
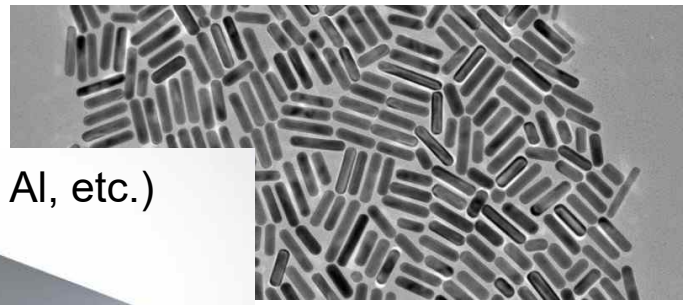
- **Graphene (2D materials)**
- **Nanoparticles**
- **Bio-polymers (biodegradable)**
- **Light metals**



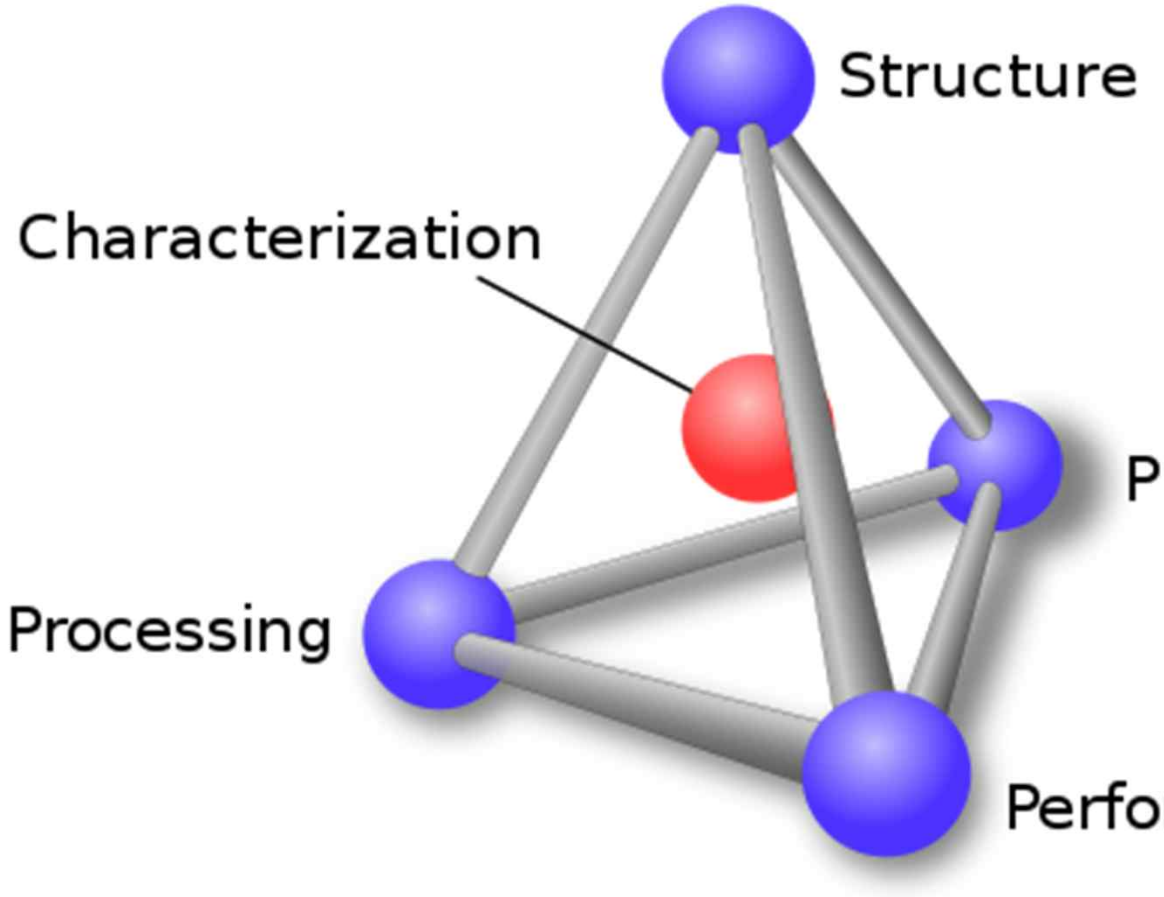
Graphene



Nanomaterials

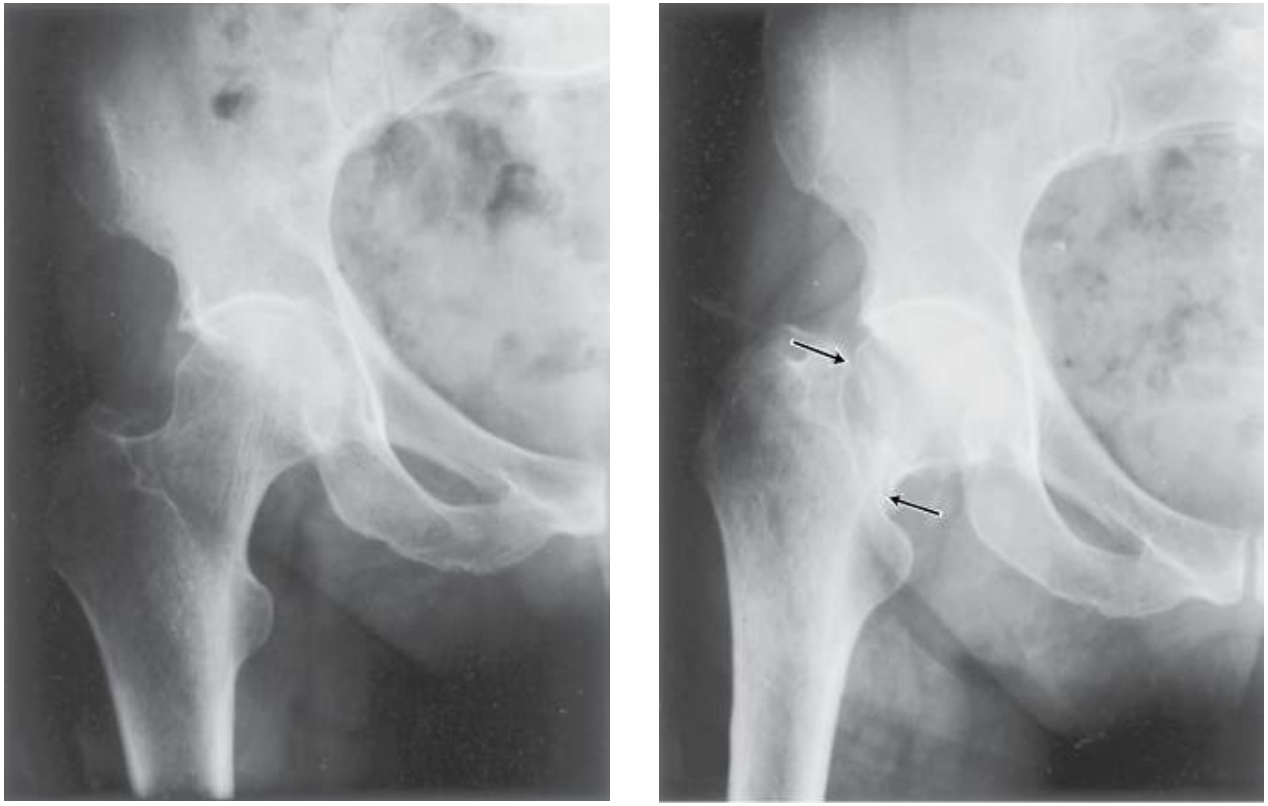
Light metals (Mg, Al, etc.)

What is Materials Science?



Example – Hip Implant

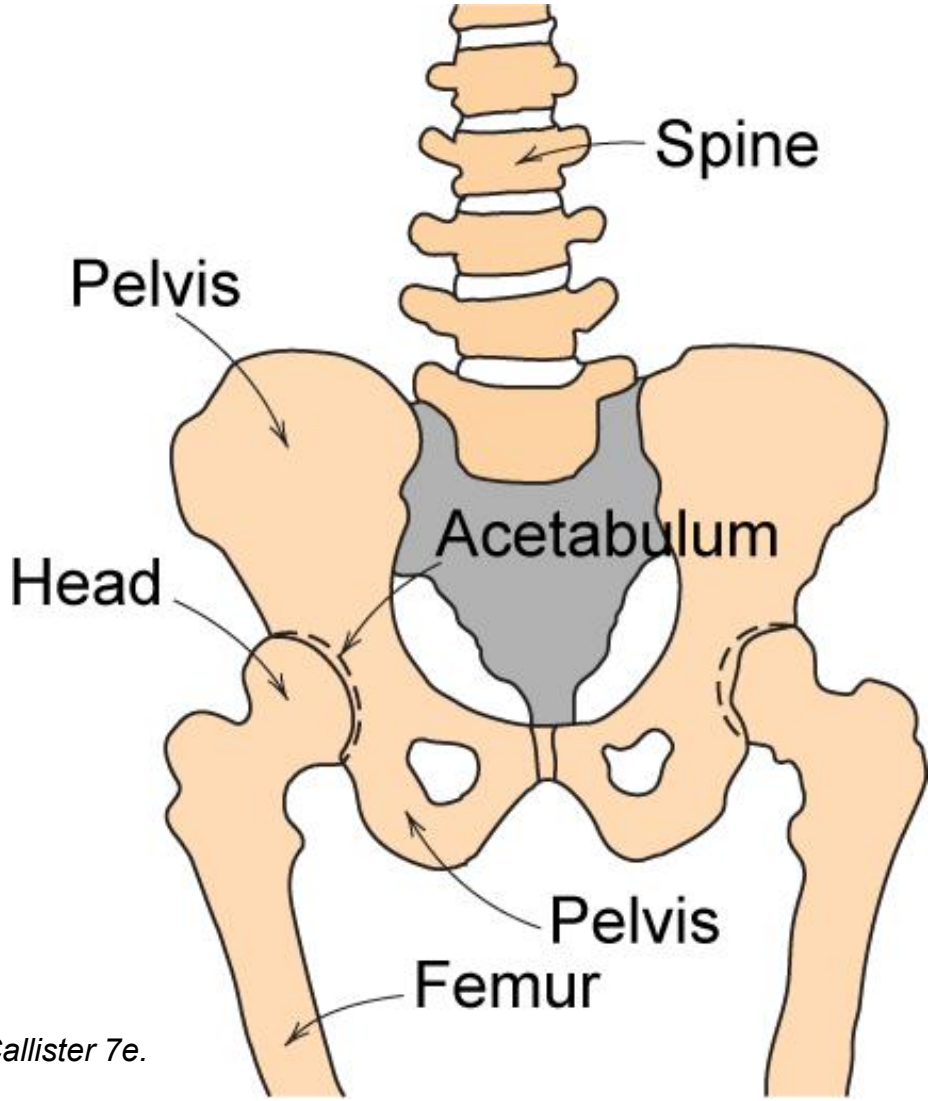
- With age or certain illnesses joints deteriorate. Particularly those with large loads (such as hip).



