EMAC276 Polymer Properties & Design

Time:	MWF, 10:35P.M. - 11:25P.M., spring semester 2023
Location:	Kent Hale Smith 119
Instructor:	Dr. Lei Zhu, Professor of Macromolecular Science and Engineering Office: Kent Hale Smith (KHS), Room 312, Tel. (216)368-5861 Office hours: Mon. - Fri. 9:00A.M. - 5:30P.M. or by appointment Email: lxz121@case.edu Website: https://case.edu/engineering/groups/leizhu/
Co-Instructors:	Dr. Andrew Olah, Adjunct Professor Office: Kent Hale Smith (KHS), Room 423 Tel. O: 216-368-0606, C: 216-272-0505, Email: amo5@case.edu Office Hours: M-W-F (preferably by appointment)
Teaching Assistants:	Nathan Maslowski: Email: nam139@case.edu

Course Description (3 credits): The course reviews chemical and physical structures of a wide range of applications for synthetic and natural polymers, and addresses "Which polymer do we choose for a specific application and why?" We examine the polymer properties, the way that these depend on the chemical and physical structures, and reviews how they are processed. We aim to understand the advantages and disadvantages of the different chemical options and why the actual polymers that are used commercially are the best available in terms of properties, processability and cost. The requirements include several written assignments and one oral presentation.

Prerequisite: ENGR 145 and EMAC 270.

Course Objectives:

This course serves as an introduction to the synthesis, properties, design and applications of industrially relevant synthetic polymers, which include polyolefins (e.g., polyethylene and polypropylene), vinyl polymers [e.g., polystyrene, poly(vinyl chloride)], diene polymers (e.g., rubbers), polyesters, polyamides, polyimides, silicone polymers, polyurethanes, epoxy polymers, etc. We aim to achieve the following objectives:

i) Understand industrial scale synthesis of certain important polymers; ← Taught, not tested

ii) Understand the basic structure and properties of these polymers. These properties include thermal, mechanical, melt viscosity, and electrical properties;

iii) Know the design of polymeric materials and their applications. In particular, know how polymer products work.

iv) Be able to design a component (structural or otherwise) to be made from polymers, reflecting a practical understanding of ultimate thermal and mechanical properties of relevance to an application.

Optional Textbook:

D. Feldman and A. Barbalata, *Synthetic Polymers: Technology, Properties, Applications*; Chapman & Hall: London, 1996.

This book can be used as a general reading, and you are not required to purchase it. Some closely related chapters will be posted on Canvas. If you need the book, you can borrow through Case library (only one copy) or Ohiolink.

Study Groups:

Study groups will consist of ~5 students. The purpose of the study groups is to provide peer-support from the homework and to work as a team on a project related to materials specification and selection.

Grades:

Homework: 15%
In-class quizzes: 10%
Final design project: 15% (oral 7% + report 8%)
Mid-term and final exams: 30% + 30%

Homework Assignment and In-class Quizzes:
Given the nature of this course, which is qualitative and information-based, we do not intend to give conventional homework assignment. Instead, take-home reading materials or online searching will be used. Short essay and in-class quizzes will be used to assess the reading and searching results.

Homework will be collected one week after being assigned. Although the homework will be graded, the homework/quiz grades will represent only a small part (25%) of your final grade. The homework you turn in should be your work alone; however, you are encouraged to discuss the homework in study groups. Generally, we will not answer questions concerning the homework. We expect that you will learn the material better by working through the homework on your own or with the study group. Late homework will be penalized 4% per weekday or weekend (Saturday + Sunday). No homework will be accepted after May 1st, 2023.

Exams:
There will be two exams at the end of each teaching period by Prof. Olah and Prof. Zhu. These exams will not be cumulative.

Final Project:
Each study group is responsible for a project involving materials specification and selection. An oral presentation (10 min) will be given at the end of the class. Details will be announced in class.

Emphasis on Ethical Considerations:
Cheating in any formats in exams, quizzes, and homework assignment is strictly forbidden throughout the course. Whoever commits cheating will be fully responsible for the consequences.

EMAC 276 Polymer Properties & Design - 2023

Dates in 2023	Subjects	Homework
Jan. 17 – 27 (Dr. Olah)	**Introduction to Polymer Industry** **Hierarchical Structures** **Mechanical Properties of Polymers** Styrenic Polymers	Assignment #1 Due on Feb. 3
Jan. 30 – Mar. 10 (Dr. Olah) (Prof. Zhu will cover Feb. 3-10)	**Polyolefin Polymers** **Vinyl Polymers** Diene Polymers **Silicone Polymers**	Assignment #2 Due on Mar. 3
Mar. 10	**Exam #1**	
Mar. 13 - 17	Spring Break	
Mar. 20 – May 1 (Dr. Zhu)	Polyesters: Thermal Plastic and Thermosets	Assignment #3 Due on Mar. 31
Mar. 6 – May 1 (Dr. Zhu)	**Polyamides and Polyimides** **Polyurethanes** **Epoxy Polymers**	Assignment #4 Due on Apr. 14 Assignment #5 Due on Apr. 28
Apr. 28 and May 1	**Final Project Presentation:** Please use what you have learned in this course to design a polymer project that can replace wood, metals or ceramics	Final project report Due on May 1
May 4-11	**Exam #2**	
May 13	**Final Grades**	

Note: If possible, we will arrange two lab observations for: i) multilayer coextrusion of polymer films (Kent Hale Smith Bldg.) and ii) 3D printing of polymers (Thinkbox). These will help you understand some of the course content and broaden your knowledge.

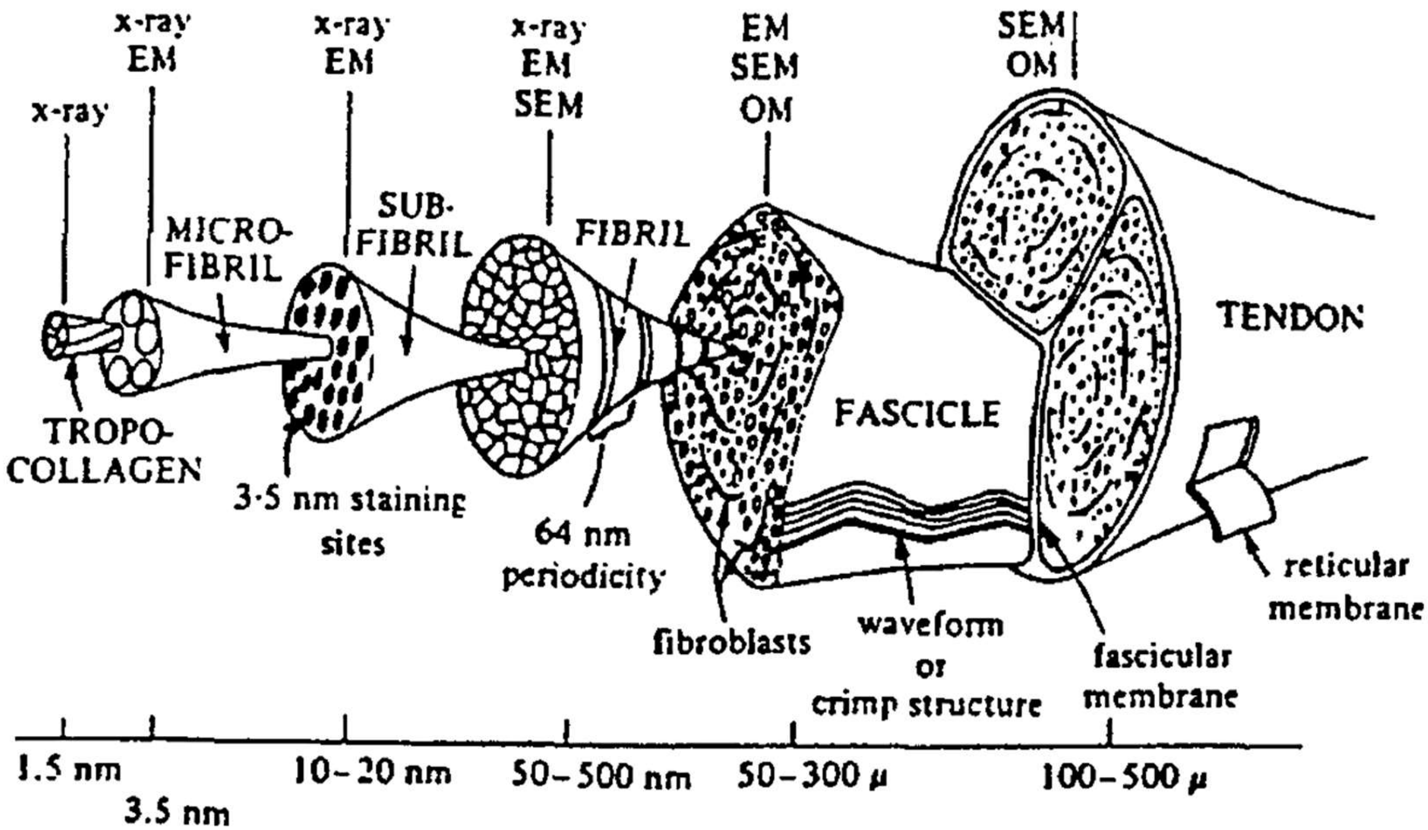
EMAC 276

Lesson 1 & 2:
Lessons From Biology: Hierarchical Structures

Prof. Eric Baer, Dr. Andy Olah, Prof. Lei Zhu

January 10 & 12, 2022

Example of a Biological Hierarchical Structure: Tendon (1978)



- **Tendons operate reversibly at uniaxial tension.**
- **The hierarchical structure absorbs energy and protects the tendon as a whole from catastrophic failure.**

Diamant, J., Keller, A., Baer, E. L. H. M., Litt, M., & Arridge, R. G. C. (1972). Proceedings of the Royal Society of London 180(1060), 293-315.
Dale, W. C., Baer, E., Keller, A., & Kohn, R. R. (1972Cellular and Molecular Life Sciences, 28(11), 1293-1295.
Niven H., Baer E., Hiltner A. (1982). Collagen Rel. Res.,2, 131-142.
Kastelic, J., Galeski, A., Baer, E. (1978). Connective tissue research, 6(1), 11-23.
Lakes R. Nature. (1993), 361(6412):511-5.

What is Meant by Hierarchical Structure

Quiz

- Hierarchical structures are assemblages of molecular units or their aggregates that are embedded or intertwined with other phases, which in turn are similarly organized at increasing size levels

- Such multilevel architectures are capable of conferring unique properties to the structure. Hierarchical structures can be prepared from metals, ceramics, or polymers, or from hybrids of various classes of these materials.

- The unifying theme for all types of materials is the pervasiveness of hierarchical structures in practically all complex systems, particularly naturally occurring ones.

Design Principle in Biological Materials:
Rules for Complex Assemblies (1994)

Known

1. Scale

- The structure is organized in discrete levels or scales.

2. Interaction

- The levels of structural organization are held together by specific interactions between components.

3. Architecture

- Highly interacting levels are organized into an oriented hierarchical composite system that is designed to meet a complex spectrum of functional requirements.
- The more complex the structure, the more functions it has.

Tirrell, D. A., Aksay, I., Baer, E. et al. (1994). Hierarchical structures in biology as a guide for new materials technology. National Academy of Sciences, Washington DC.

Outline

1. Hierarchical Structures in Animals

a. Mammalian Hierarchical Systems

b. Photonic Layered Systems — Butterfly Wings

c. Inorganic/Organic Layered System — Nacre Shells and Bone

2. Hierarchical Structures in Plants

3. Polymeric Hierarchical Structures and Others

4. Complex Assembly in Biological Materials

Outline

1. Hierarchical Structures in Animals

a. **Mammalian Hierarchical Systems**

i. Tendon

ii. Human Hair

b. Photonic Layered Systems

c. Inorganic/Organic Layered Systems

2. Hierarchical Structures in Plants

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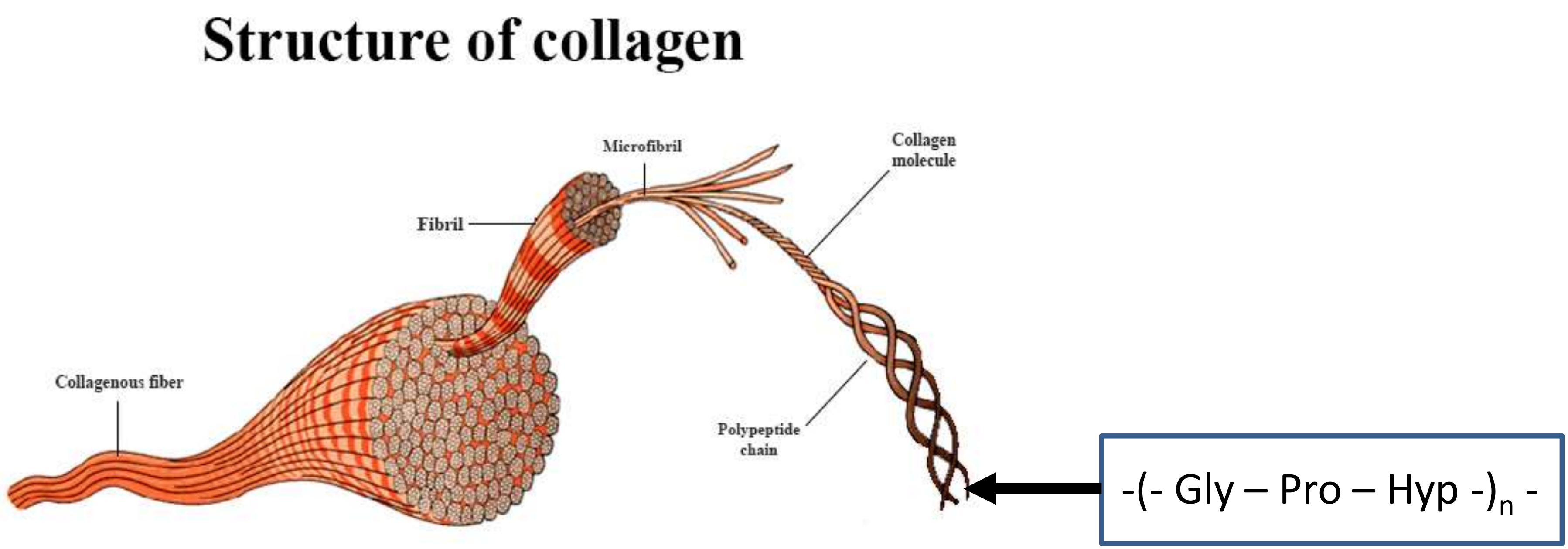
Uniaxial Mechanical System: Tendon