Adapted from Fig. 22.25, *Callister 7e.*

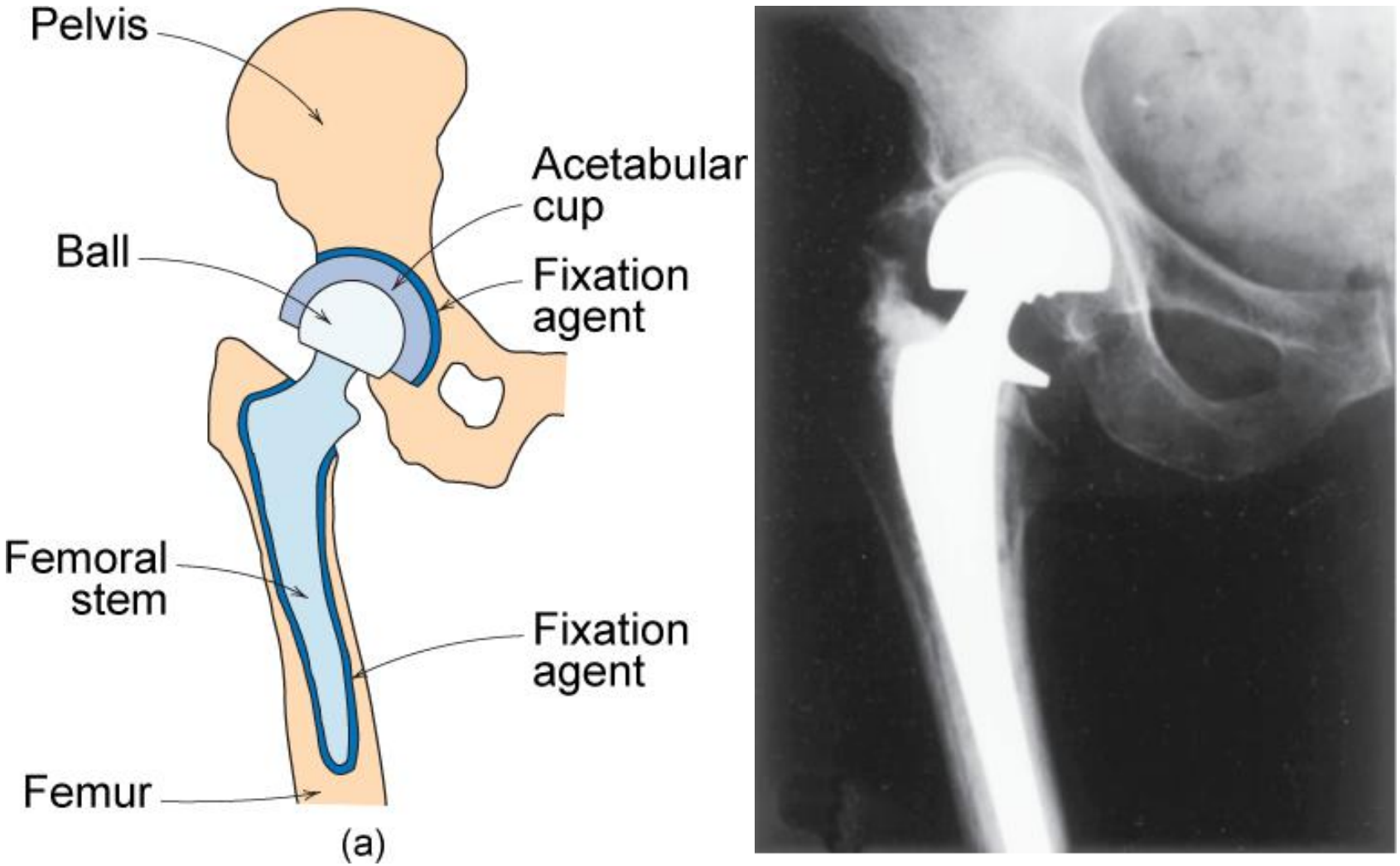
Example – Hip Implant

- Requirements
  - mechanical strength (many cycles)
  - good lubricity
  - biocompatibility



Adapted from Fig. 22.24, *Callister 7e.*

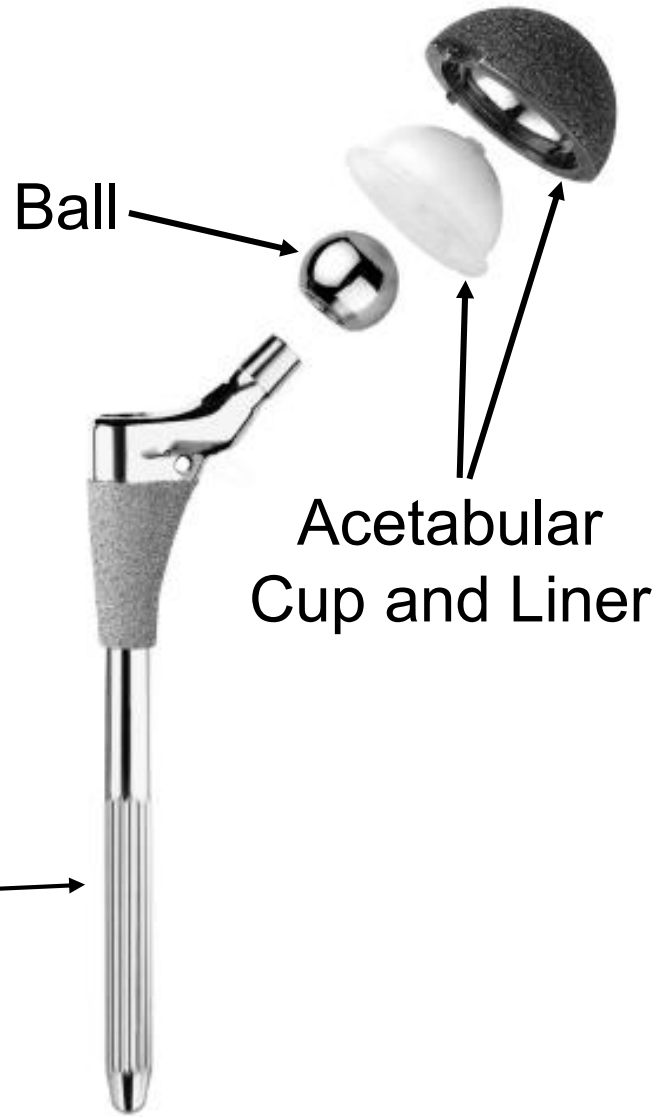
Example – Hip Implant



Adapted from Fig. 22.26, *Callister 7e.*

Hip Implant

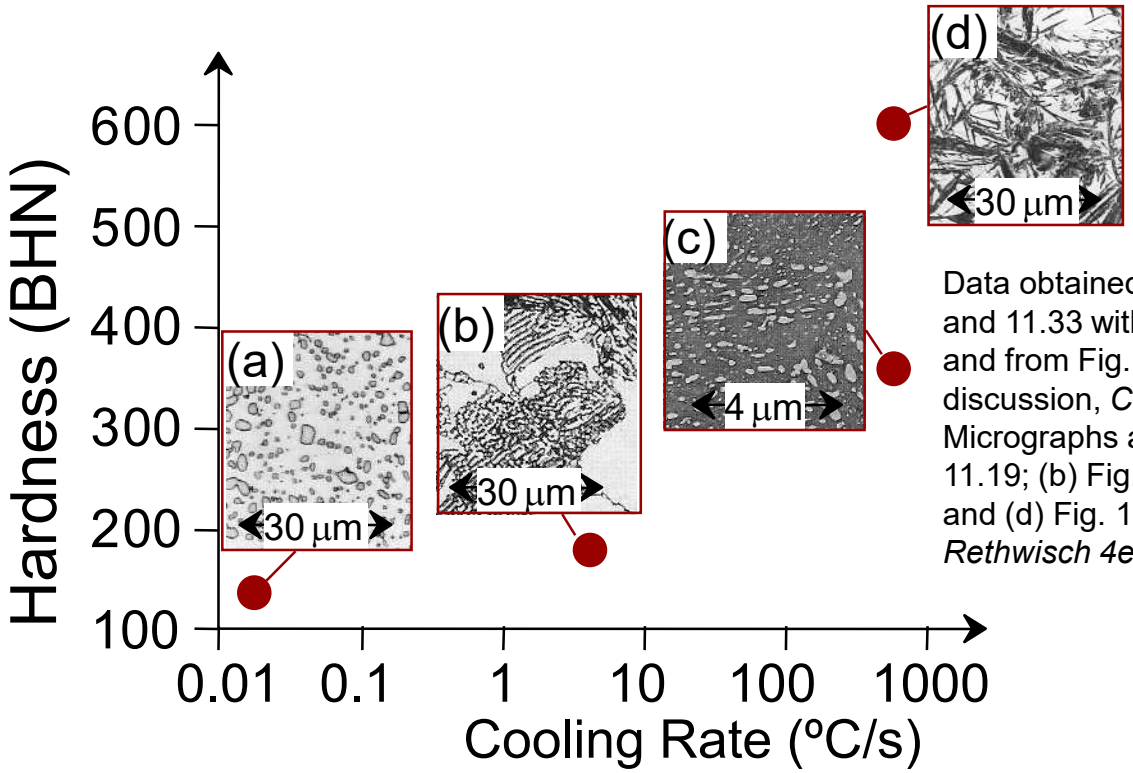
- Key problems to overcome
  - fixation agent to hold acetabular cup
  - cup lubrication material
  - femoral stem – fixing agent
  - must avoid any debris in cup



Adapted from chapter-opening photograph, Chapter 22, *Callister 7e.*

Structure, Processing, & Properties

- Properties depend on [ ]
  ex: hardness vs structure of steel



Data obtained from Figs. 11.31(a) and 11.33 with 4 wt% C composition, and from Fig. 14.8 and associated discussion, *Callister & Rethwisch 4e*. Micrographs adapted from (a) Fig. 11.19; (b) Fig. 10.34;(c) Fig. 11.34; and (d) Fig. 11.22, *Callister & Rethwisch 4e*.

- [ ] can change structure
  ex: structure vs cooling rate of steel

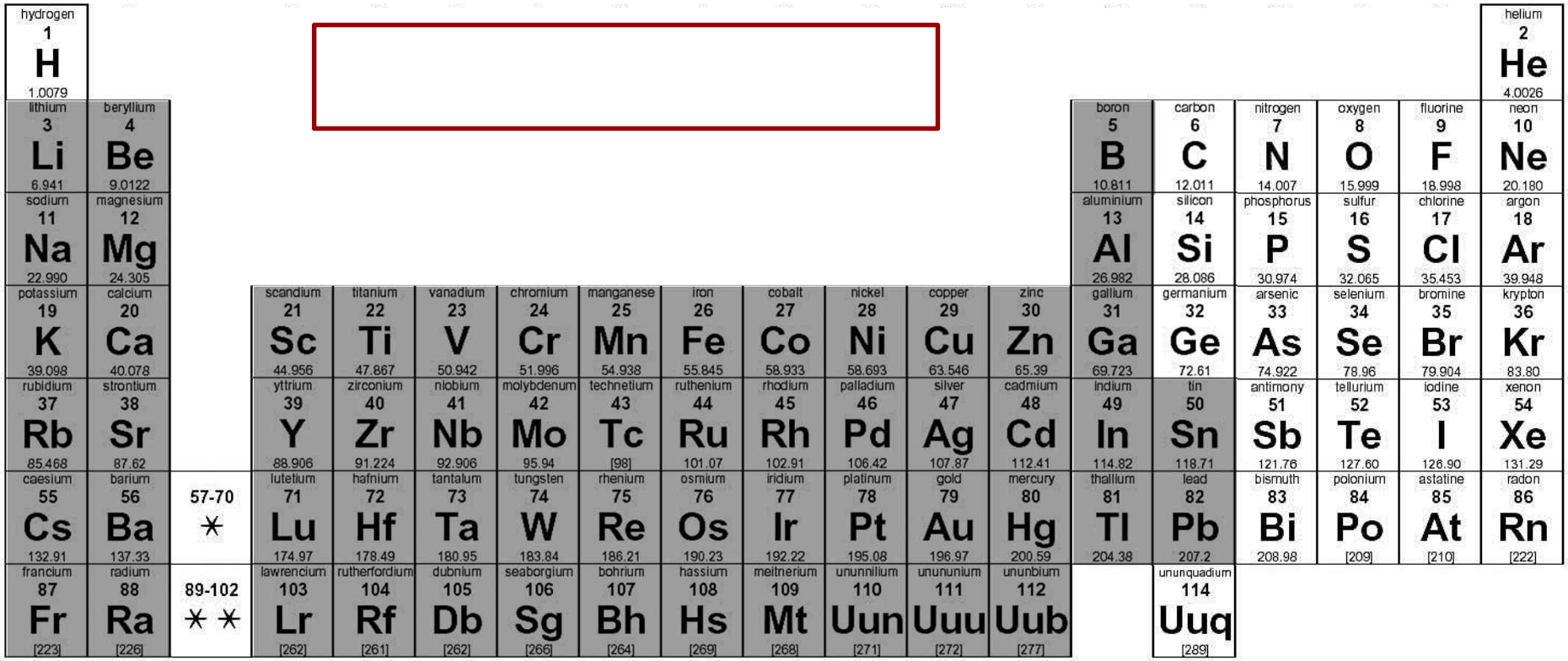
Types of Materials

-
  - Strong, ductile
  - High thermal & electrical conductivity
  - Opaque, reflective.