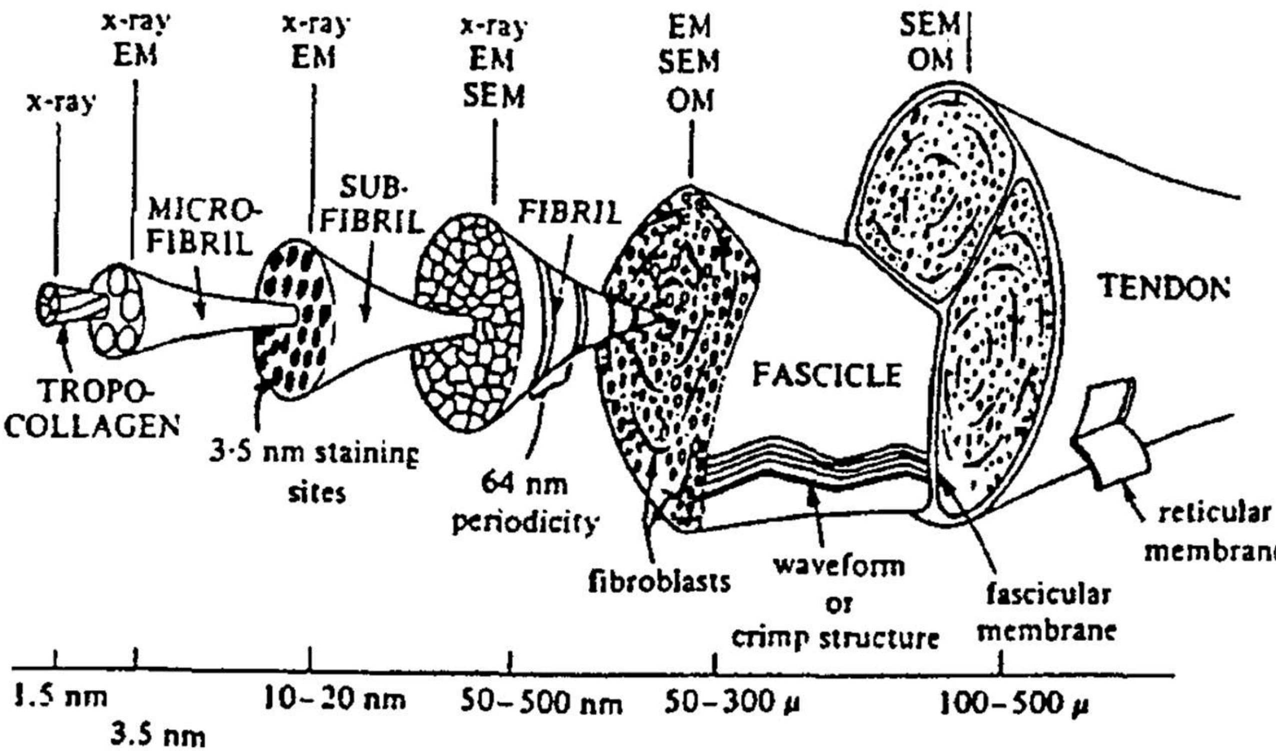


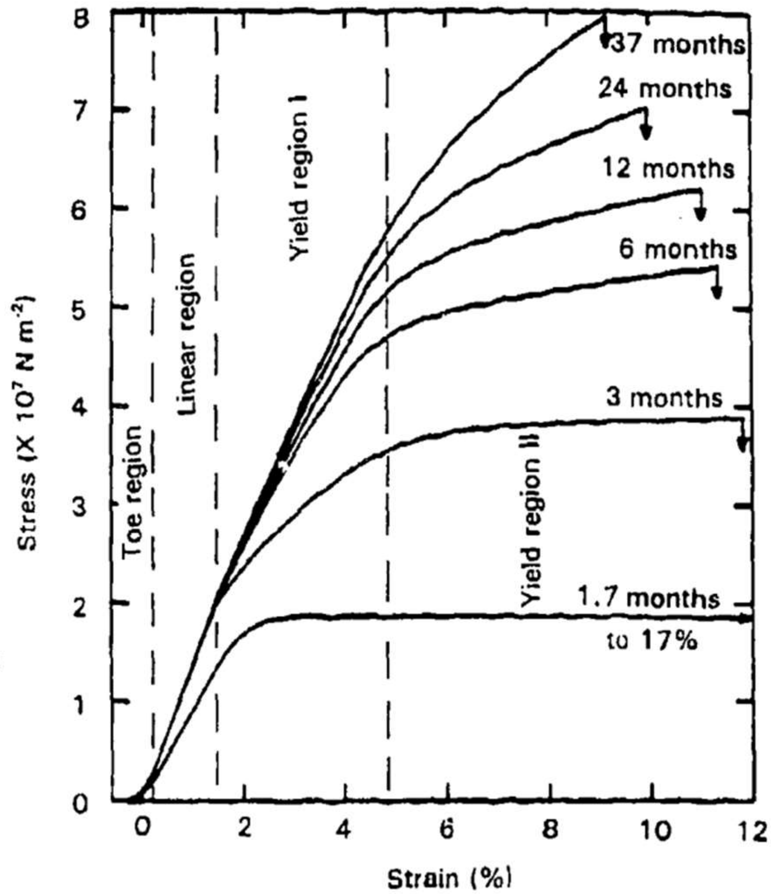
Collagen consists of three polypeptide chains. These so-called α-chains are wrapped around each other to form triple-helical macromolecules: a unique structure, size and amino acid sequence.

In collagenous sequences, glycine (Gly) is present as every third residue. This enables the formation of the three chains into a triple-helical structure. Thus, the common feature for all collagens is a sequence that can be expressed as (Gly-X-Y)*n, where X and Y are frequently represented by proline (Pro) and hydroxyproline (Hyp), respectively.

This sequence is necessary for the collagen to assemble the fibrils that subsequently form fibers, providing unmatched structural integrity for the extracellular matrix of conjunctive tissues.

Uniaxial Mechanical System: Tendon (1978)



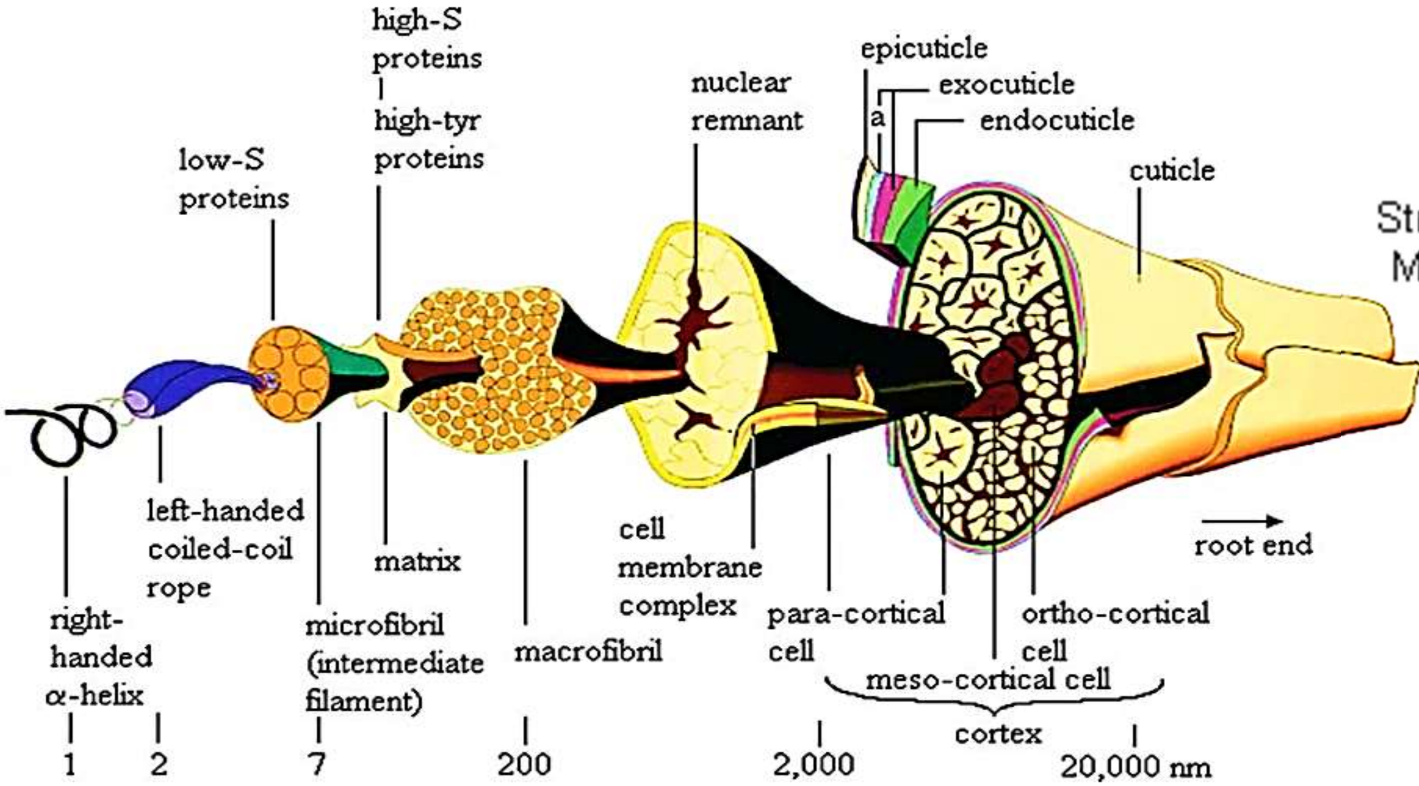


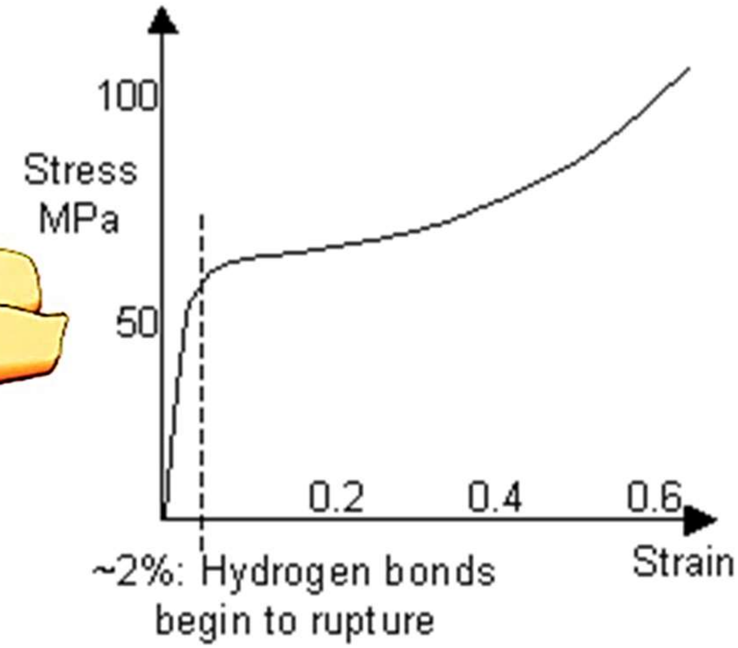
Stress-strain behavior of rat tail tendon as a function of age

- **Tendons operate reversibly at uniaxial tension.**
- **The hierarchical structure absorbs energy and protects the tendon as a whole from catastrophic failure.**

Diamant, J., Keller, A., Baer, E. L. H. M., Litt, M., & Arridge, R. G. C. (1972). Proceedings of the Royal Society of London 180(1060), 293-315.
Dale, W. C., Baer, E., Keller, A., & Kohn, R. R. (1972Cellular and Molecular Life Sciences, 28(11), 1293-1295.
Niven H., Baer E., Hiltner A. (1982). Collagen Rel. Res.,2, 131-142.
Kastelic, J., Galeski, A., Baer, E. (1978). Connective tissue research, 6(1), 11-23.
Lakes R. Nature. (1993), 361(6412):511-5.

Uniaxial Mechanical System: Human Hair (2002)





- Hair is a proteinaceous fiber with a strongly hierarchical organization of subunits, from the α-keratin chains, via intermediate filaments, to the fiber.
- Human hair is stronger than Nylon 6 fiber.

Astbury, W., Street, A., (1931). General. Phil. Trans. Roy. Soc. A 230, 75–101.
Popescu, C., Höcker, H. (2007). Chemical Society Reviews, 36(8), 1282-1291.
Feughelman, M. (2002). Journal of Applied Polymer Science, 83(3), 489-507.

Outline

1. Hierarchical Structures in Animals

a. Mammalian Hierarchical Systems

b. Photonic Layered Systems

i. Butterfly wings
ii. Beetle elytra
iii. Inorganic/Organic Layered Systems

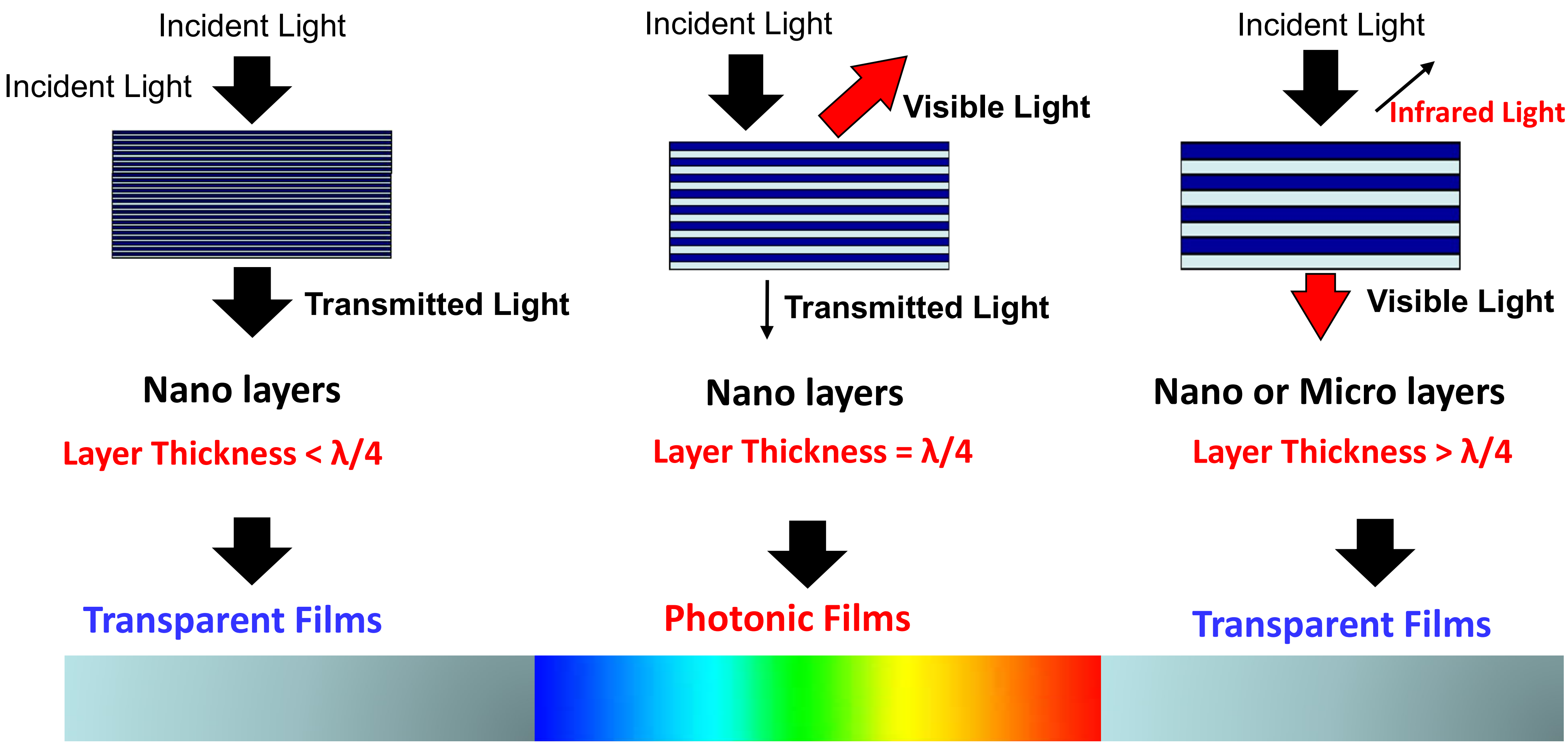
2. Hierarchical Structures in Plants

3. Complex Assembly in Biological Materials

4. Polymeric Hierarchical Structures and Others

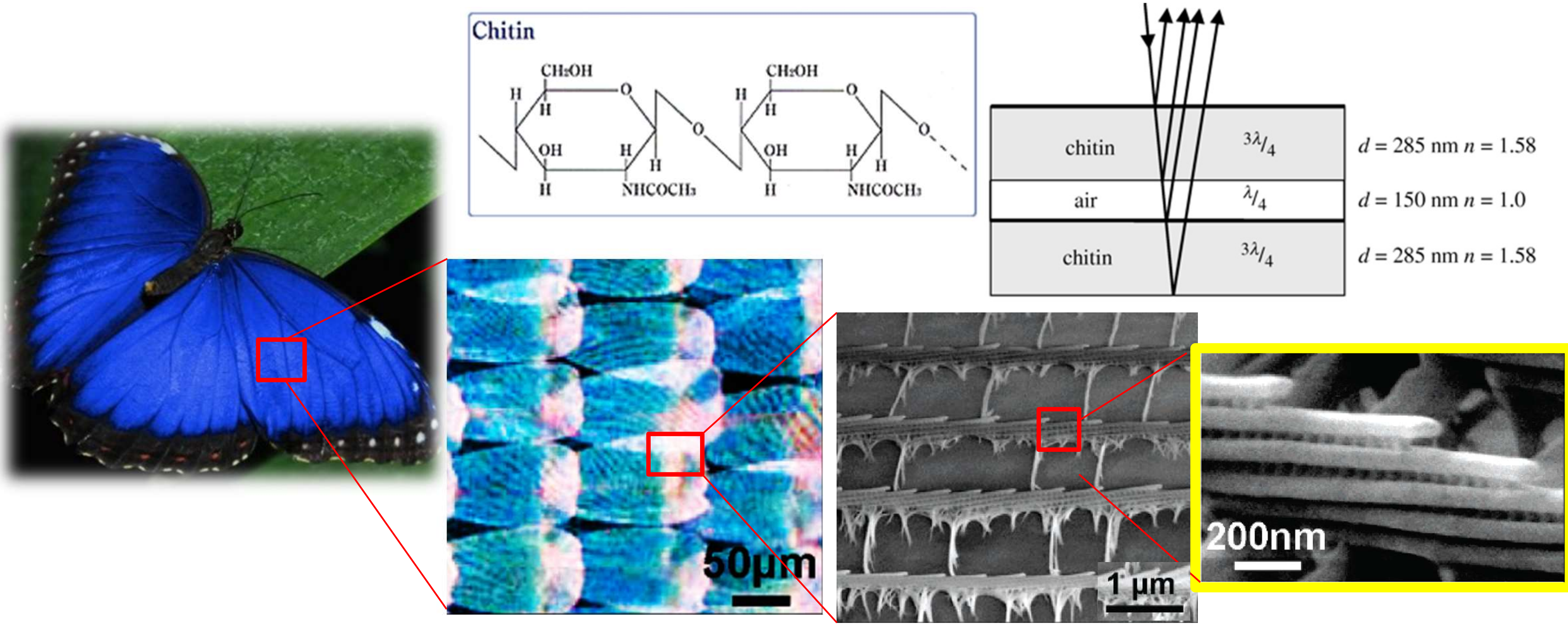
Optical Effects in Multilayer Structures

n_A-n_B ≥0.05, λ=visible light



- **The optical effects of multilayered structures change with layer thickness.**

Photonic Layered Systems: Butterfly Wings



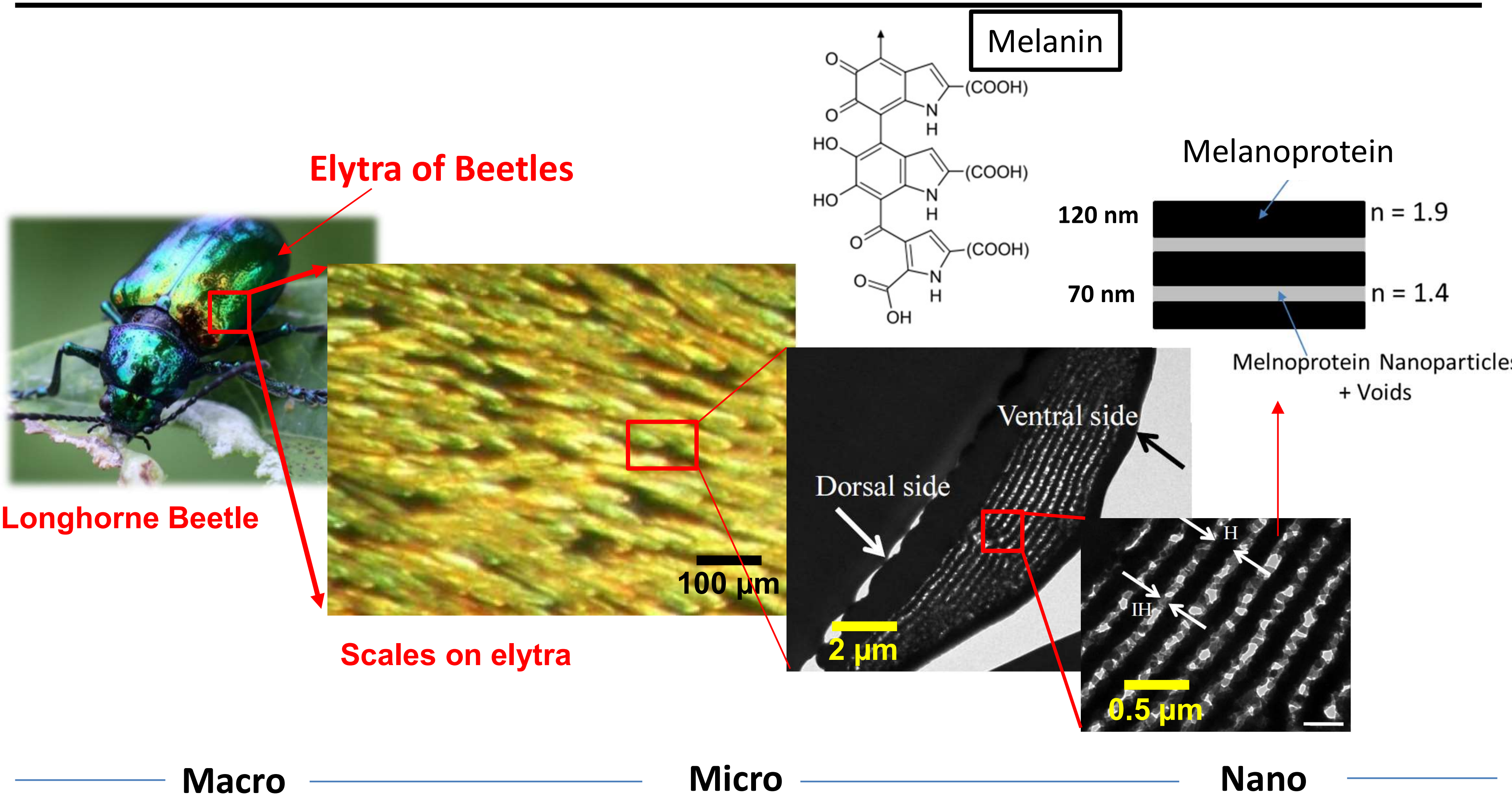
Morpho retenor — Scales in Butterfly Wing — Lamellar Structure — Periodic Layered Structure

Macro — Micro — Nano

- **Periodic structure creates photonic band gap that gives brilliant blue color.**
- **Periodicity is different in different butterflies, thus giving different color to their wings.**

Liu, X., Zhang, S., Zhang, H. (2016). Optik, 127(4), 1729-1733.
Huang, J., Wang, X., Wang, Z. (2006). Nano letters, 6(10), 2325-2331.

Photonic Layered Systems: Elytra of Beetles



- The iridescent coloration of scales originates from a multilayer structure.
- Scales, being hydrophilic, change color upon swelling in wet state.
- The elytra changes color under stress condition, e.g. presence of pray.

Liu, F., Dong, B., Liu, X., Zheng, Y., Zi, J. (2009). Optics express, 17(18), 16183-16191.
Gebeshuber, I., Lee, D. (2012). Nanostructures for coloration

Outline

1. Hierarchical Structures in Animals

a. Mammalian Hierarchical Systems

b. Fibrillar System

c. Photonic Layered Systems

d. Inorganic/Organic Layered Systems

i. Nacre Shell
ii. Bone

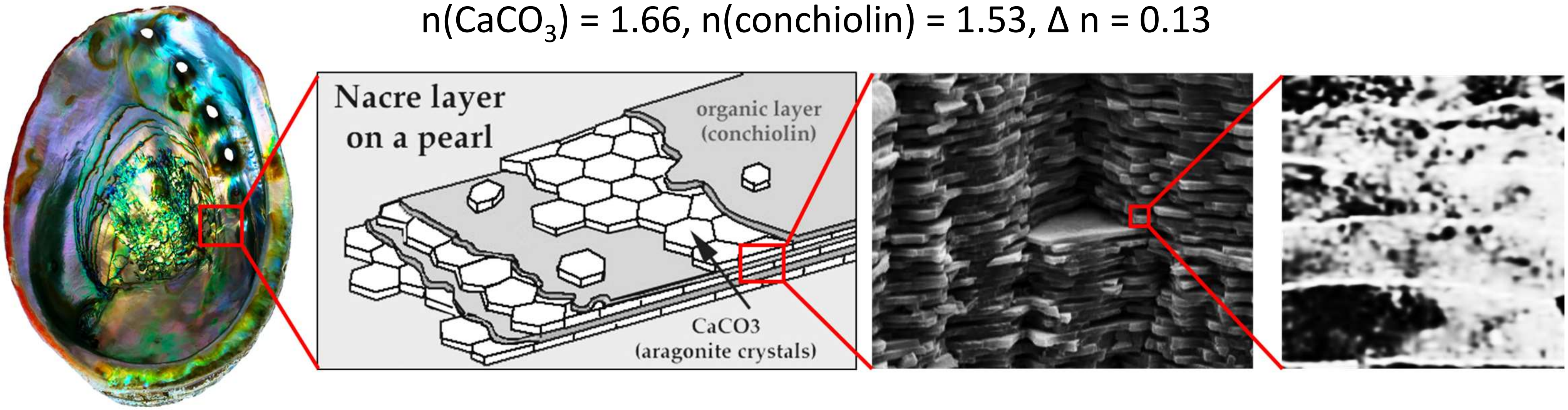
2. Hierarchical Structures in Plants

3. Polymeric Hierarchical Structures and Others

4. Complex Assembly in Biological Materials

Organic/Inorganic Layered System: Nacre Shell

n($CaCO_3$) = 1.66, n(conchiolin) = 1.53, Δ n = 0.13



Abalone Shell

'Brick & Mortar Structure' of Nacre Sheet

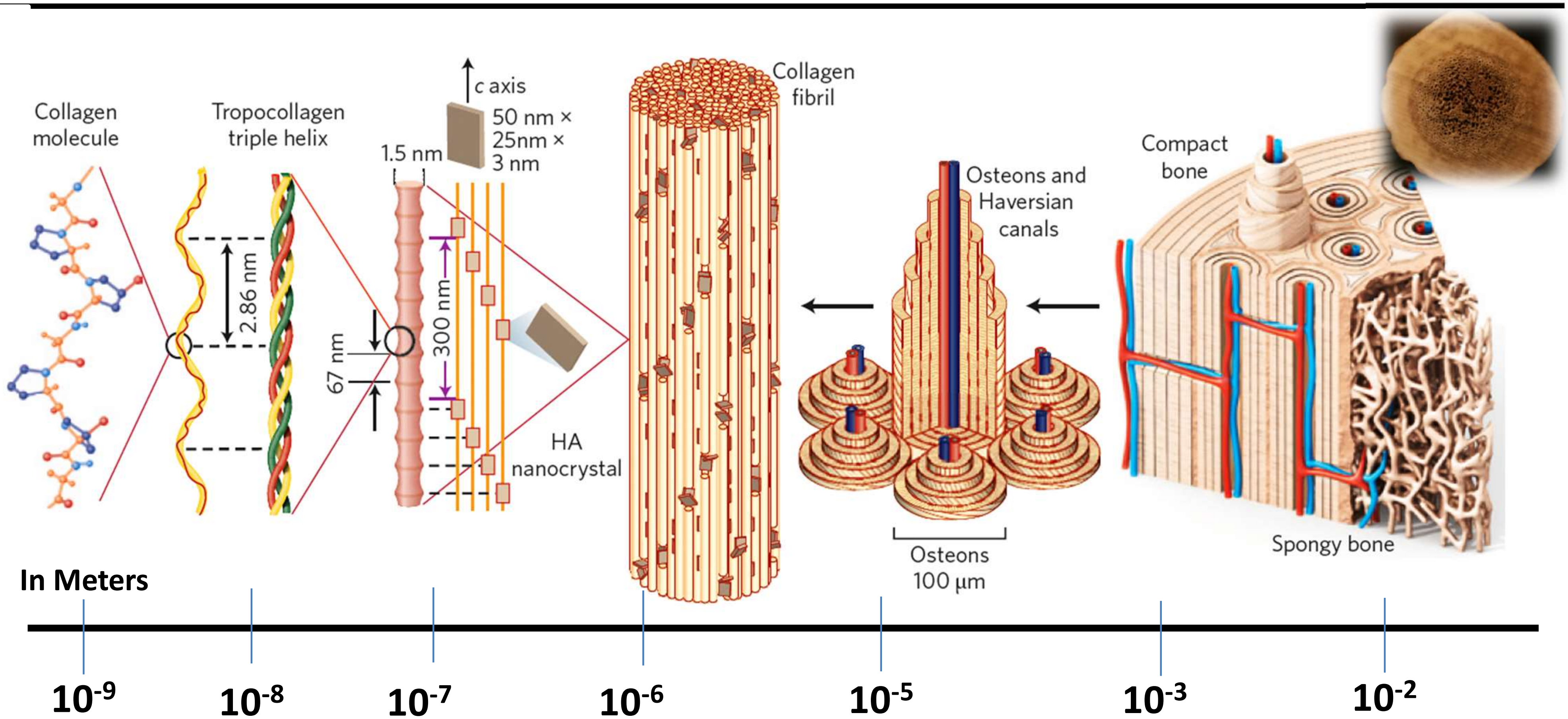
Aragonite Platelets

Layers of Aragonite Tablets

- **The organic content act as the ductile fraction preventing crack growth**
- **Elastic moduli at dry and wet state are 70 and 60 GPa, respectively.**
- **Tensile strength at dry and wet states are 170 and 130 MPa, respectively.**
- **The flexural strength of nacre, between 100 and 200 MPa, is comparable to that of many common ceramics.**

Barthelat F. Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences. 2007 Dec 15;365(1861):2907-19.
Barthelat F, Tang H, Zavattieri PD, Li CM, Espinosa HD. Journal of the Mechanics and Physics of Solids. 2007 Feb 28;55(2):306-37.
Sun J, Bhushan B. Hierarchical structure and mechanical properties of nacre: a review. Rsc Advances. 2012;2(20):7617-32.

Organic/Inorganic Layered Systems: Bone



- **Bone is highly fracture resistant due to its complex hierarchical structure both at the exterior and interior.**
- **The Young's modulus of cortical bone varies from 8 to 24 GPa.**

Meyers, M., Chen, P., Lin, A. Y., Seki, Y. (2008). Prog. in Mat. Sci., 53(1), 1-206.
Wegst, U., Bai, H., Saiz, E., Tomsia, A., Ritchie, R. (2015). Nature materials, 14(1), 23-36.