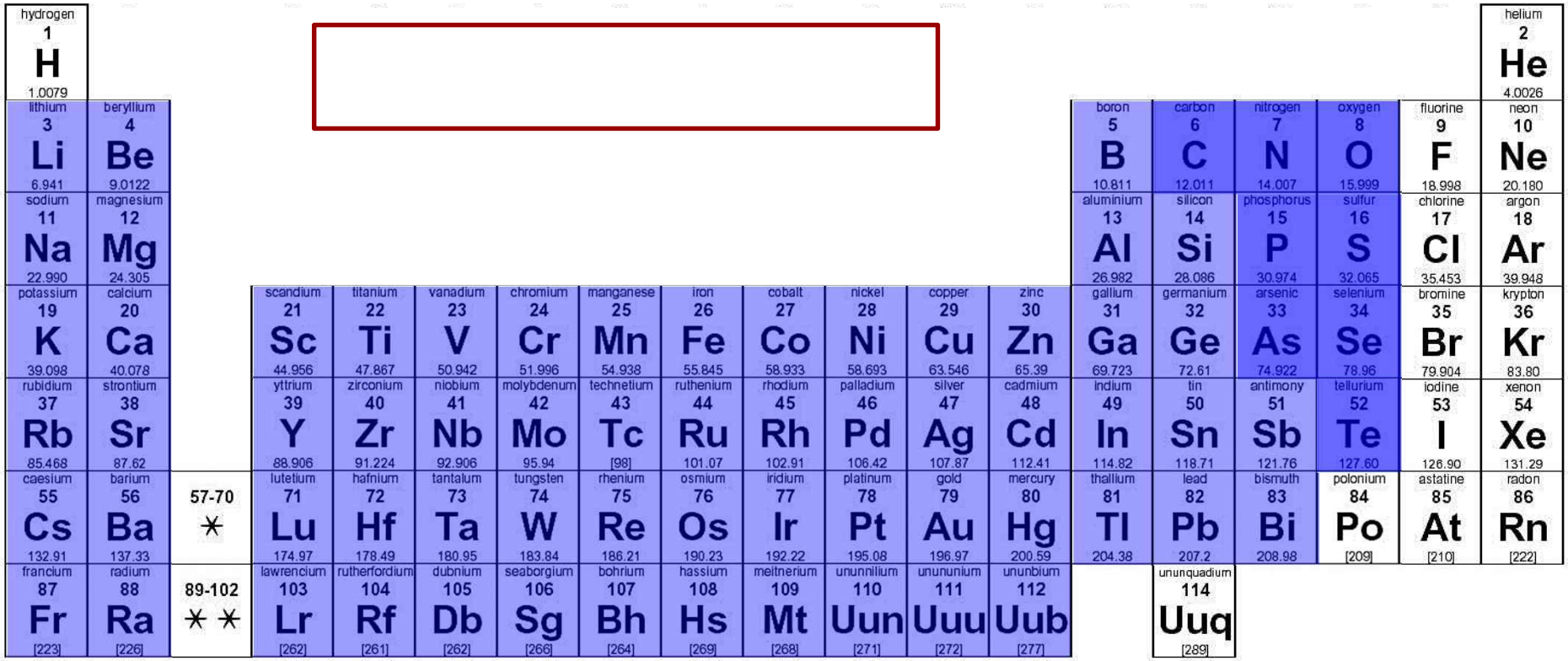
- Ceramics: ionic bonding (refractory) – compounds of metallic & non-metallic elements (oxides, carbides, nitrides, sulfides)
  - Brittle, glassy, elastic
  - Non-conducting (insulators)

- Polymers/plastics: Covalent bonding → sharing of e's
  - Soft, ductile, low strength, low density
  - Thermal & electrical insulators
  - Optically translucent or transparent.

Periodic table



Periodic table



Periodic table

hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

The Materials Selection Process

1. Pick Application ⟶ Determine required Properties

   Properties: mechanical, electrical, thermal, magnetic, optical, deteriorative.

2. Properties ⟶ Identify candidate Material(s)

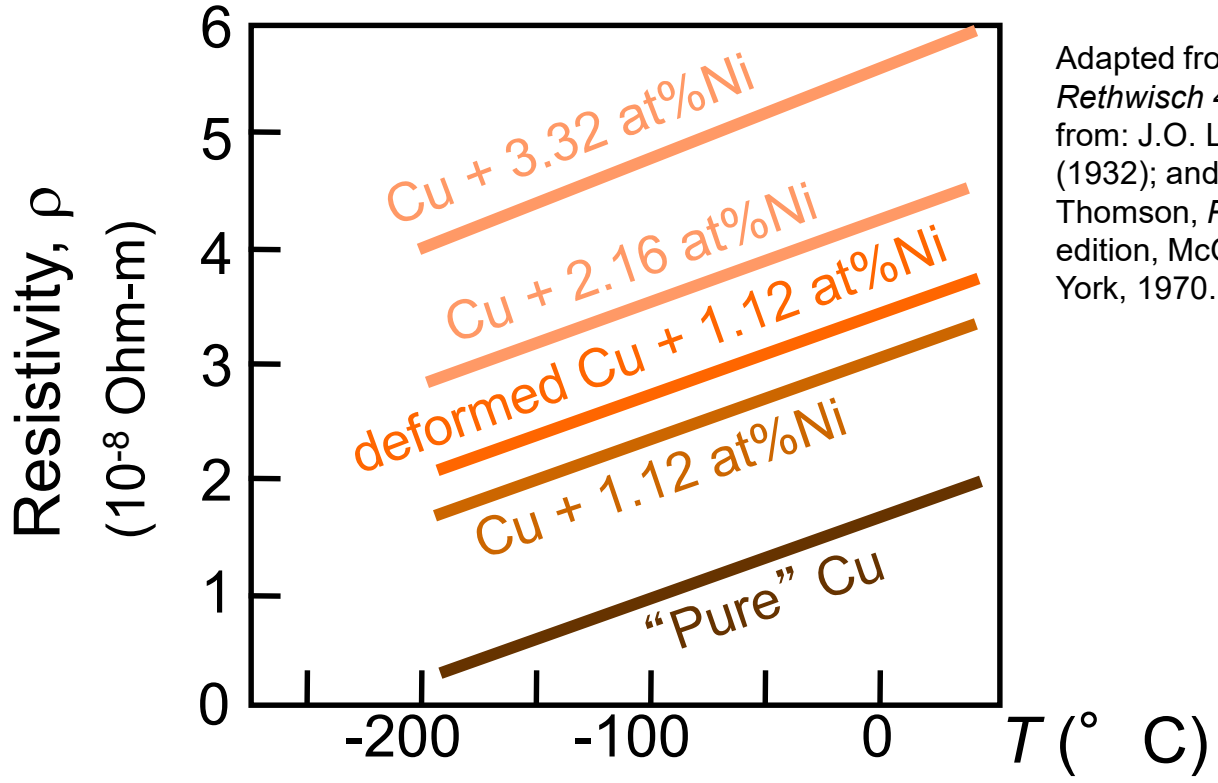
   Material: structure, composition.

3. Material ⟶ Identify required Processing

   Processing: changes *structure* and overall *shape*
   ex: casting, sintering, vapor deposition, doping
   forming, joining, annealing.

ELECTRICAL

- Electrical Resistivity of Copper:



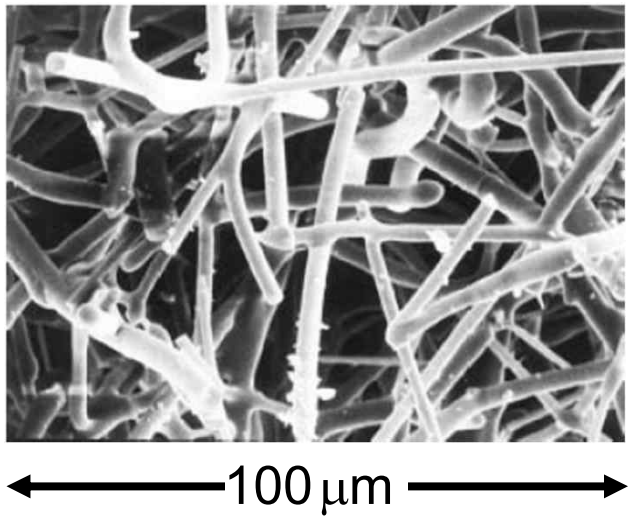
Adapted from Fig. 12.8, *Callister & Rethwisch 4e.* (Fig. 12.8 adapted from: J.O. Linde, *Ann Physik* **5**, 219 (1932); and C.A. Wert and R.M. Thomson, *Physics of Solids*, 2nd edition, McGraw-Hill Company, New York, 1970.)

- Adding "impurity" atoms to Cu increases [ ].
- Deforming Cu increases resistivity.

THERMAL

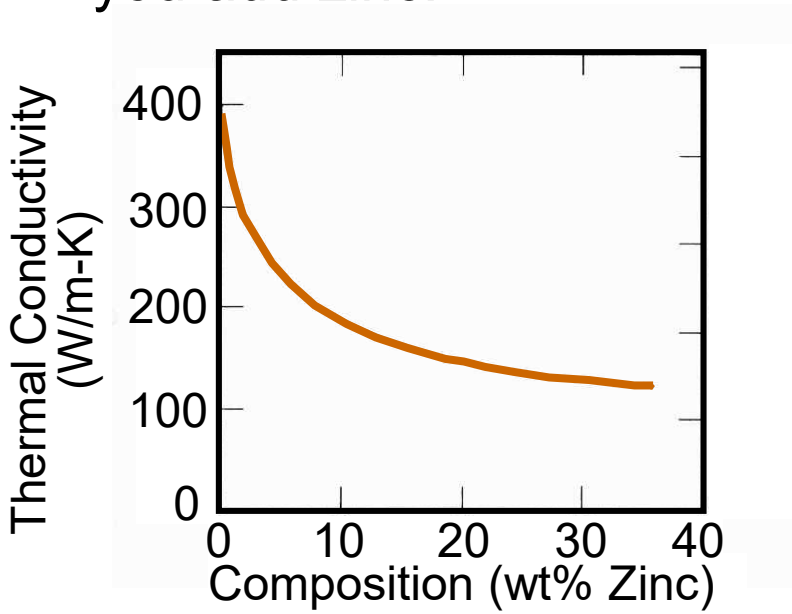
- Space Shuttle Tiles:
  -- Silica fiber insulation offers low heat [ ].

Adapted from chapter-opening photograph, Chapter 17, *Callister & Rethwisch 3e.* (Courtesy of Lockheed Missiles and Space Company, Inc.)



Adapted from Fig. 19.4W, *Callister 6e.* (Courtesy of Lockheed Aerospace Ceramics Systems, Sunnyvale, CA) (Note: "W" denotes fig. is on CD-ROM.)

- Thermal Conductivity of Copper:
  -- It decreases when you add zinc!



Adapted from Fig. 17.4, *Callister & Rethwisch 4e.* (Fig. 17.4 is adapted from *Metals Handbook: Properties and Selection: Nonferrous alloys and Pure Metals*, Vol. 2, 9th ed., H. Baker, (Managing Editor), American Society for Metals, 1979, p. 315.)

MAGNETIC

- Magnetic Storage:
  -- Recording medium is magnetized by recording head.

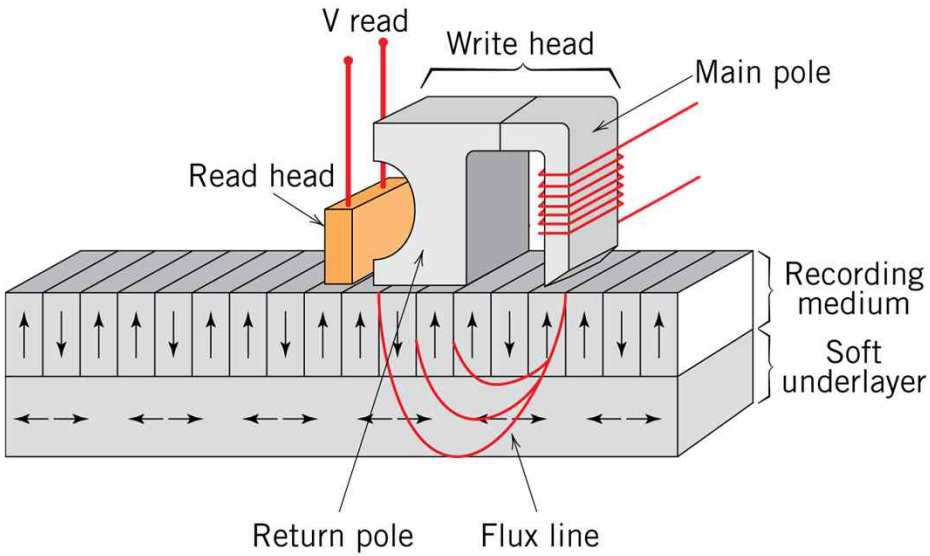
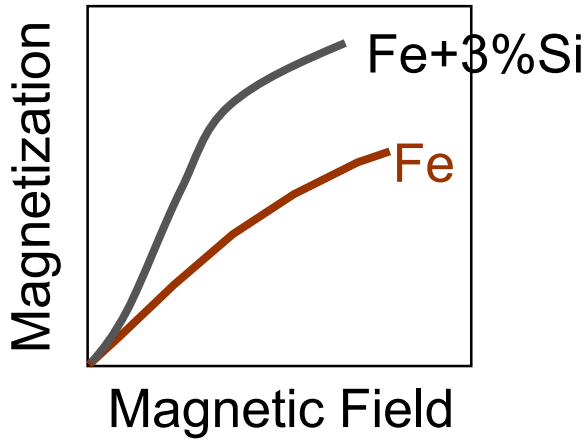


Fig. 18.23, *Callister & Rethwisch 4e.*

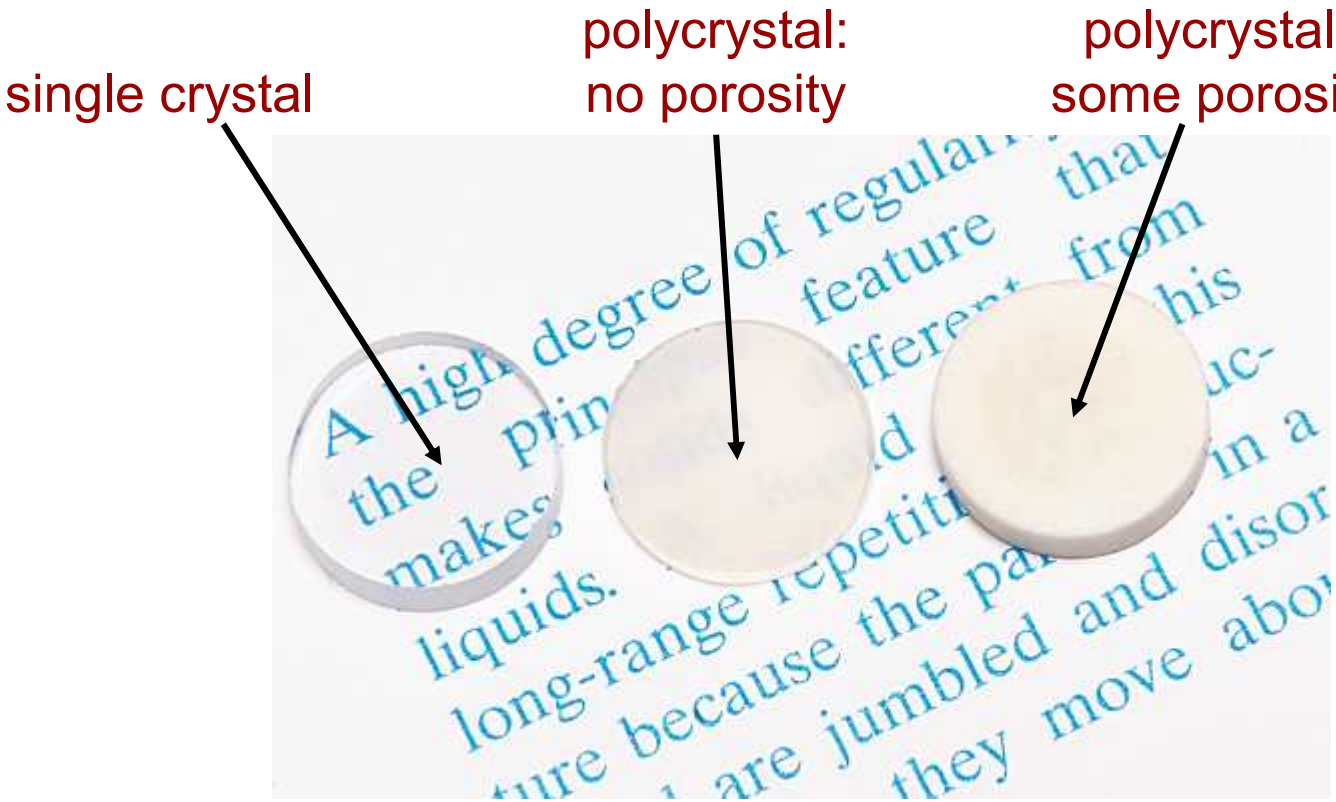
- Magnetic Permeability vs. Composition:
  -- Adding 3 atomic % Si makes Fe a better recording medium!



Adapted from C.R. Barrett, W.D. Nix, and A.S. Tetelman, *The Principles of Engineering Materials*, Fig. 1-7(a), p. 9, 1973. Electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.

OPTICAL

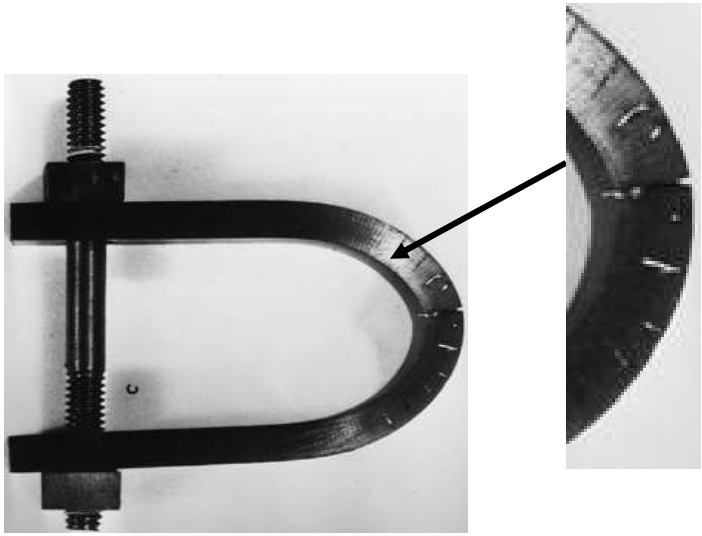
- Transmittance:
  -- Aluminum oxide may be transparent, translucent, or opaque depending on the material's structure (i.e., single crystal vs. polycrystal, and degree of porosity).



Adapted from Fig. 1.2, *Callister & Rethwisch 4e.* (Specimen preparation, P.A. Lessing; photo by S. Tanner.)

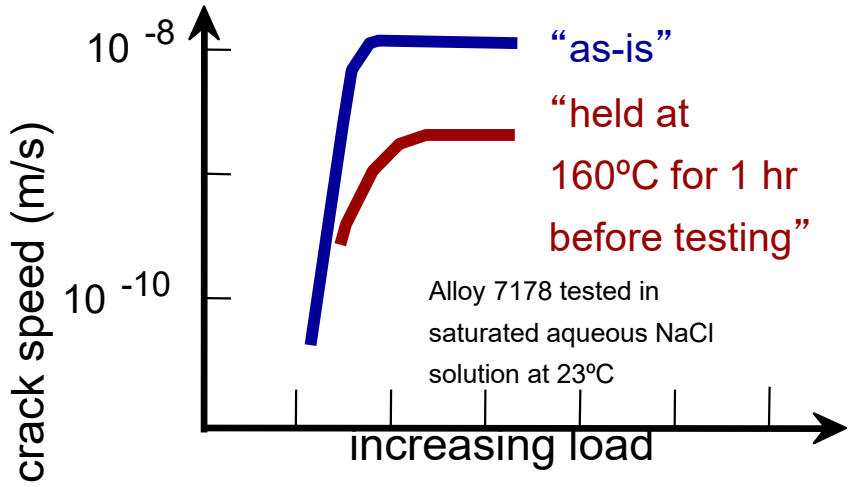
DETERIORATIVE

- Stress & Saltwater... -- causes cracks!



Adapted from Fig. 16.21, *Callister & Rethwisch 4e.* (from *Marine Corrosion, Causes, and Prevention*, John Wiley and Sons, Inc., 1975.)

- Heat treatment: slows crack speed in salt water!



Adapted from Fig. 11.20(b), R.W. Hertzberg, "Deformation and Fracture Mechanics of Engineering Materials" (4th ed.), p. 505, John Wiley and Sons, 1996. (Original source: Markus O. Speidel, Brown Boveri Co.)

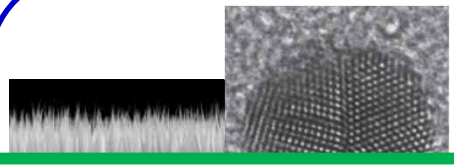
SUMMARY

Course Goals:

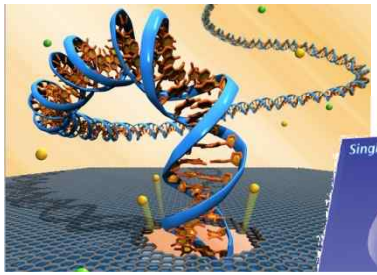
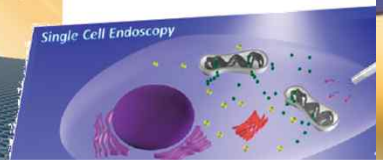
- Use the right material for the job.
- Understand the relation between properties, structure, and processing.
- Recognize new design opportunities offered by materials selection.

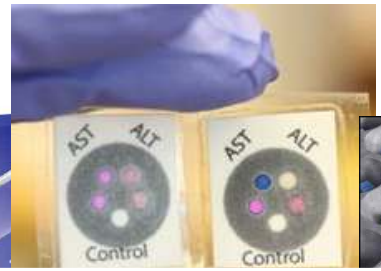
Biomaterials science

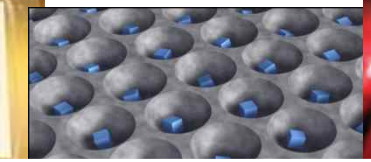
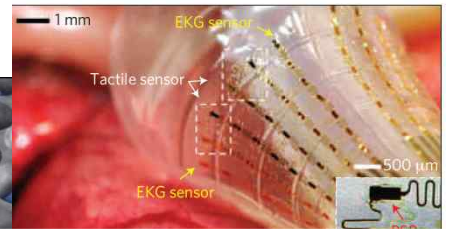
Materials Science




Bio-Material Interface



- DNA sequencin
- Clinical Devices

Periodic table

Biological systems!

hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Periodic table

Polymers!