Outline

1. Hierarchical Structures in Animals

a. Mammalian Hierarchical Systems
b. Photonic Layered Systems
c. Inorganic/Organic Layered Systems

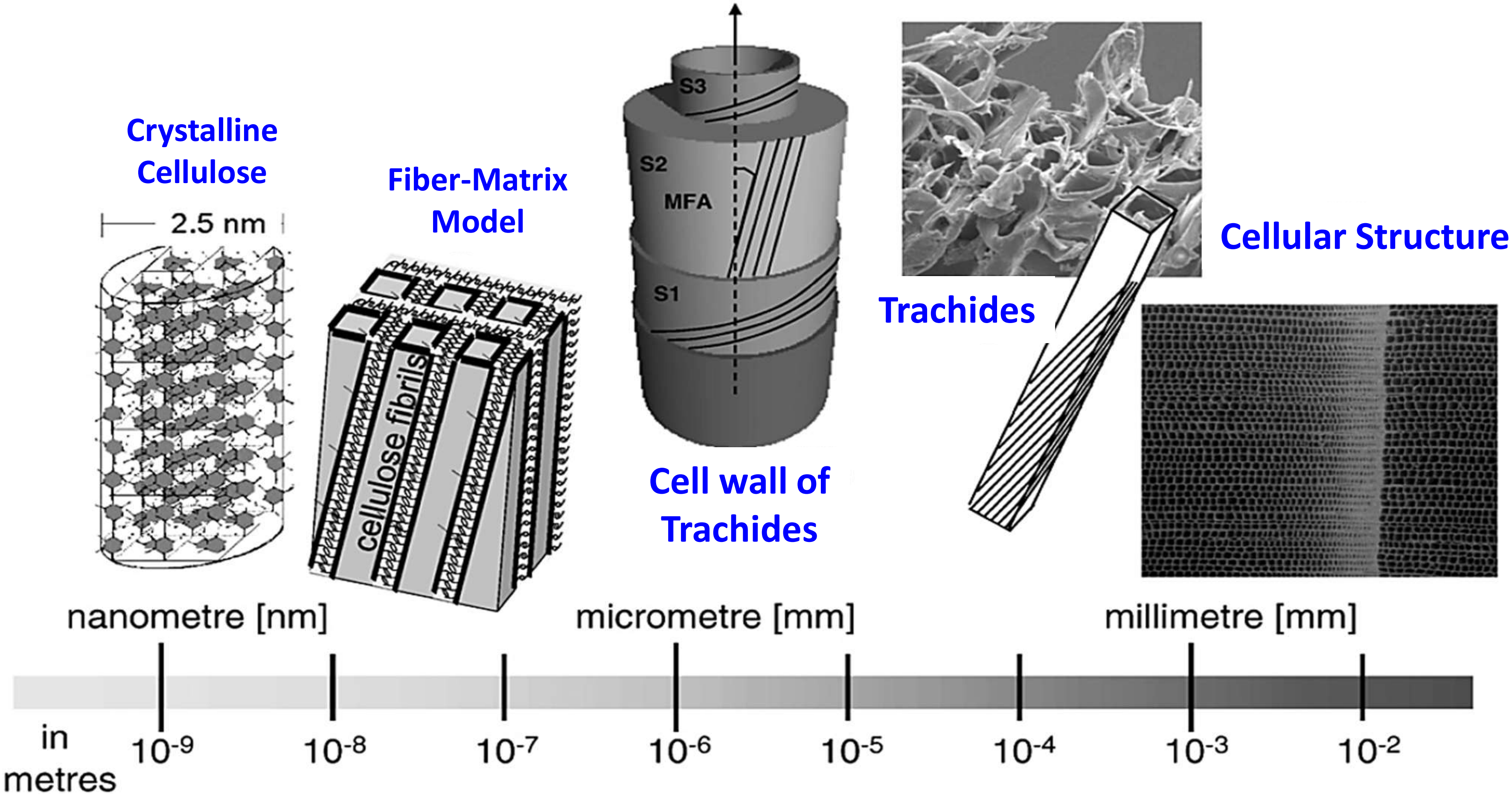
2. Hierarchical Structures in Plants

i. Wood Cellulose
ii. Bamboo

3. Polymeric Hierarchical Structures and Others

4. Complex Assembly in Biological Materials

Hierarchical Structures in Plants: Wood Cellulose



- **The mechanical properties of wood are highly anisotropic due to the preferred orientation of cellulose fibrils (parallel to the trunk).**
- **The stiffness and strength are greatest in the axial direction by a factor of 2–20 than that in the radial and tangential directions, depending on the species.**

Gibson, L., Ashby, M. (1999). Cellular solids: structure and properties.
Meyers, M., Chen, P., Lin, A. Y., Seki, Y. (2008). Prog. in Mat. Sci., 53(1), 1-206.

Hierarchical Structures in Plants: Wood Cellulose

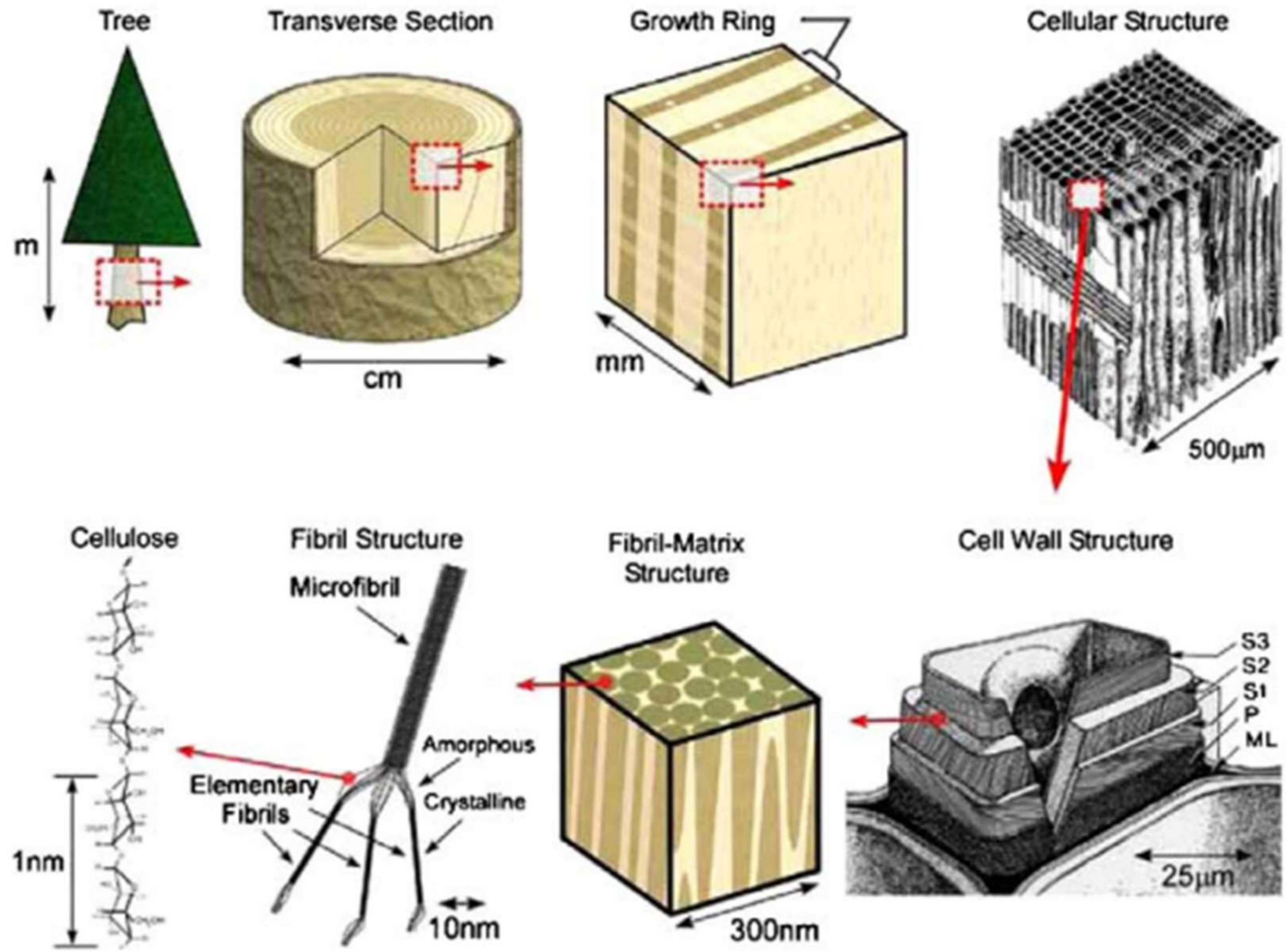


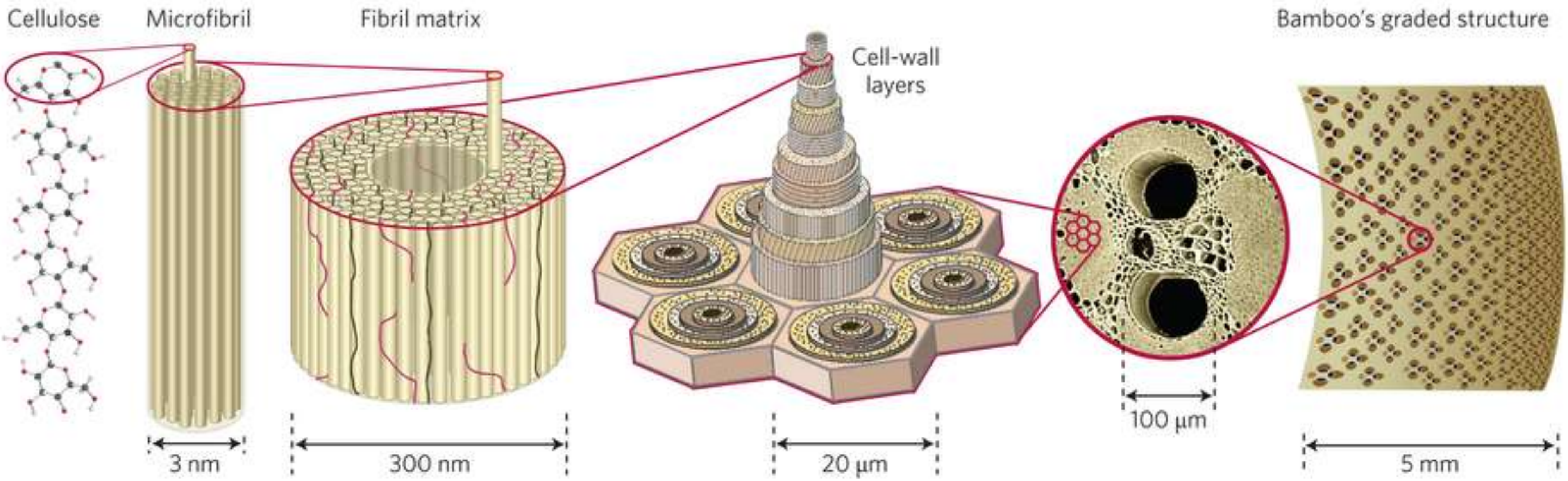
Figure 1. Structure of wood from the tree to the CNCs (after [2]). ML = middle lamellae between tracheids, P = primary cell wall, S1, S2, S3 = cell wall layers.

Meas. Sci. Technol. **22** (2011) 024005 (10pp) doi:10.1088/0957-0233/22/2/024005

Development of the metrology and imaging of cellulose nanocrystals

Michael T Postek[1,4], András Vladár[1], John Dagata[1], Natalia Farkas[1], Bin Ming[1], Ryan Wagner[2], Arvind Raman[2], Robert J Moon[2,3], Ronald Sabo[3], Theodore H Wegner[3] and James Beecher[3]

Hierarchical Structures in Plants: Bamboo

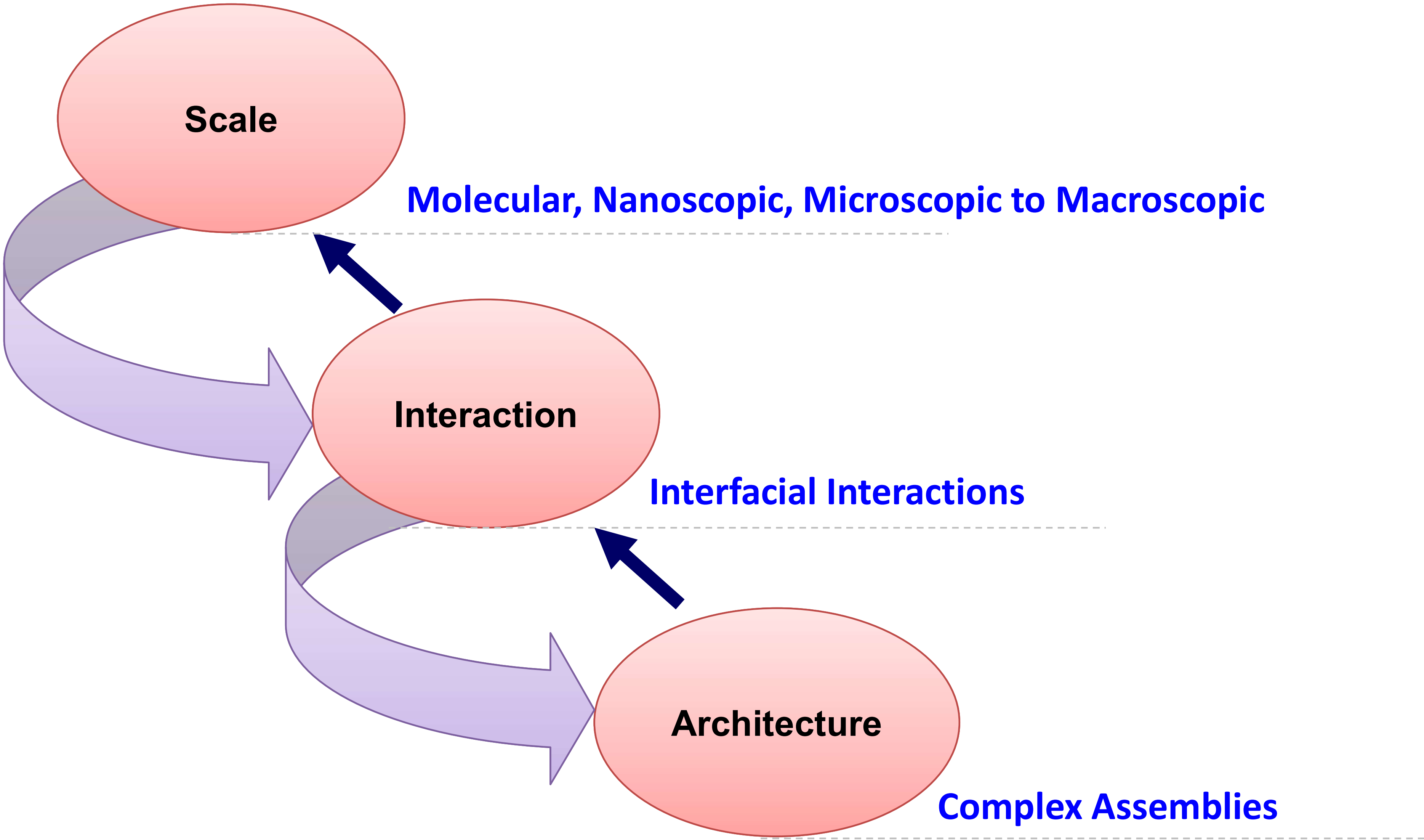


Porosity ~50%

- **The hierarchical structure of bamboo comprises three fundamental tissues named epidermis, vascular bundles and parenchyma ground.**
- **Graded cellular structure can be observed in bamboo culm. The size of cellular vascular bundles is bigger (~400 μm) near the core and smaller (150μm) near the epidermis .**
- **Each vascular bundle can be identified as subcellular structure. The diameter of cells is ~100μm.**

Habibi, M. , Lu, Y. (2014). Scientific reports, 4.
Wang, X., Ren, H., Zhang, B., Fei, B., Burgert, I. (2011). Journal of the Royal Society Interface, 0462.
Wegst, U., Bai, H., Saiz, E., Tomsia, A., Ritchie, R. (2015). Nature materials, 14(1), 23-36.

Important Components of Hierarchical Structures



Tirrell, D. A., Aksay, I., Baer, E. et al. (1994). Hierarchical structures in biology as a guide for new materials technology. National Academy of Sciences, Washington DC.

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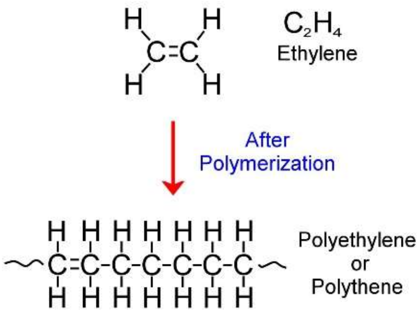
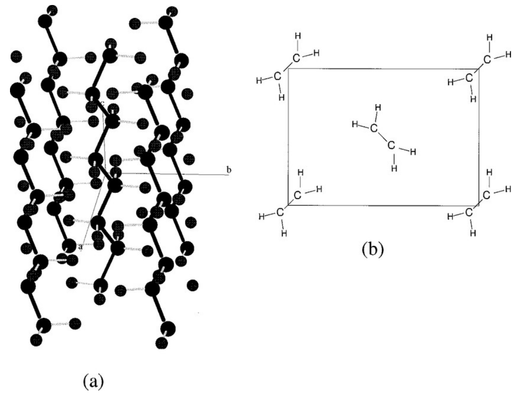
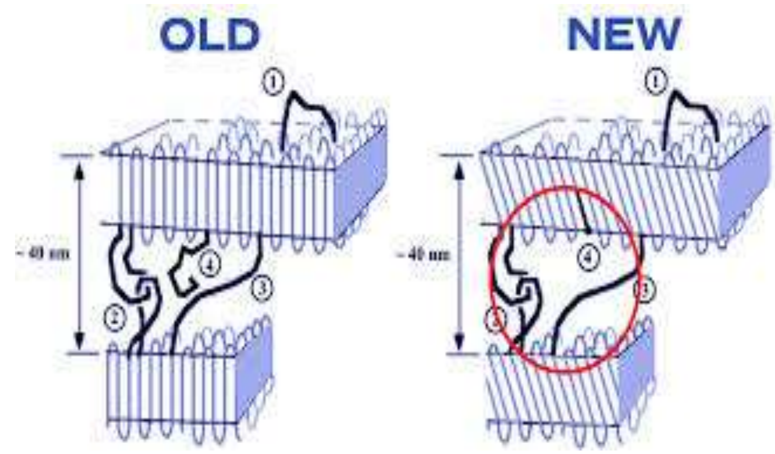
Polymeric Hierarchical Structure: Spherulites





PE Unit Cell - orthorhombic
a = 0.74069 nm
b = 0.49491 nm
c = 0.25511 nm
c – chain axis



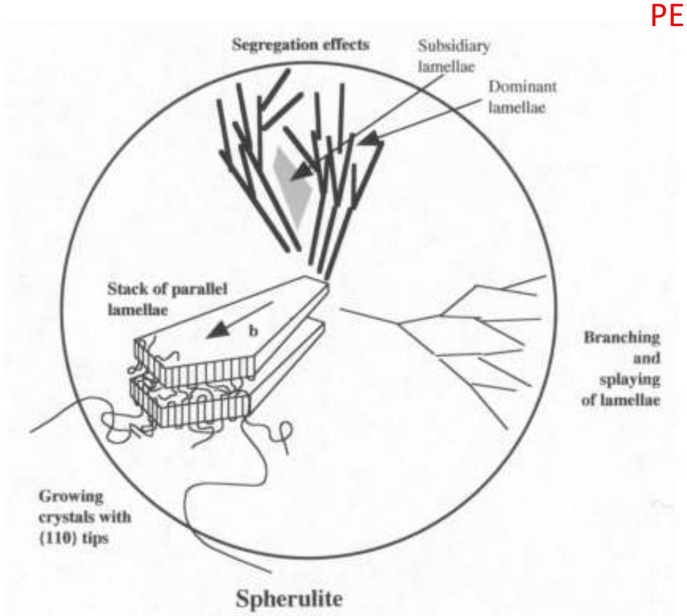
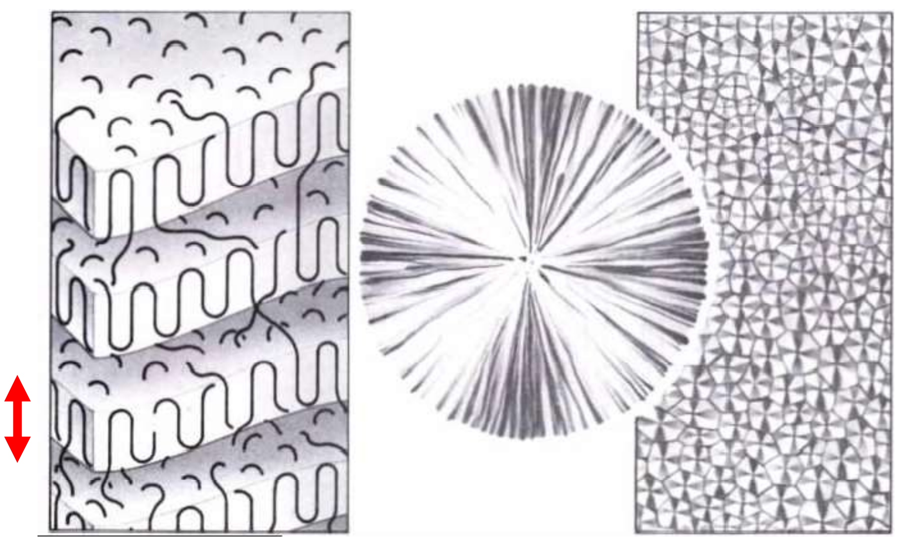


Fig. 6.8. Schematic drawing of the morphological hierarchy of a polyethylene spherulite.

10 nm ~ 100 nm



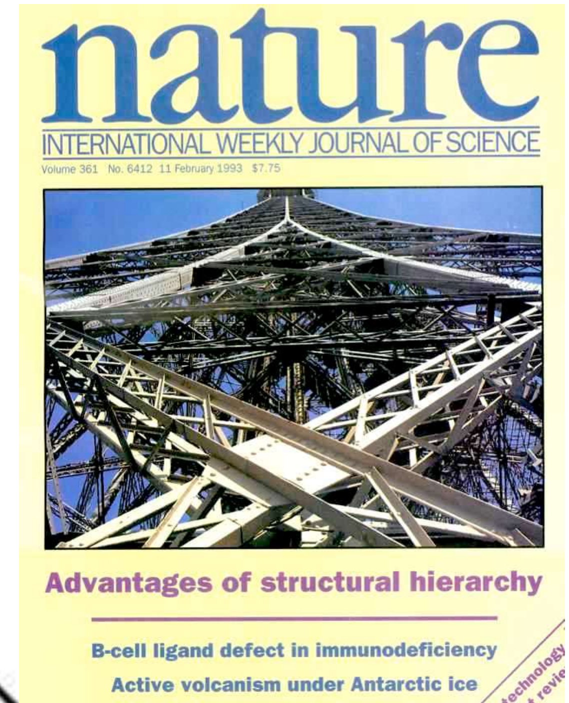
10 µm ~ 500 µm

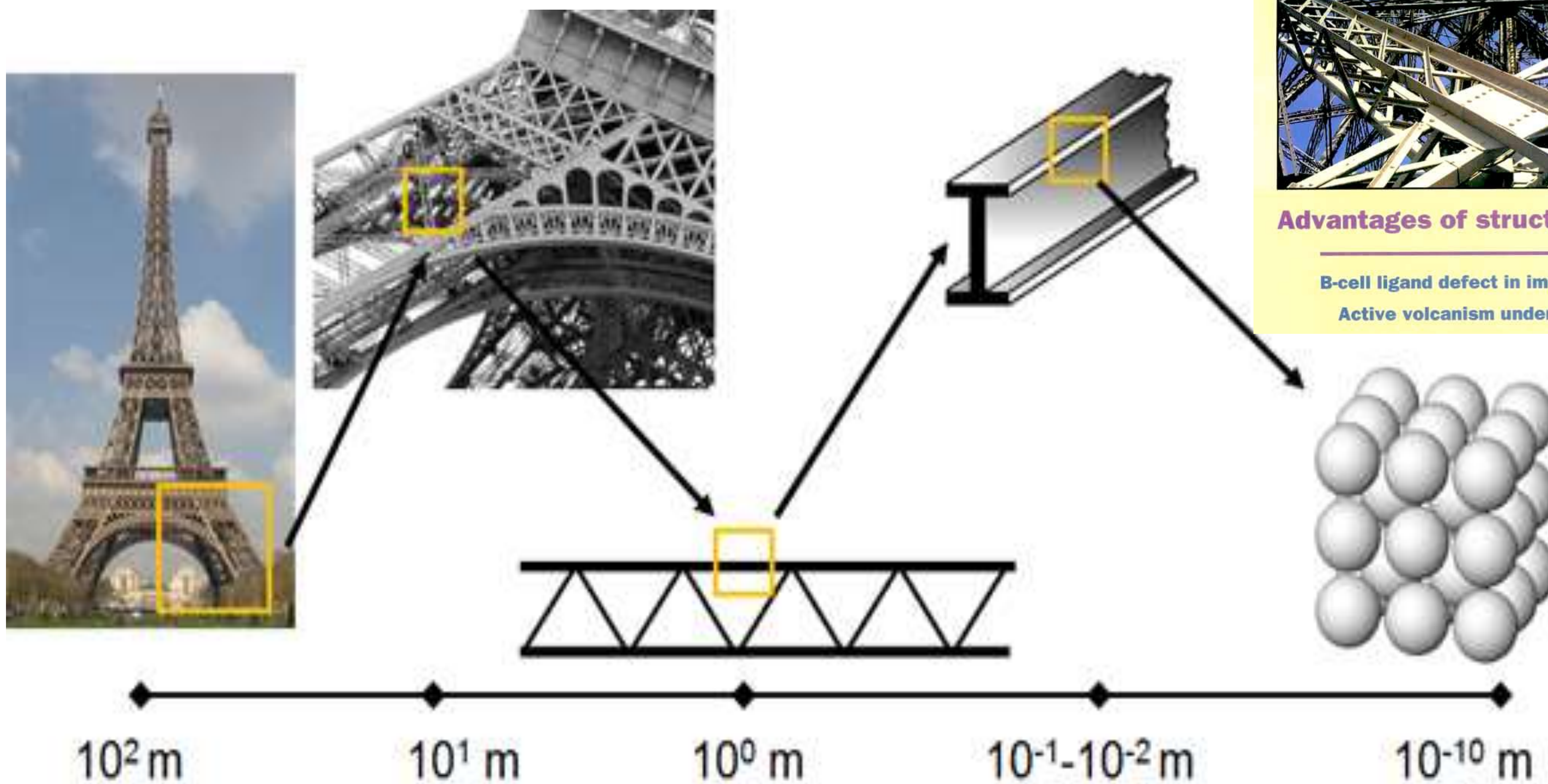
Spherulitic Structure of Semi-crystalline Materials

Sunburst-like structures formed as the polymer solidified and crystal growth began at nucleation points and radiated outward.

Baer, E. (1986). Advanced polymers. Sci. Am.;(United States), 255(4).

Hierarchical Structure of Eiffel Tower

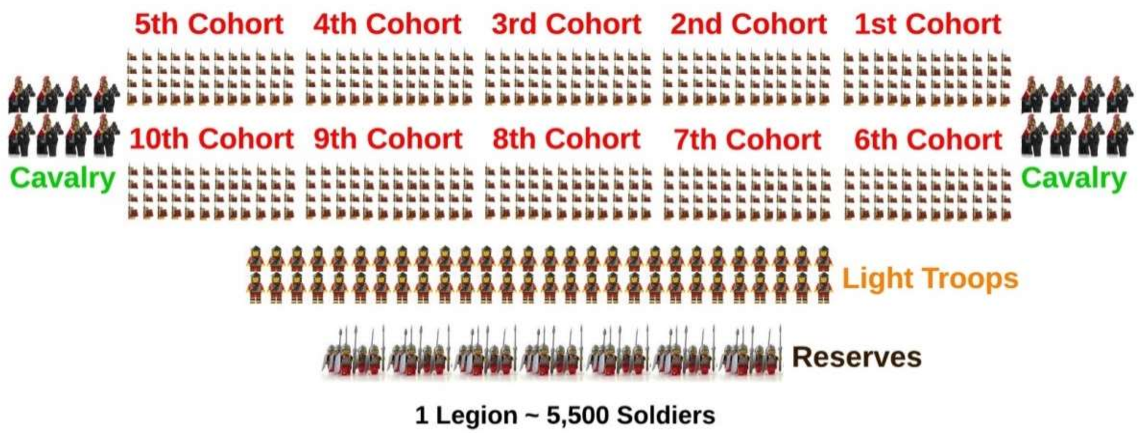




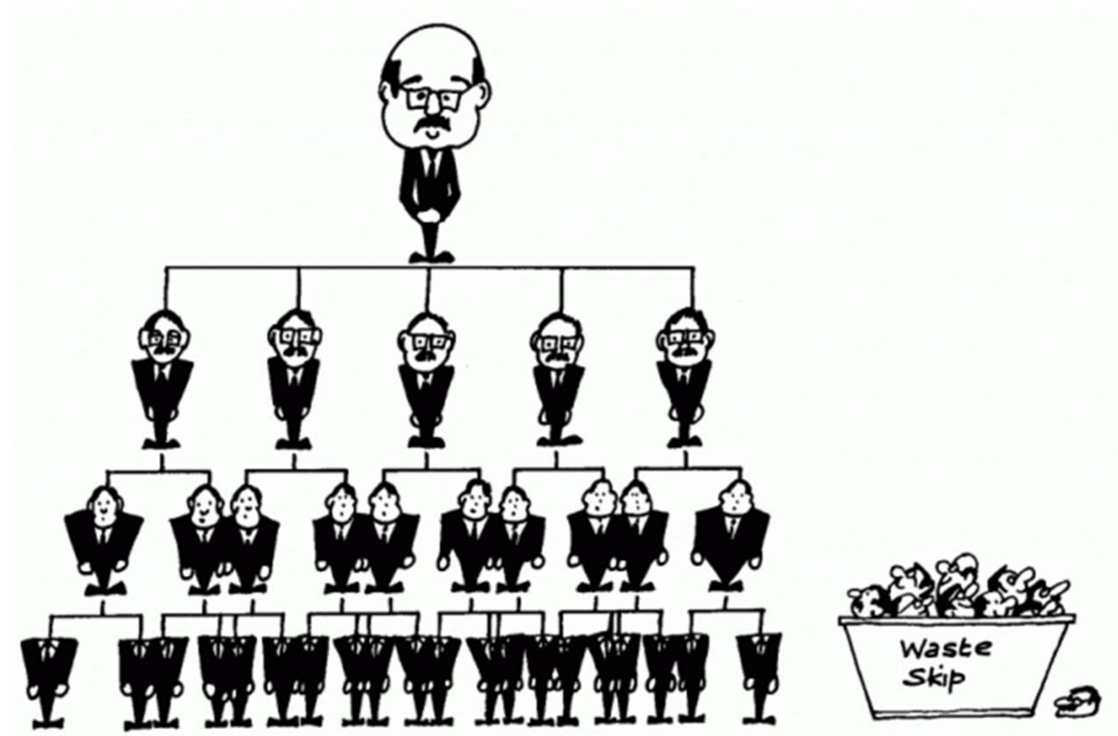
http://www.iupui.edu/~bbml/boneintro.shtml