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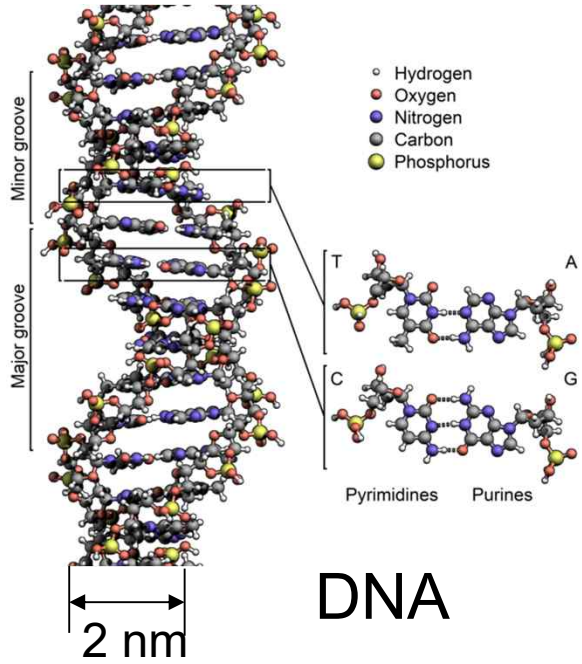
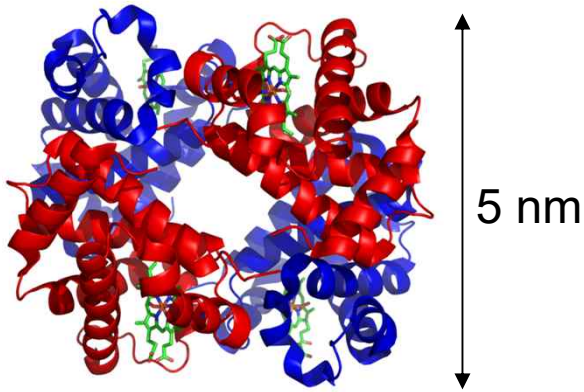
Biological systems

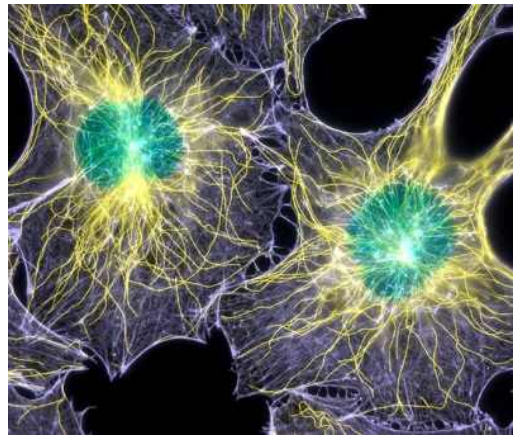
- Biosystems are governed by nanoscale processes and structures that have been optimized over millions of years
- Biologists have been operating for many years at the molecular level, in the range of nanometers (DNA and proteins) to micrometers (cells)



DNA



Protein
(Hemoglobin)

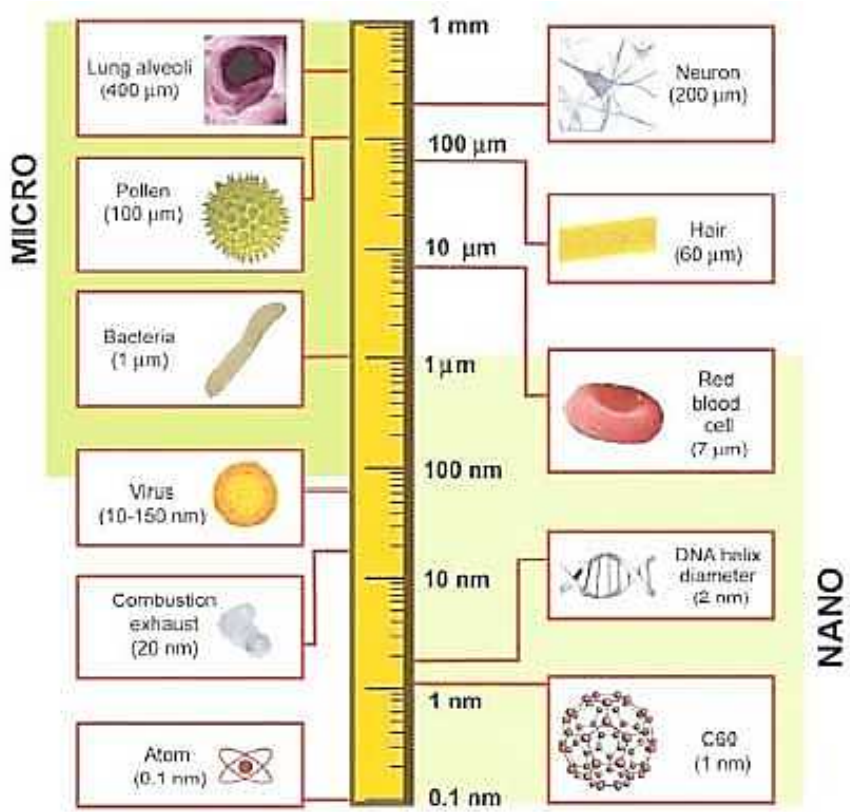


Cells (~30 μm)

Length scale of biological components

Table 3.9 Size of biological components

Biological structure	Dimension	Shape
Plant cells	50–100 μm	Polyhedral
Animal cells	10–70 μm	Variable
Platelet	3 μm	Discoid
Red cell (erythrocyte)	7 μm	Discoid
White blood cell	12 μm	Round
Muscle cell (skeletal)	30 cm (length)	Cylindrical
	10–100 μm (diameter)	
Muscle cell (smooth)	30–200 μm (length)	Spindle
	5–10 μm (diameter)	
Liver cell (hepatocyte)	25 μm	Polyhedral
Nerve cell (neuron)		
Body	5–150 μm	Variable
Axon	Up to 100 cm long	
Bacteria	1–5 μm	
Virus particle	20–50 nm	
Ribosome	20 nm	
Amyloid fibril diameter	10 nm	
Hemoglobin	65 Å	
Myoglobin	36 Å	
Glucose	7 Å	
Amino acid – alanine	5 Å	
Water molecule	2.4 Å	
Water, tetrahedral cluster	5 Å	
Sodium ion (crystal radius)	0.95 Å	
Sodium ion (hydrated)	5 Å	
Potassium ion (crystal radius)	1.33 Å	
Sodium channel inside dimension	5 Å	
Potassium channel inside dimension	3 Å	
Double layer dimension	5–10 Å	
Lipid bilayer thickness	40–50 Å	
Mitochondria	0.5 μm × 1.5 μm	
Lysosome		
Primary	50 nm	
Secondary	200–500 nm	
Nuclear pore complex	50 nm	
Coated pit (clathrin coated)	150 nm	
Nucleus	3–10 μm	
Diameter of DNA double helix	20 Å	

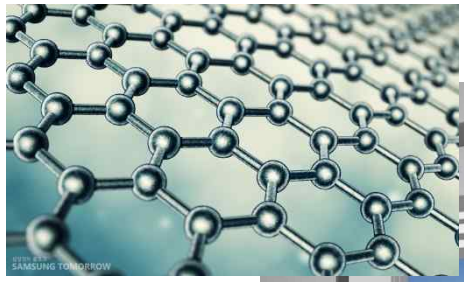


Materials

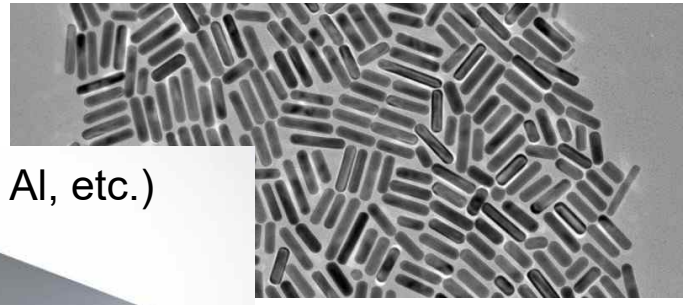
- Glass
- Silicon
- Polymer
- Ceramics

.

- Graphene (2D materials)
- Nanoparticles
- Bio-polymers (biodegradable)
- Metals



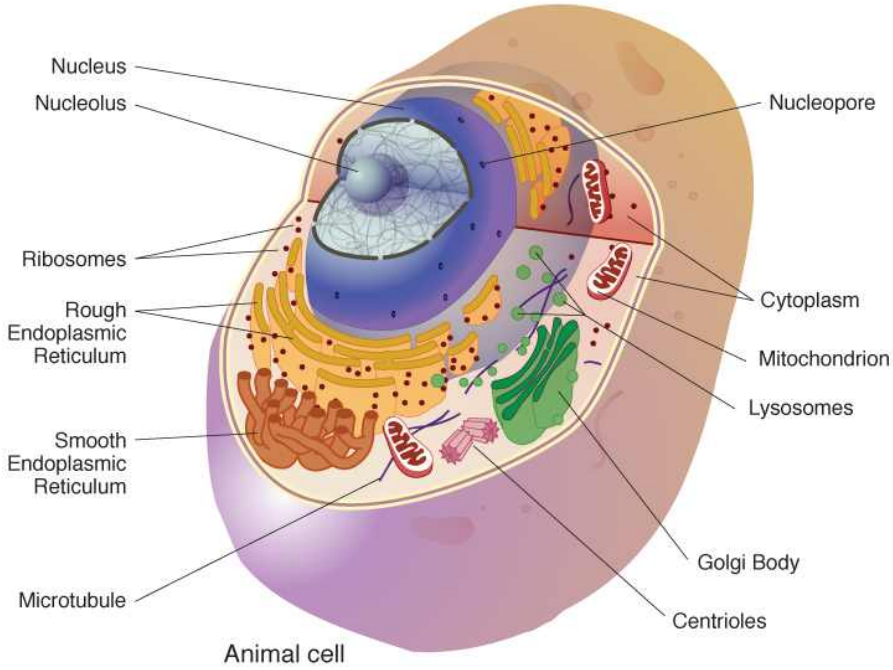
Graphene

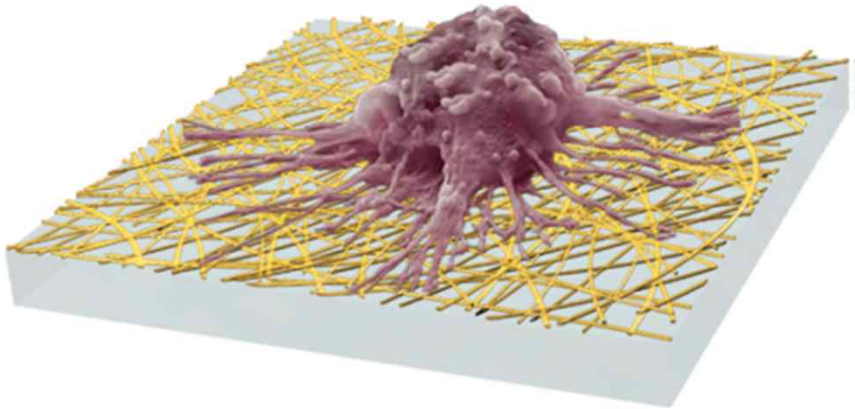


Nanorods

Light metals (Mg, Al, etc.)

Cells

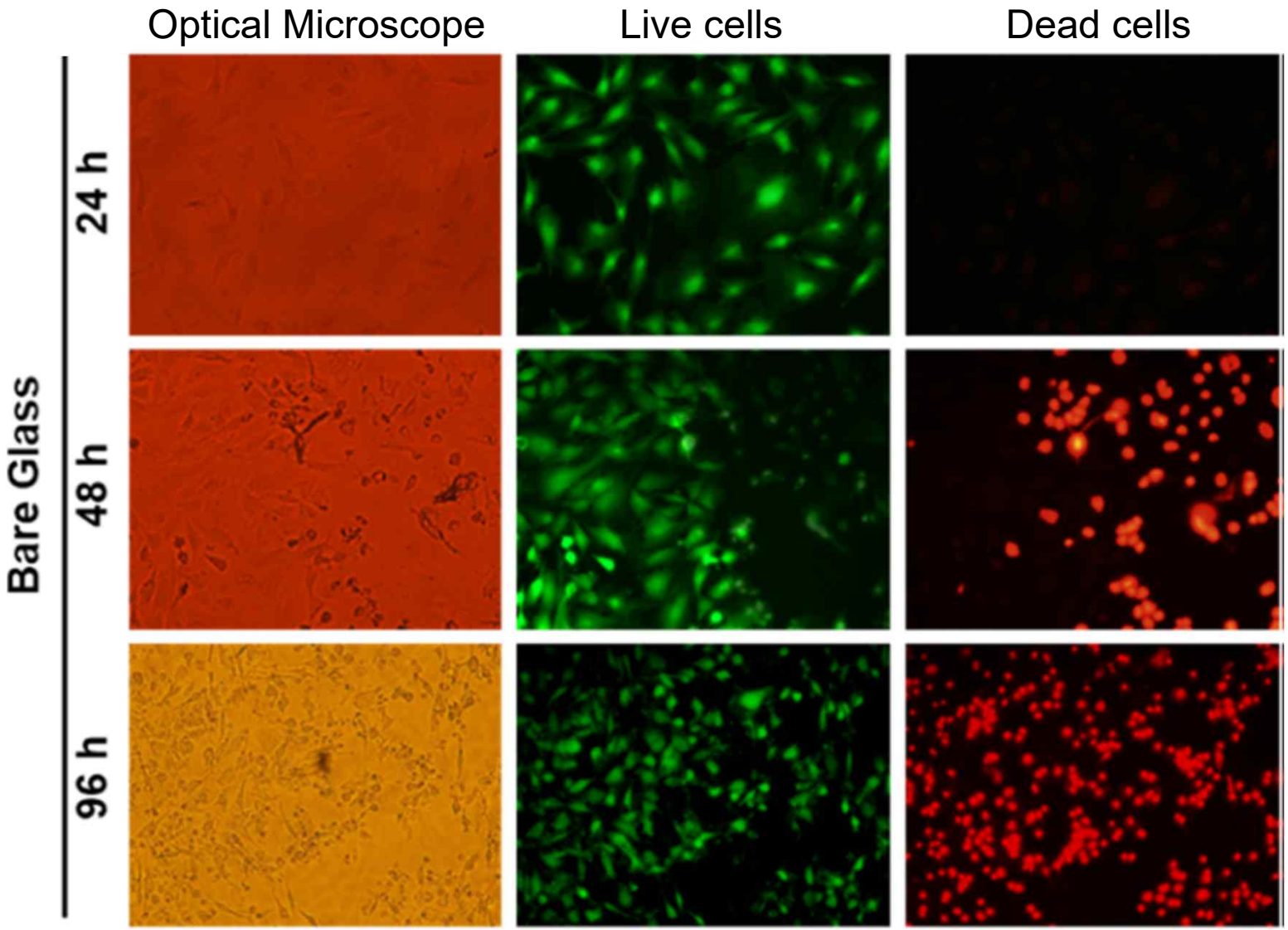




Cells on materials

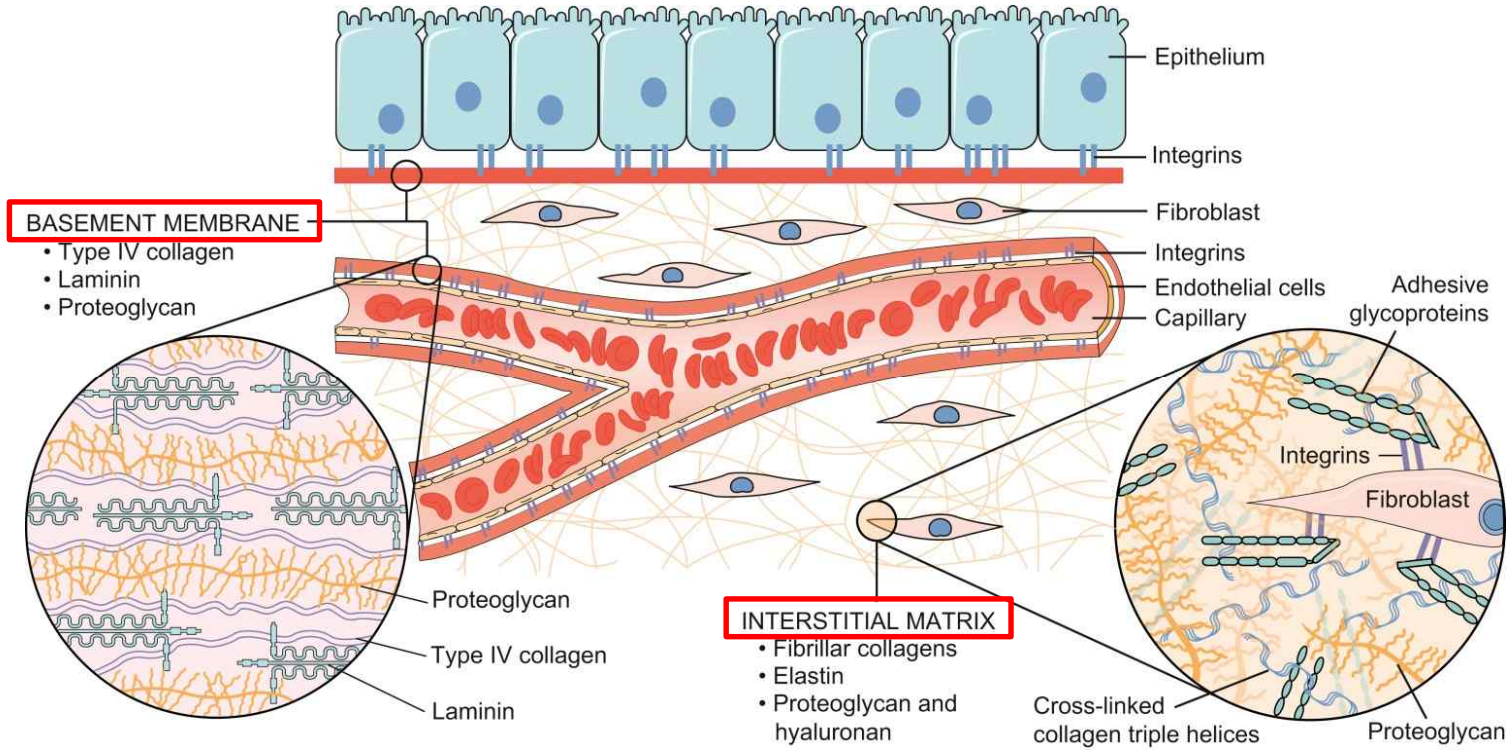
https://geneed.nlm.nih.gov/topic_subtopic.php?tid=1

What will happen if a cells sit on a glass?



Jin Woong Lee *et al., Nano Letters*, **2018**, *18*, 7619-7627

Extracellular matrix



Molecules in ECM:

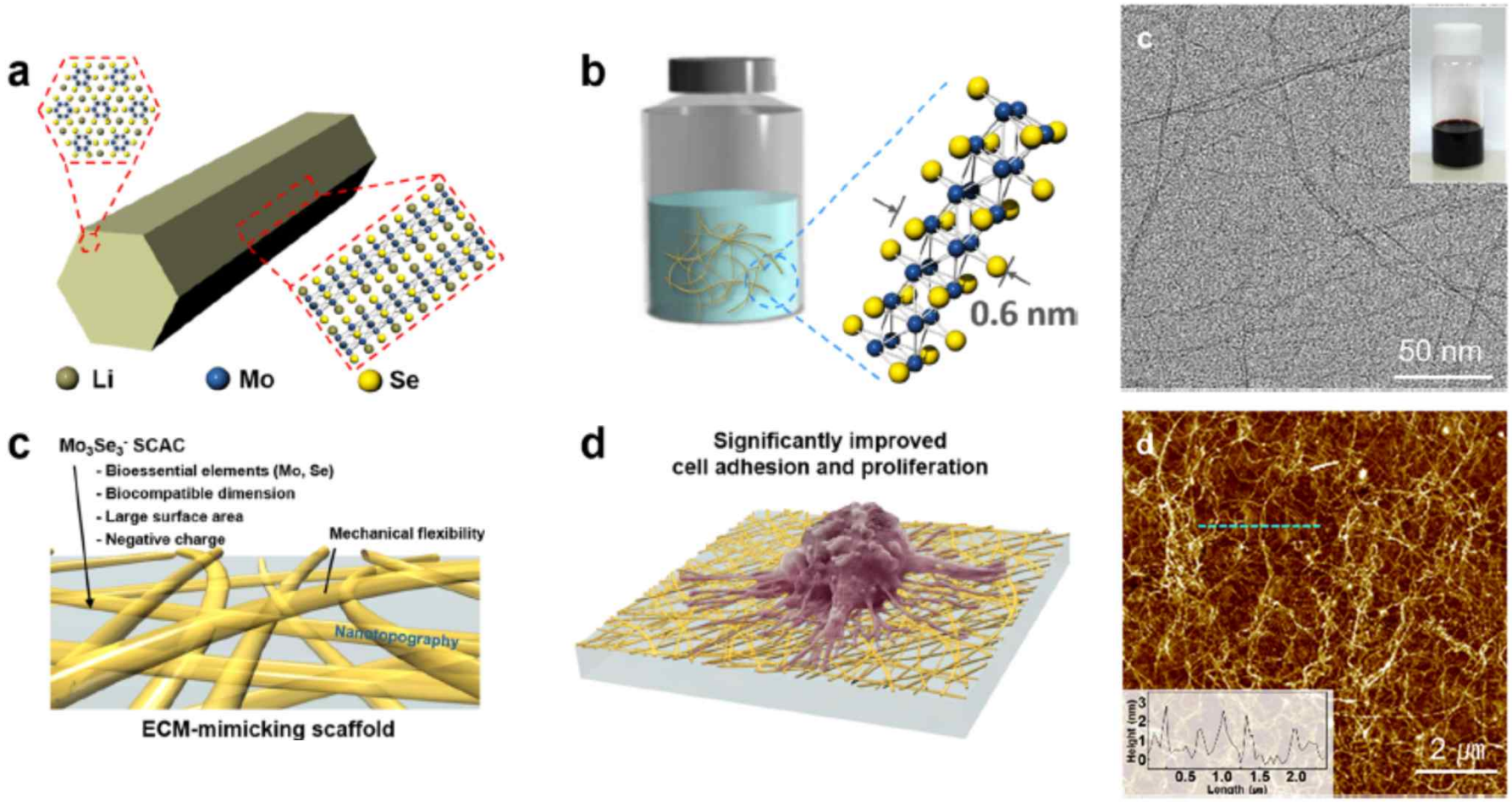
- Proteins (Collagen, Elastin, Fibronectin, Laminin)
- Glycosaminoglycan
- Proteoglycan

Characteristics of ECM molecules

Table S1. Diameter and surface charge of primary extracellular matrix components.