Hierarchical Structure in Management

Formation of Roman Army
(200 BC)
1 Century = 80 Soldiers
1 Cohort = 6 Centuries



Hierarchy of Modern Enterprises



Forbes.com

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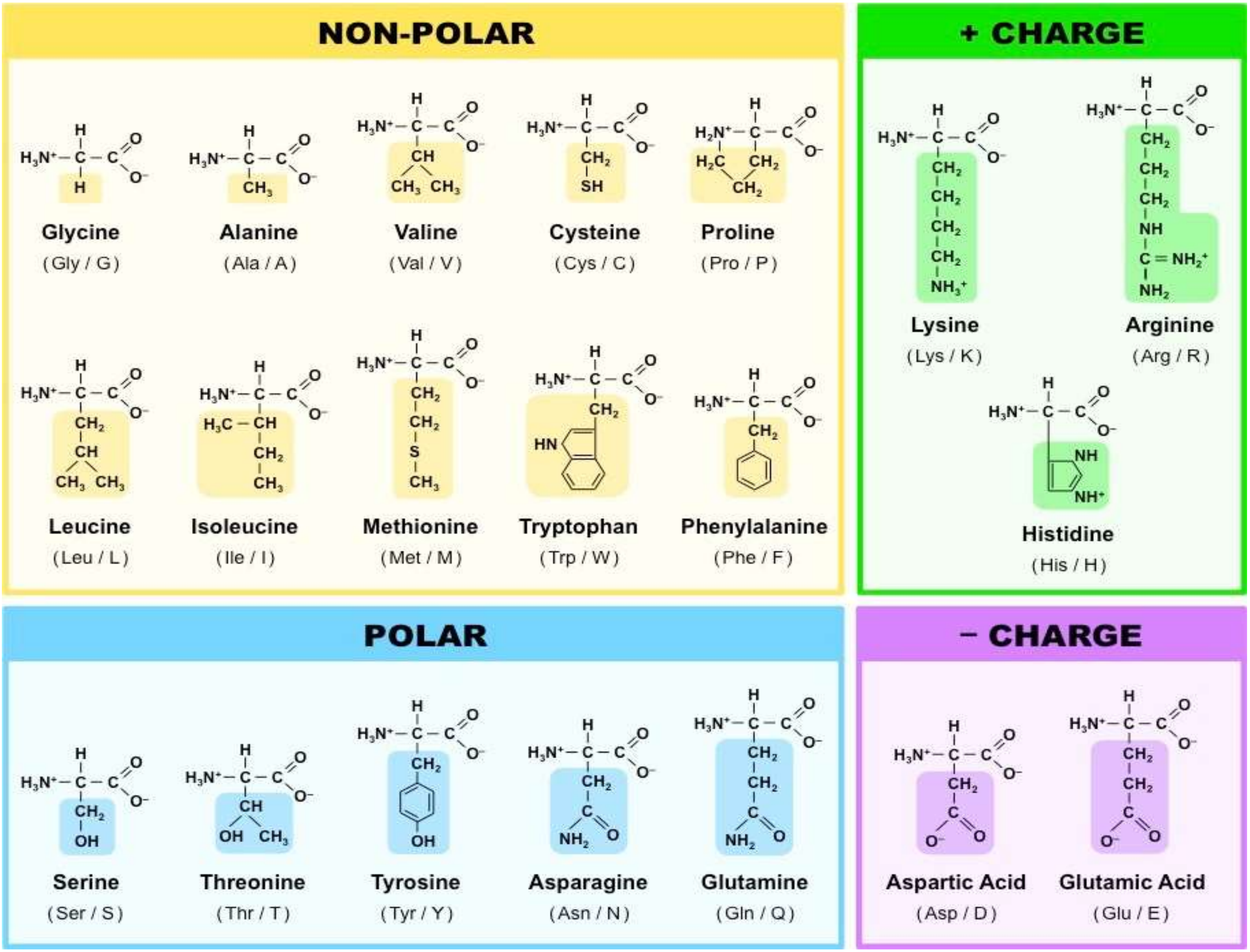
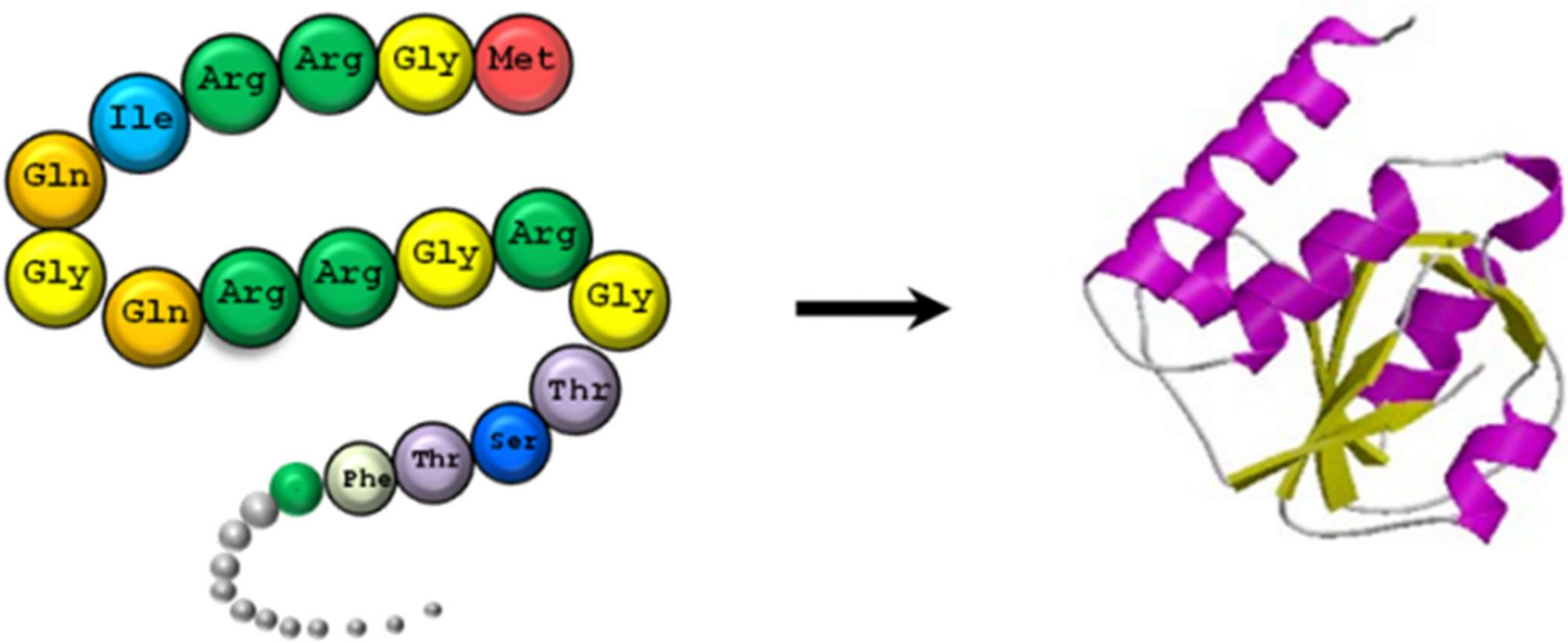
Protein Hierarchical Structures are Based on Amino Acid Sequence

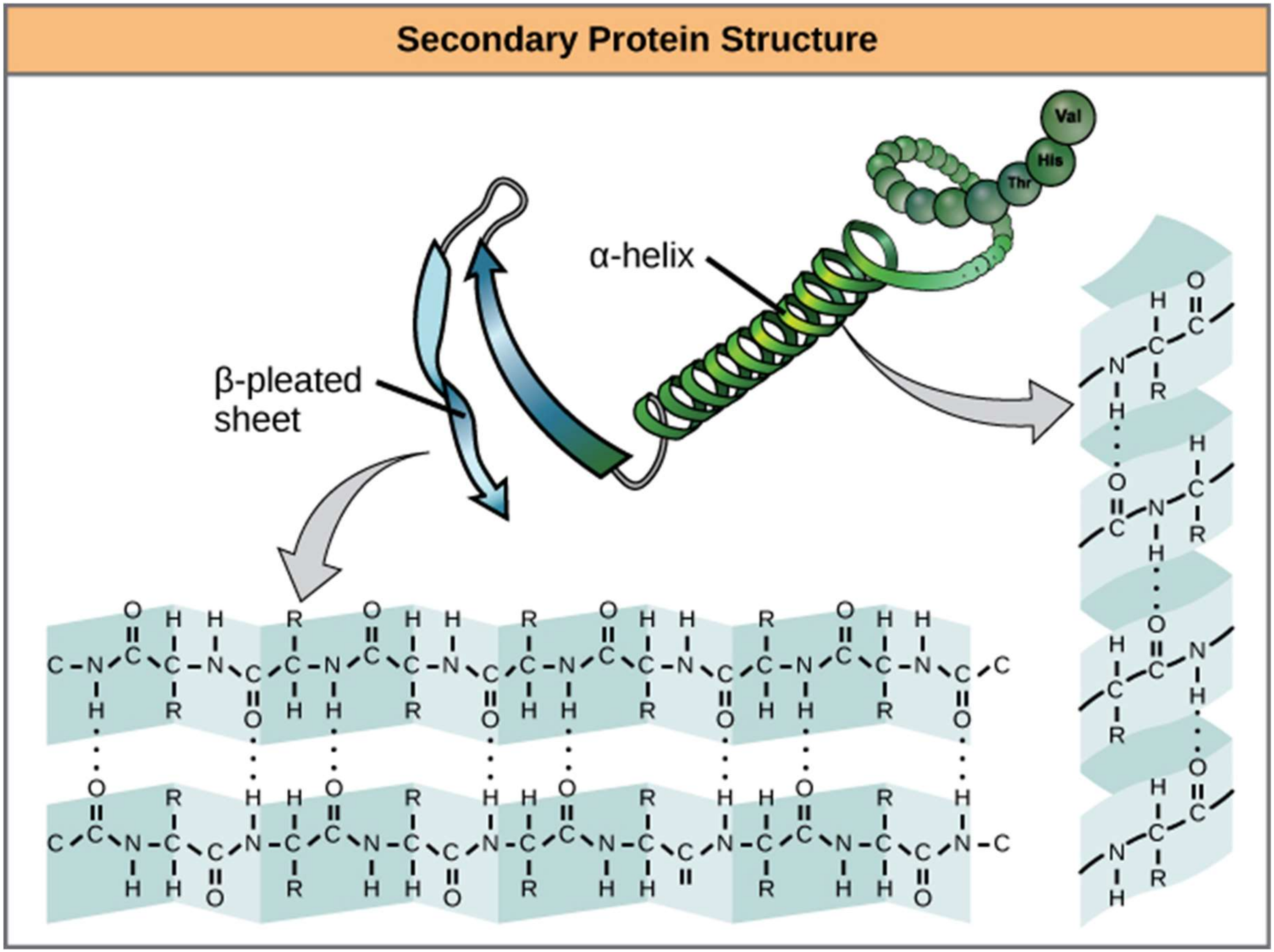


A Linear Sequence of a Large Number of Amino Acids Forms the Primary Protein Structure

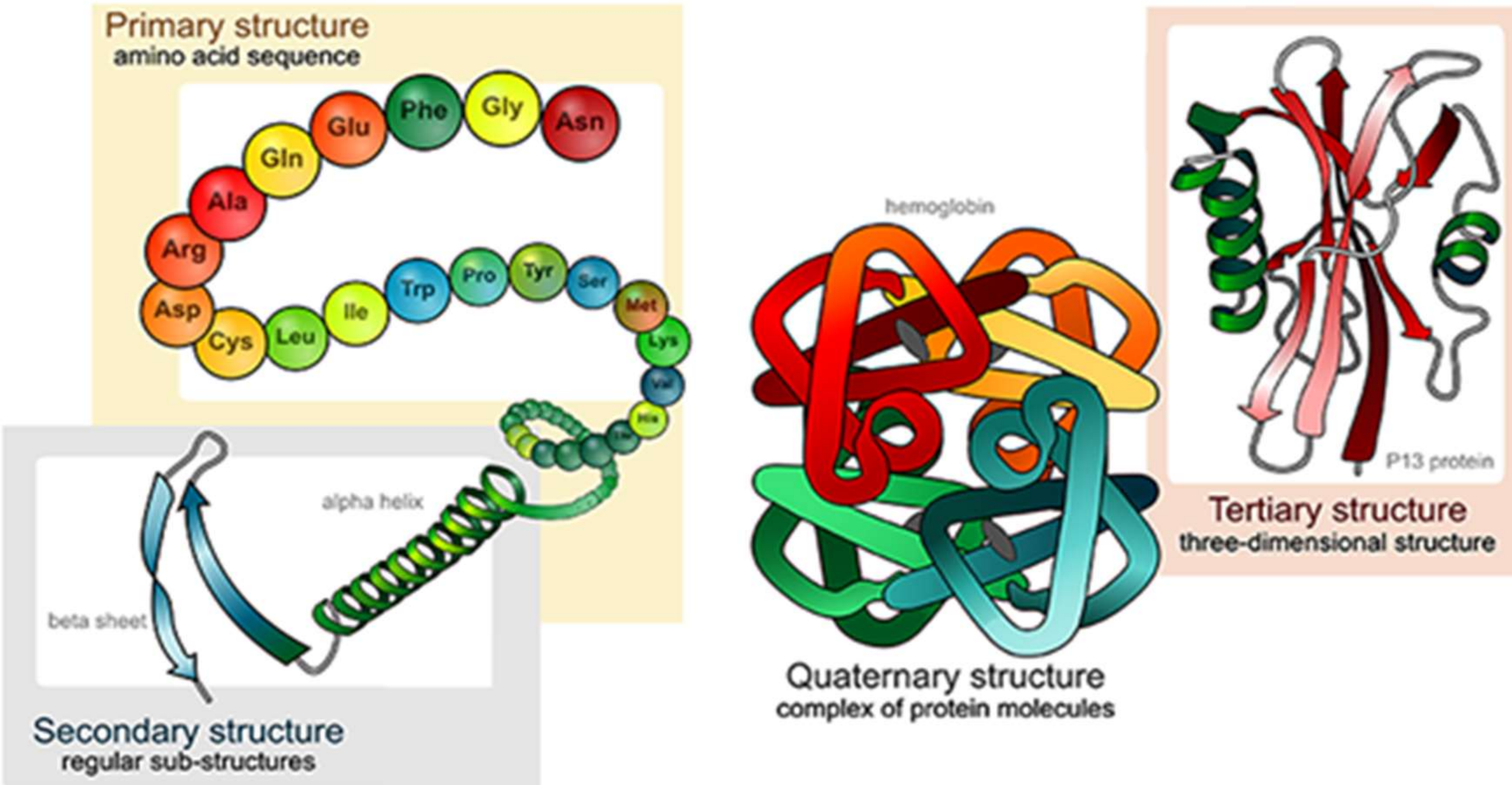


The Intramolecular Interactions Among Specific Segments of the Amino Acids in the Primary Structure Forms the Secondary Structure

Intrarmolecular Bonding Details of the Alpha Helix and Beta Sheet Imparting Protein Semi-Rigidity and Structure



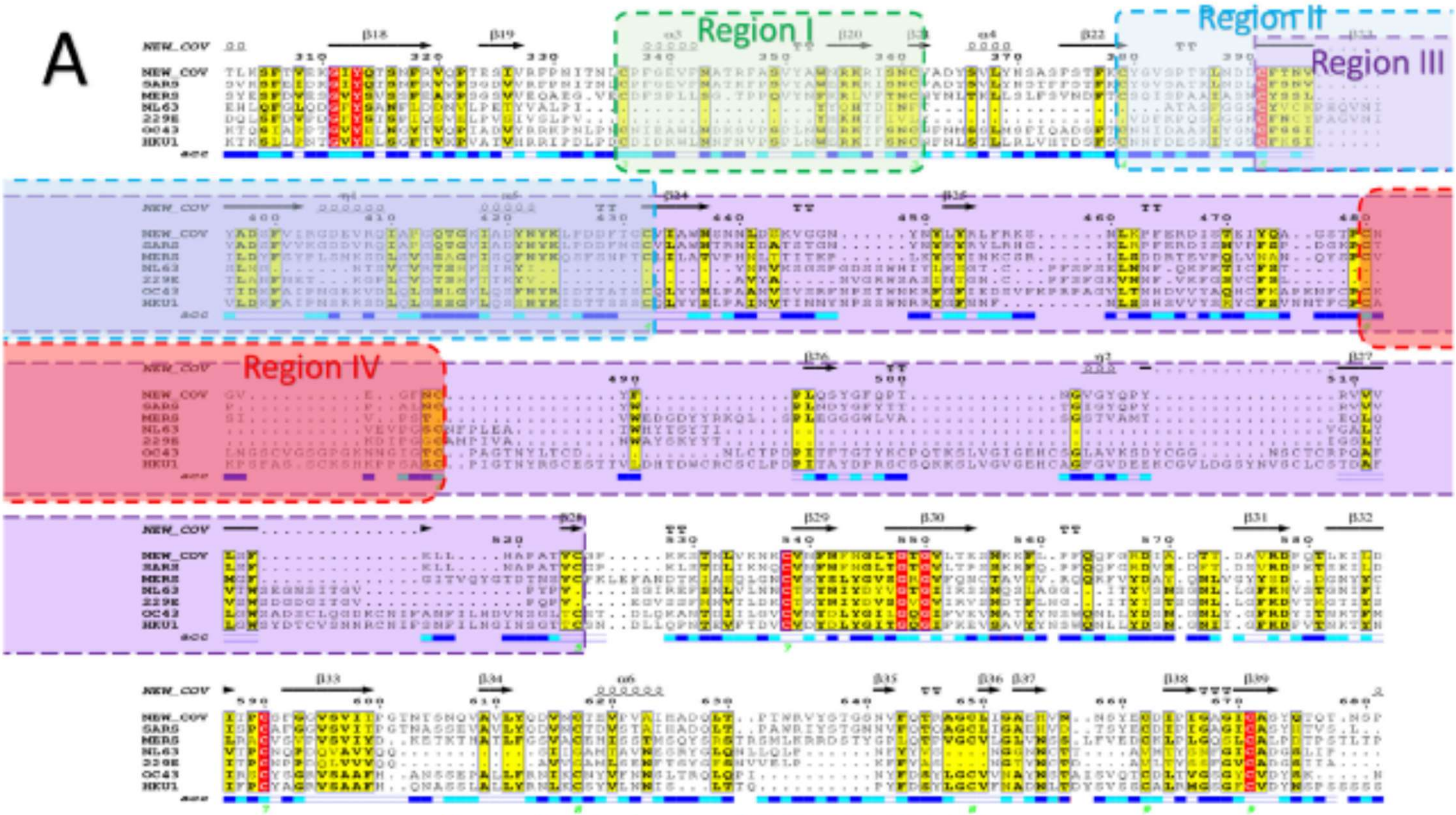
Tertiary and Quaternary Protein Hierarchical Structure Based on Amino Acid Sequence



<u>Tertiary Structure</u> – Three Dimensional Spatial Configuration of a Single Protein

<u>Quaternary Structure</u> – Complexing of Two or More Proteins into a Semi-Rigid Structure; i.e., Hemoglobin (above)