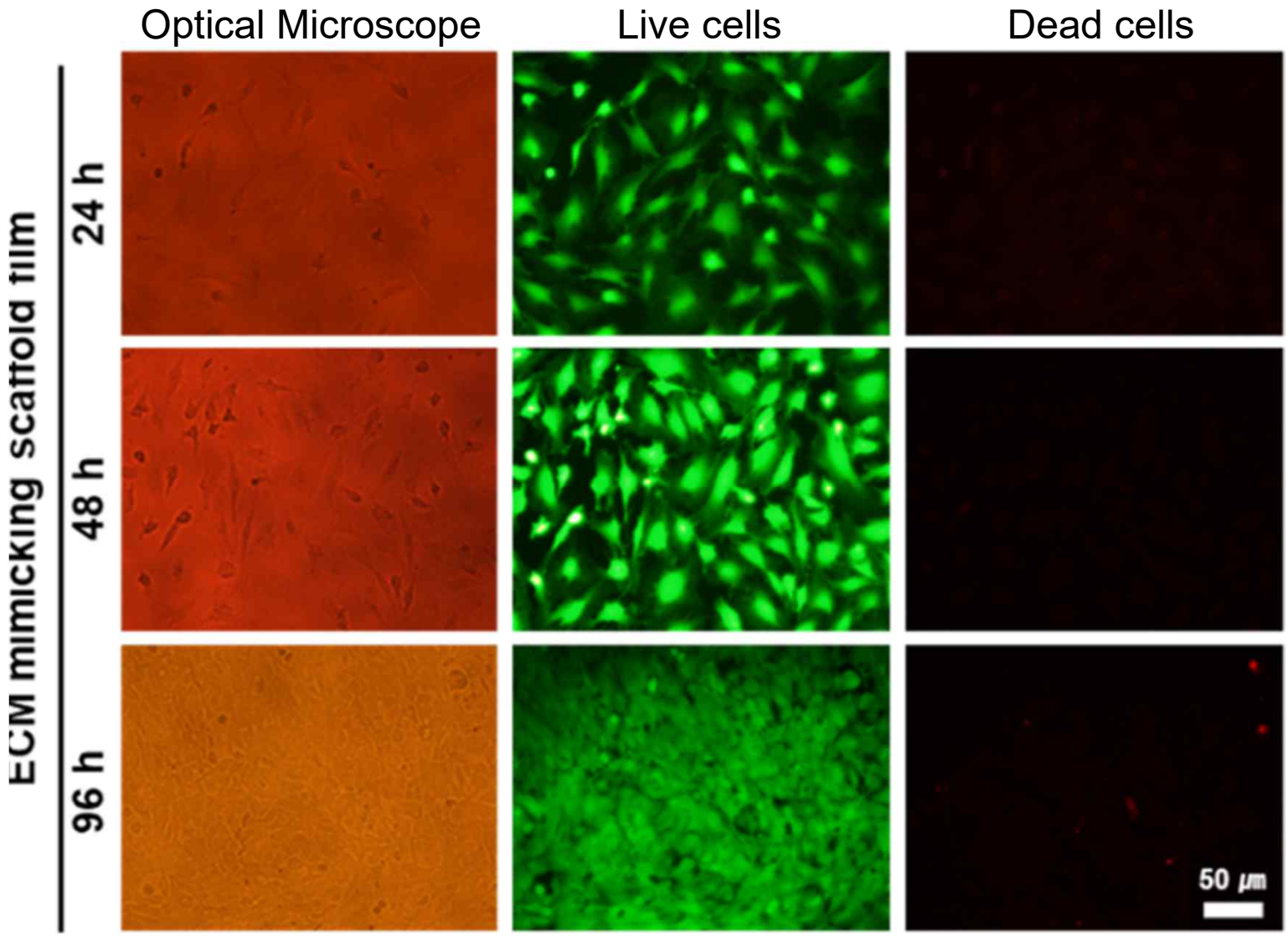
Primary ECM Components	Diameter of components	Surface charge
Collagen molecule (tropocollagen)	1.5 nm [1-6]	−12.2 ± 0.7 mV [7]
Collagen Type I (skin, bone) fibril	67 nm [8-10]	
Type II (cartilage) fibril	80 nm [11, 12]	
Type III (Vessel) fibril	67 nm [13]	
Type IV (Basement membrane) fibril	4 nm [14, 15]	
Laminin	2 nm [16]	−50 mV [17, 18]
Elastin	7 nm [19, 20]	−24 ± 2 mV [21 22]
Vitronectin	6 nm [23]	−20 mV [18]
Glycosaminoglycans (GAGs)	0.7 nm [24]	Negatively charged [25, 26]

ECM mimicking material

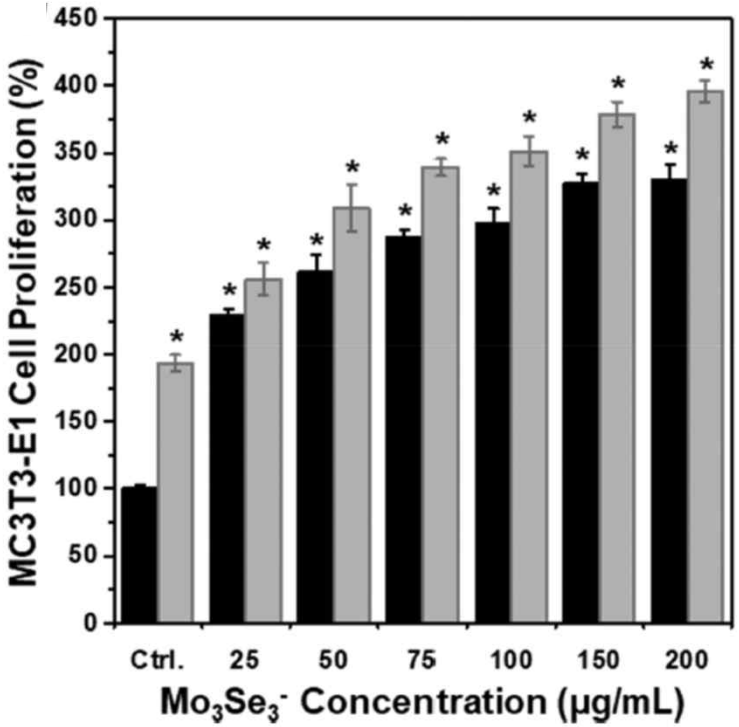


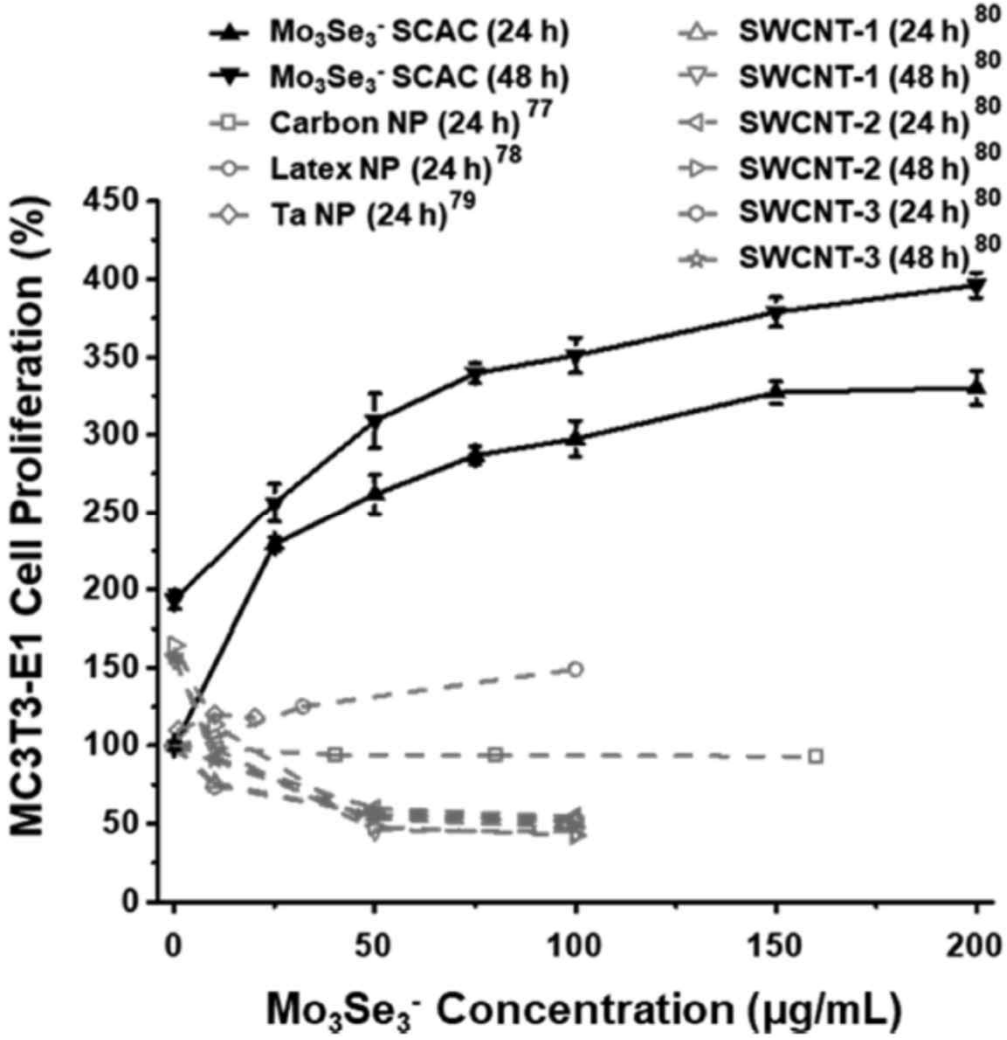
Jin Woong Lee *et al., Nano Letters*, **2018**, *18*, 7619-7627

How can we improve cells sitting on a glass?