Common Virus Spike Protein Hierarchical Structure Based on Amino Acid Sequence



Journal of Infection 80 (2020) 554–562

COVID-19 spike-host cell receptor GRP78 binding site prediction

Ibrahim M. Ibrahim[a], Doaa H. Abdelmalek[a], Mohammed E. Elshahat[a], Abdo A. Elfiky[a,b,*]

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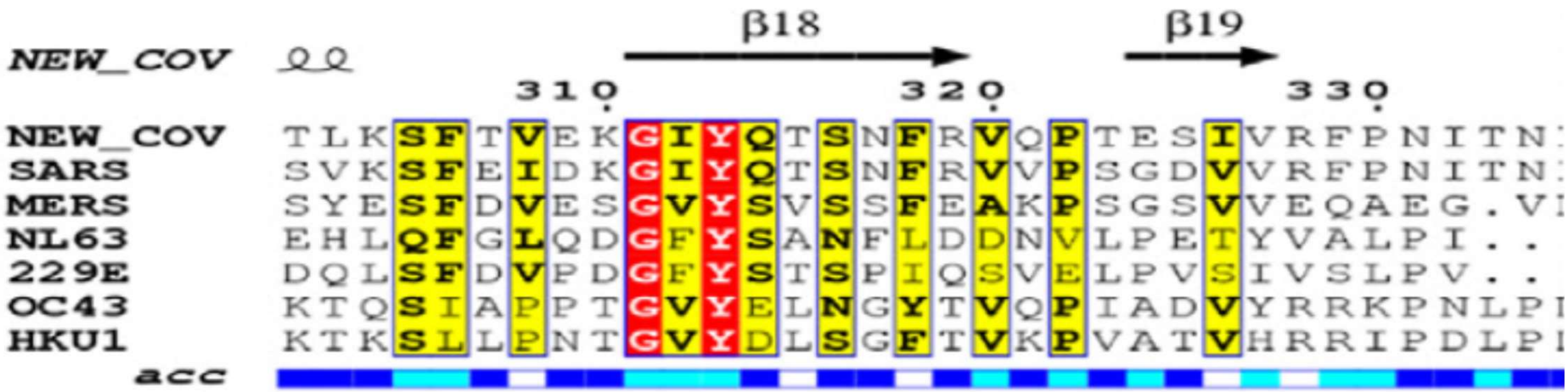
Section of the Common Viruses Spike Protein Amino Acid Sequence Mutations



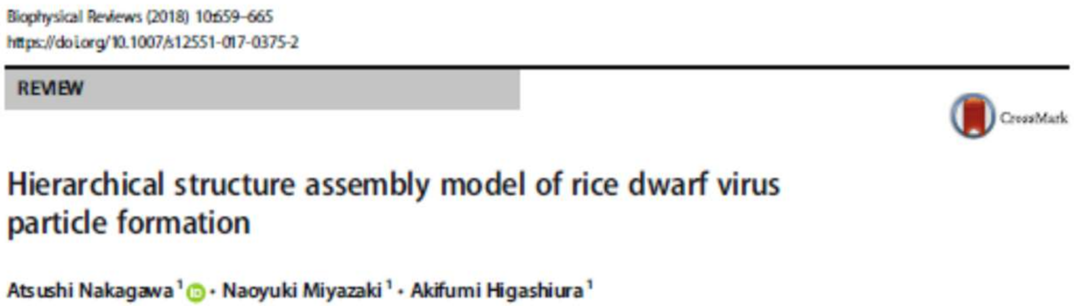
Common human coronaviruses

1. 229E (alpha coronavirus)
2. NL63 (alpha coronavirus)
3. OC43 (beta coronavirus)
4. HKU1 (beta coronavirus)

Common human coronaviruses, including types 229E, NL63, OC43, and HKU1, usually cause mild to moderate upper-respiratory tract illnesses, like the common cold. Most people get infected with one or more of these viruses at some point in their lives. This information applies to common human coronaviruses and **should not be confused with** coronavirus disease 2019 (formerly referred to as 2019 Novel Coronavirus).

Eg., T-L-K-S-F-T . . . = Threonine - Leucine - Lysine – Serine – Phenylalanine – Threonine - . . .

Virus Hierarchical Structure Based on Protein Association


Biophysical Reviews (2018) 10:659–665
https://doi.org/10.1007/s12551-017-0375-2

REVIEW

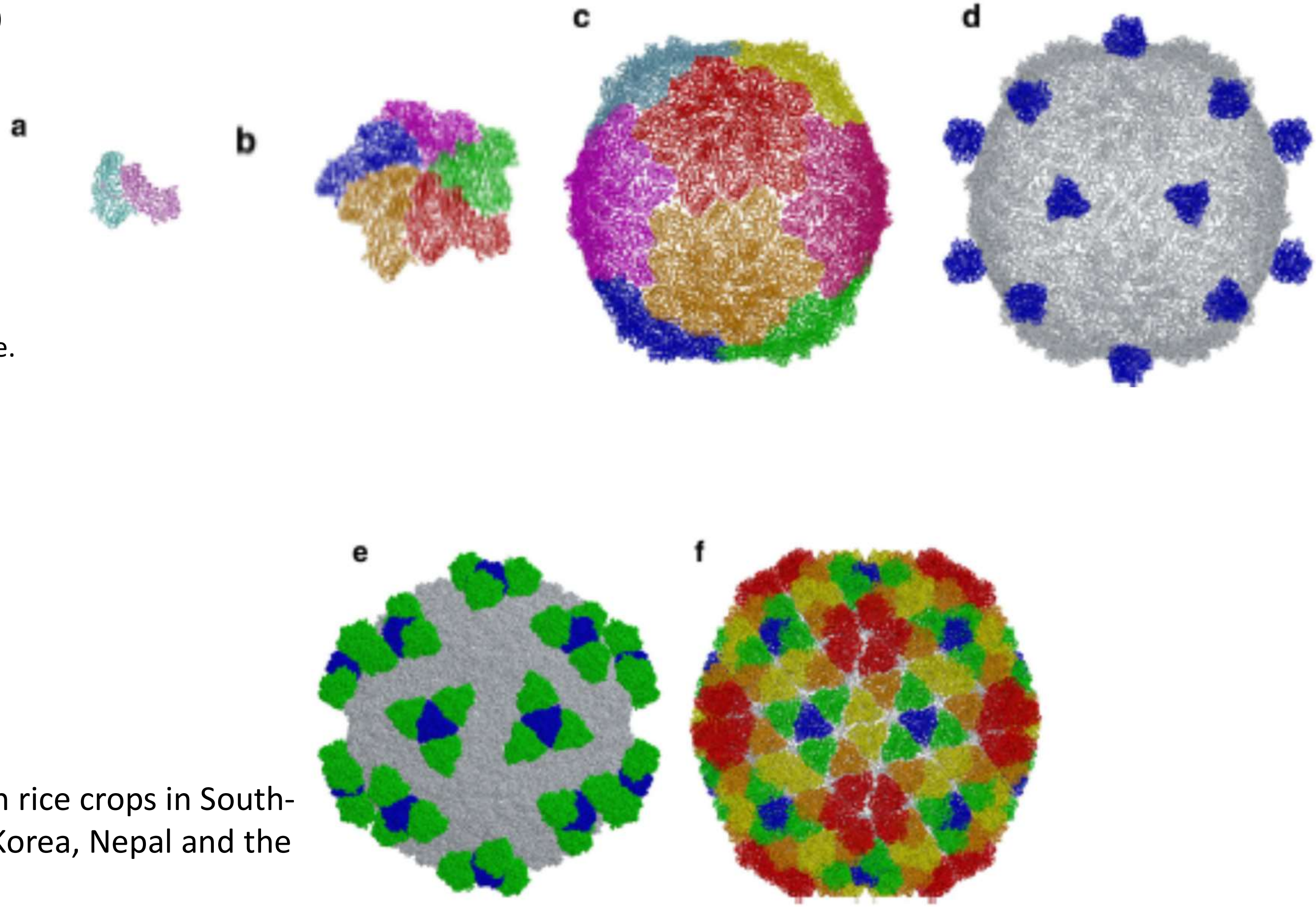
Hierarchical structure assembly model of rice dwarf virus particle formation

Atsushi Nakagawa[1] · Naoyuki Miyazaki[1] · Akifumi Higashiura[1]

Rice Dwarf Virus

Proposed Rice Dward Virus (RDV) Model

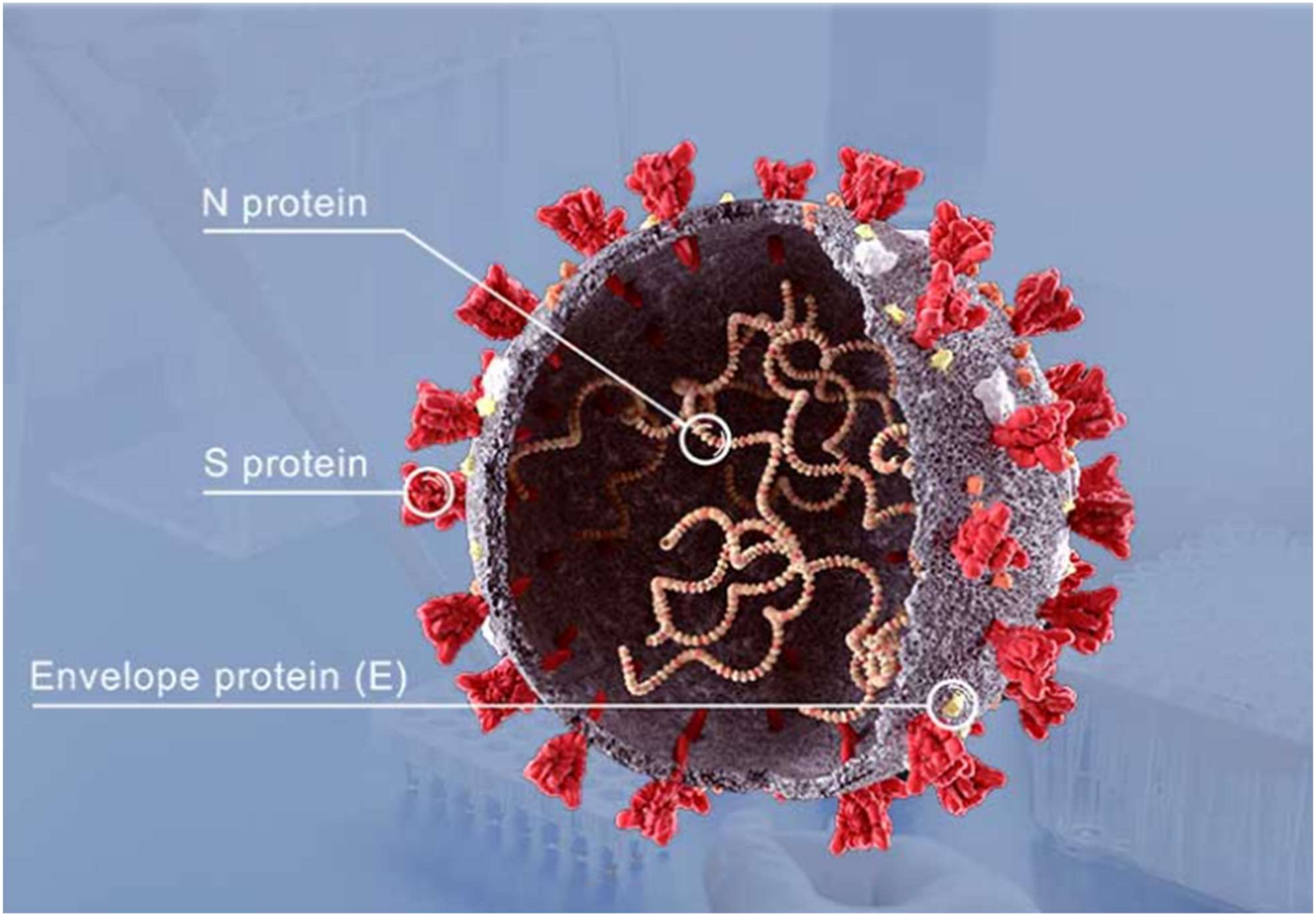
a. Two protein chains associate into a dimer.
b. Five dimers associate symmetrically around a 5-fold axis to form a decamer.
c. Icosahedral symmetry forms an outer shell around a center core.
d. PS trimers form at the 3-fold axis positions.
e. Attachment of additional PS trimers.
f. Completion of PS trimer attachment to surface forming final structure



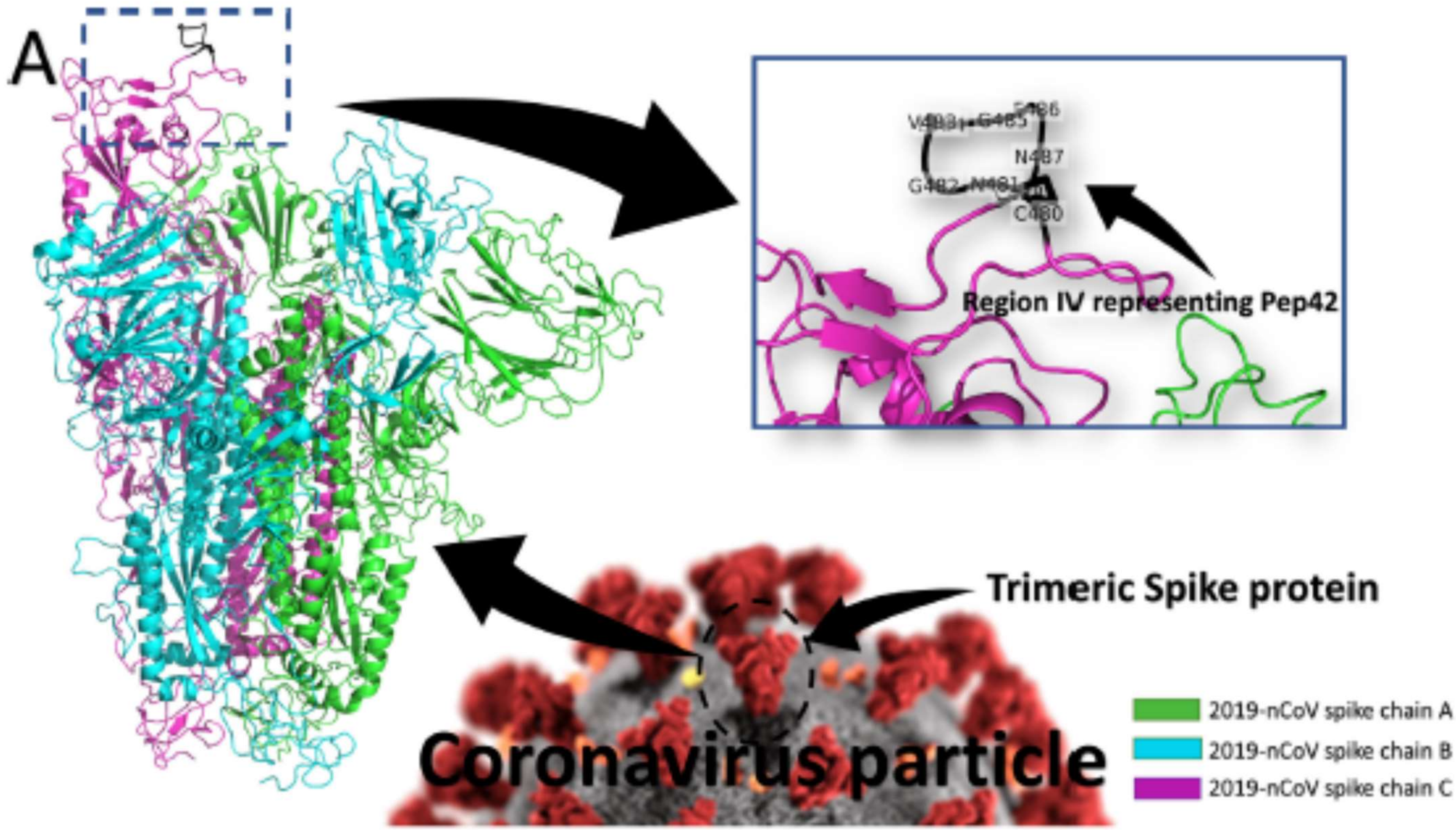
Rice Dwarf Virus

RDV causes severe disease in rice crops in South-East Asia, China, Japan and Korea, Nepal and the Philippines.