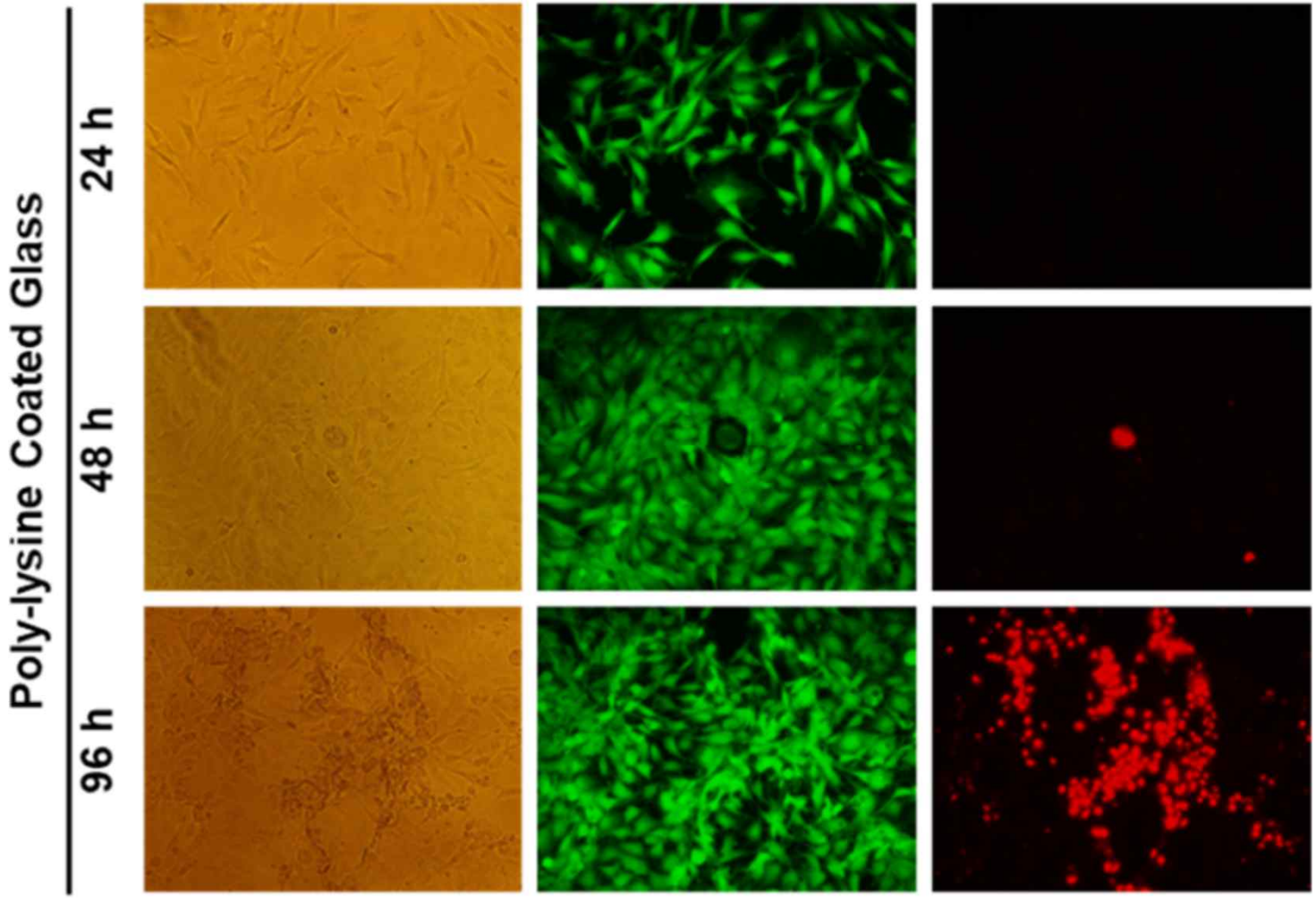


Cell Proliferation

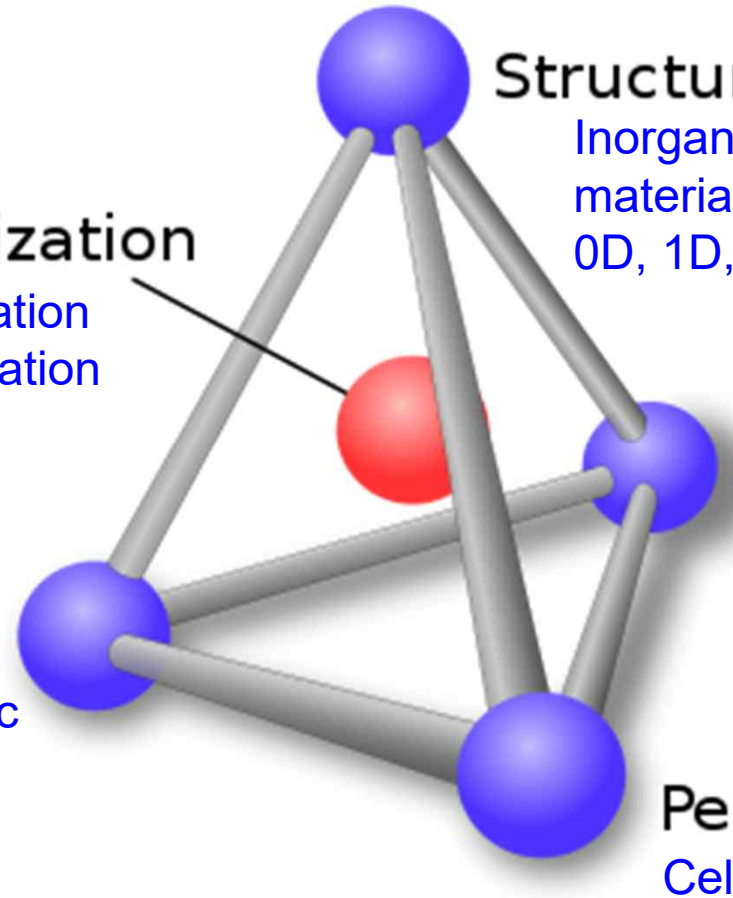




In comparison to poly-Lysine functionalized glass



Bio-integrated Materials Science



Structure

Inorganic, metallic, polymeric materials
0D, 1D, 2D nanostructures

Characterization

Materials characterization
Biological characterization

Properties

Surface properties
Mechanical properties
Physical properties
Chemical properties

Processing

Synthesis, fabrication, etc

Performance

Cell growth, bacteria death, cell targeting, contains/ releases drug, interaction with biomolecules, etc

The Properties of Biological System

- Biomolecules (DNA, peptide, proteins, lipids…)
- Cells (human cells, bacteria, virus)
- Tissues (bone tissues)

Thank you very much!

Contact information:
jhlee7@skku.edu
https://www.bionanomaterials.org

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다.

- 주제: Bio-integrated Materials Science (JU)_Day 1
- 시간: 2021년 10월 6일 02:00 오후 서울

- Zoom 회의 참가
- https://us02web.zoom.us/j/88596826357?pwd=UjRaOUpjK3M4Mm9Qb0F0TnhUcHZRZz09

- 회의 ID: 885 9682 6357
- 암호: Ju1234
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- +1 312 626 6799 미국 (Chicago)
- +1 346 248 7799 미국 (Houston)
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- 암호: 234071
- 현지 번호 찾기: https://us02web.zoom.us/u/kb8gMPUM6H

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- Zoom 회의 참가
- https://us02web.zoom.us/j/87578671156?pwd=R3VrMnl0YzBzdHBHNzJpNDgyWnp1QT09

- 회의 ID: 875 7867 1156
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +13126266799,,87578671156#,,,,*940754# 미국 (Chicago)
- +13462487799,,87578671156#,,,,*940754# 미국 (Houston)

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- +1 646 558 8656 미국 (New York)
- +1 669 900 9128 미국 (San Jose)
- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- 회의 ID: 875 7867 1156
- 암호: 940754
- 현지 번호 찾기: https://us02web.zoom.us/u/kWNaxLHxl

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다.

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 10월 11일 10:00 오전 서울

- Zoom 회의 참가
- https://us02web.zoom.us/j/89791357693?pwd=TWZHRFUyeDE3RVZubVFJNlIUSXZUQT09

- 회의 ID: 897 9135 7693
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +16699009128,,89791357693#,,,,*366188# 미국 (San Jose)
- +12532158782,,89791357693#,,,,*366188# 미국 (Tacoma)

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- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- +1 312 626 6799 미국 (Chicago)
- +1 346 248 7799 미국 (Houston)
- +1 646 558 8656 미국 (New York)
- 회의 ID: 897 9135 7693
- 암호: 366188
- 현지 번호 찾기: https://us02web.zoom.us/u/kdkoKCM6d8

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다. 4일

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 10월 13일 01:00 오후 베이징, 상하이

- Zoom 회의 참가
- https://us02web.zoom.us/j/84747461023?pwd=eTRNa0pWanhYMnk1NzJXUXphNlc0dz09

- 회의 ID: 847 4746 1023
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +16699009128,,84747461023#,,,,*494910# 미국 (San Jose)
- +12532158782,,84747461023#,,,,*494910# 미국 (Tacoma)

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- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- +1 312 626 6799 미국 (Chicago)
- +1 346 248 7799 미국 (Houston)
- +1 646 558 8656 미국 (New York)
- 회의 ID: 847 4746 1023
- 암호: 494910
- 현지 번호 찾기: https://us02web.zoom.us/u/kc96avdd30

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다. 5일

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 10월 15일 01:00 오후 베이징, 상하이

- Zoom 회의 참가
- https://us02web.zoom.us/j/82064688452?pwd=N0VwWGE0cGlvYW5zOXF3VGpMYVdMQT09

- 회의 ID: 820 6468 8452
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +16465588656,,82064688452#,,,,*770239# 미국 (New York)
- +16699009128,,82064688452#,,,,*770239# 미국 (San Jose)

- 위치에 따라 전화 걸기
- +1 646 558 8656 미국 (New York)
- +1 669 900 9128 미국 (San Jose)
- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- +1 312 626 6799 미국 (Chicago)
- +1 346 248 7799 미국 (Houston)
- 회의 ID: 820 6468 8452
- 암호: 770239
- 현지 번호 찾기: https://us02web.zoom.us/u/kboAgTxhMl

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다. 6일

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 10월 20일 01:00 오후 베이징, 상하이

- Zoom 회의 참가
- https://us02web.zoom.us/j/85427623138?pwd=OEx6WlNnelhjWGM1b05BVTZZZU1MUT09

- 회의 ID: 854 2762 3138
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +13126266799,,85427623138#,,,,*646732# 미국 (Chicago)
- +13462487799,,85427623138#,,,,*646732# 미국 (Houston)

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- +1 346 248 7799 미국 (Houston)
- +1 646 558 8656 미국 (New York)
- +1 669 900 9128 미국 (San Jose)
- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- 회의 ID: 854 2762 3138
- 암호: 646732
- 현지 번호 찾기: https://us02web.zoom.us/u/kb1NEYfff

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다. 7일

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 10월 22일 01:00 오후 베이징, 상하이

- Zoom 회의 참가
- https://us02web.zoom.us/j/87939423128?pwd=RTdKR2tVR3dBYmxNYVRsOWdya085dz09

- 회의 ID: 879 3942 3128
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +16465588656,,87939423128#,,,,*996282# 미국 (New York)
- +16699009128,,87939423128#,,,,*996282# 미국 (San Jose)

- 위치에 따라 전화 걸기
- +1 646 558 8656 미국 (New York)
- +1 669 900 9128 미국 (San Jose)
- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- +1 312 626 6799 미국 (Chicago)
- +1 346 248 7799 미국 (Houston)
- 회의 ID: 879 3942 3128
- 암호: 996282
- 현지 번호 찾기: https://us02web.zoom.us/u/kdosusS2

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다. 8일

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 10월 27일 01:00 오후 베이징, 상하이

- Zoom 회의 참가
- https://us02web.zoom.us/j/85930829727?pwd=WU44MFhPOWtrSHl4aXJvWmxqM0VaZz09

- 회의 ID: 859 3082 9727
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +13462487799,,85930829727#,,,,*484558# 미국 (Houston)
- +16465588656,,85930829727#,,,,*484558# 미국 (New York)

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- +1 346 248 7799 미국 (Houston)
- +1 646 558 8656 미국 (New York)
- +1 669 900 9128 미국 (San Jose)
- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- +1 312 626 6799 미국 (Chicago)
- 회의 ID: 859 3082 9727
- 암호: 484558
- 현지 번호 찾기: https://us02web.zoom.us/u/keqSmbLnOE

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다. 9일

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 10월 29일 01:00 오후 베이징, 상하이

- Zoom 회의 참가
- https://us02web.zoom.us/j/86081299354?pwd=QVpnMWorNDB3SU1ZT3dWVFZuY0JqUT09

- 회의 ID: 860 8129 9354
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
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- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- 회의 ID: 860 8129 9354
- 암호: 674753
- 현지 번호 찾기: https://us02web.zoom.us/u/kWtqQRa33

- Jung Heon Lee이(가) 예약된 Zoom 회의에 귀하를 초대합니다. 10일

- 주제: Bio-integrated Materials Science (JU)
- 시간: 2021년 11월 1일 09:00 오전 베이징, 상하이

- Zoom 회의 참가
- https://us02web.zoom.us/j/85929873448?pwd=bkFKL1Z1eG9mZEpOWTBHWEZLNjJJUT09

- 회의 ID: 859 2987 3448
- 암호: Ju1234
- 한 번의 탭으로 오디오 회의에 참가
- +13126266799,,85929873448#,,,,*126241# 미국 (Chicago)
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- +1 253 215 8782 미국 (Tacoma)
- +1 301 715 8592 미국 (Washington DC)
- 회의 ID: 859 2987 3448
- 암호: 126241
- 현지 번호 찾기: https://us02web.zoom.us/u/kcrvODfUxA