Three Major Protein Contributions to the Covid-19 Structure



Hierarchical Structure Covid-19 Spike is Based on Three Complexing Proteins

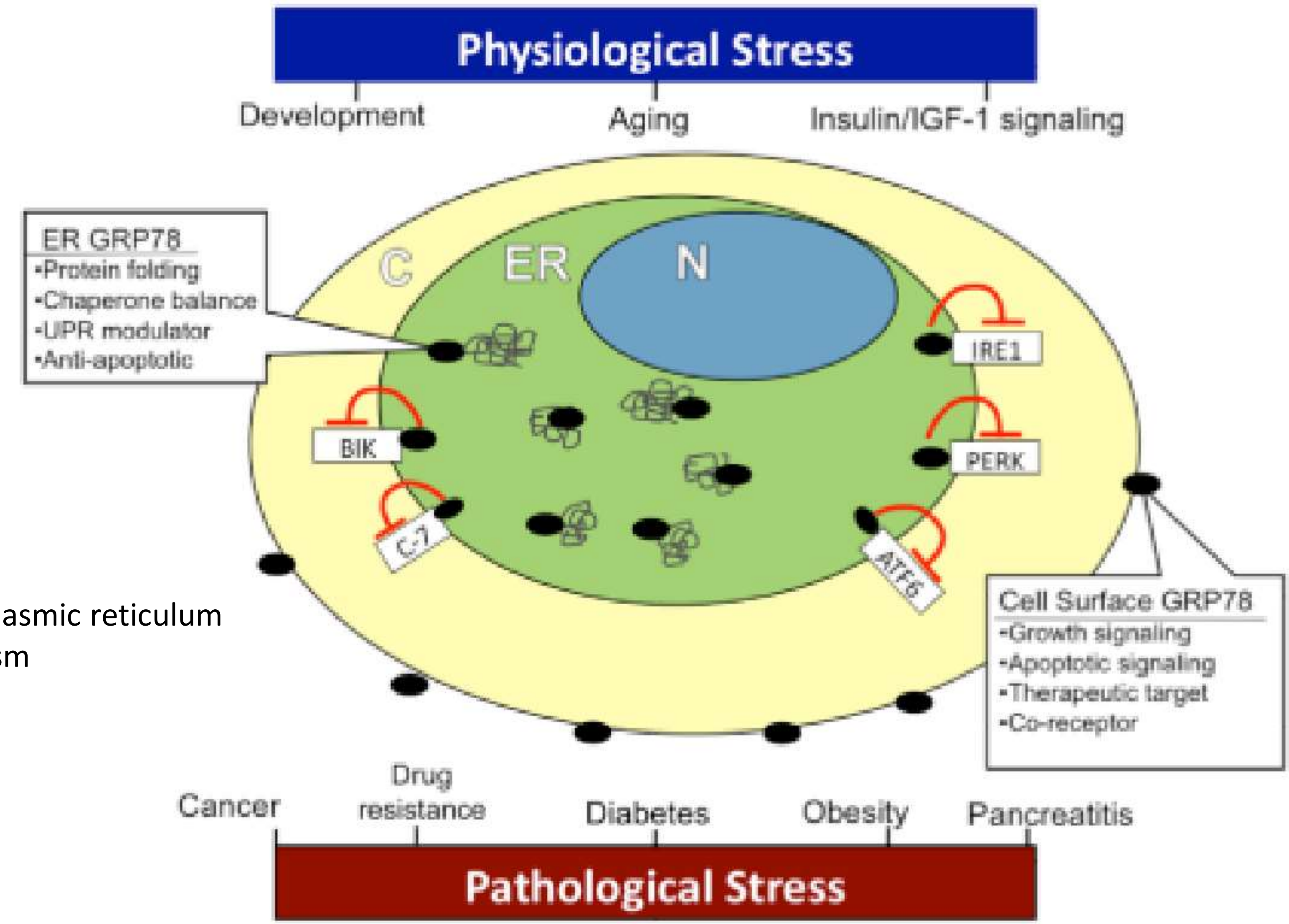


Published in final edited form as:
Curr Opin Cell Biol. 2011 April ; 23(2): 150–156. doi:10.1016/j.ceb.2010.09.007.

The Human respiratory system contains GRP78 = Glucose Regulated Protein 78 Released Under Physiological and Pathological Stress

The critical role of GRP78 in physiologic and pathologic stress

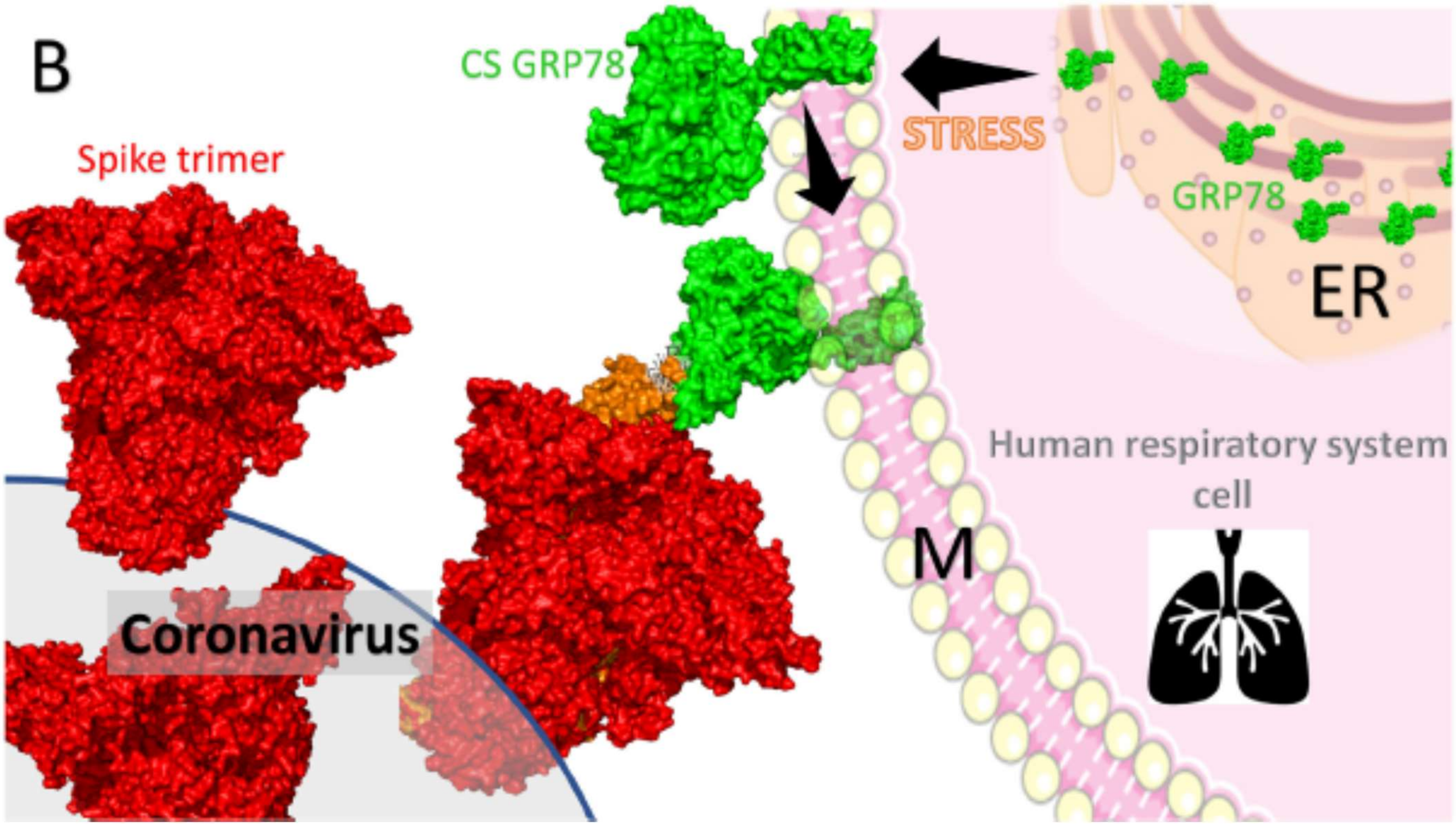
Kyle T. Pfaffenbach and **Amy S. Lee**[1]
Department of Biochemistry and Molecular Biology, University of Southern California Keck School of Medicine, USC Norris Comprehensive Cancer Center, 1441 Eastlake Avenue, Los Angeles, California 90089-9176 USA



N = nucleus
ER = endoplasmic reticulum
C = cytoplasm

Coronavirus Spike Protein Complexing with GRP78

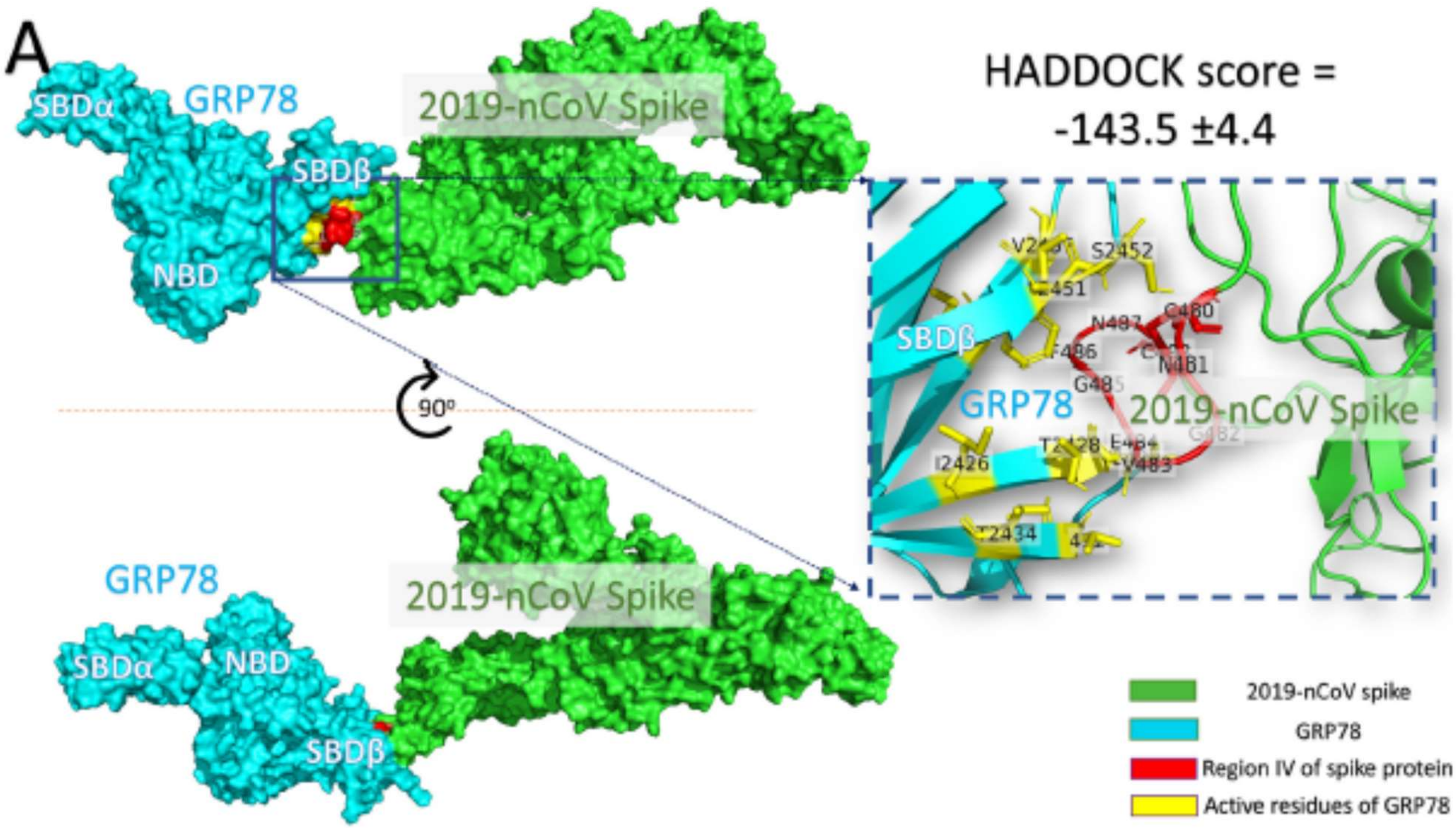
The "handshake" between Coronavirus and the Human Respiratory System



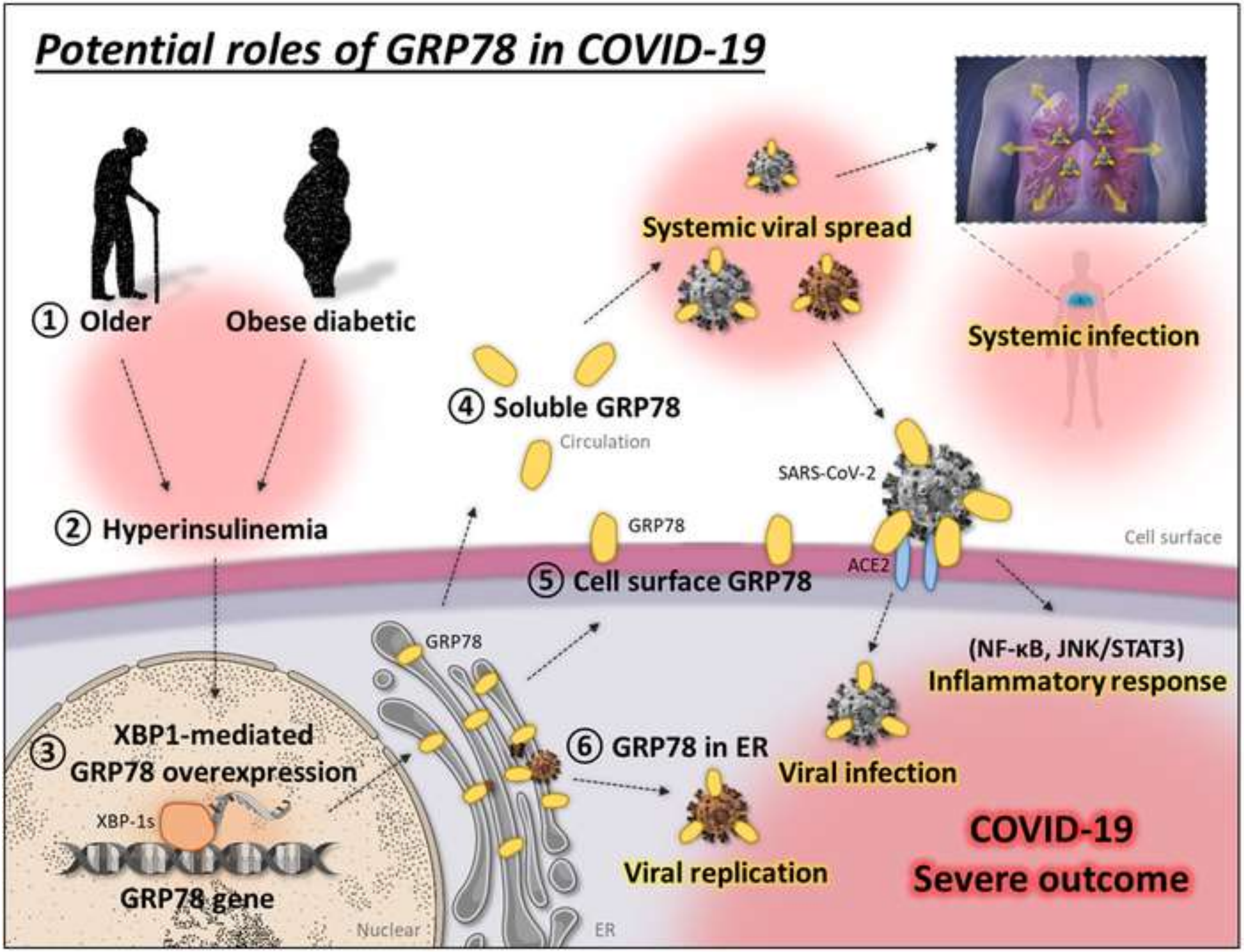
N = nucleus
ER = endoplasmic reticulum M = Cell Membrane
C = cytoplasm

Detailed Complexing of the Covid-19 Spike to GRP78

The "handshake" Details of the Coronavirus Spike Reaction with the Human Respiratory System Protein GRP78



Simple Representation of Infection Pathway and Spread of Covid-19 via GRP78 and ACE2



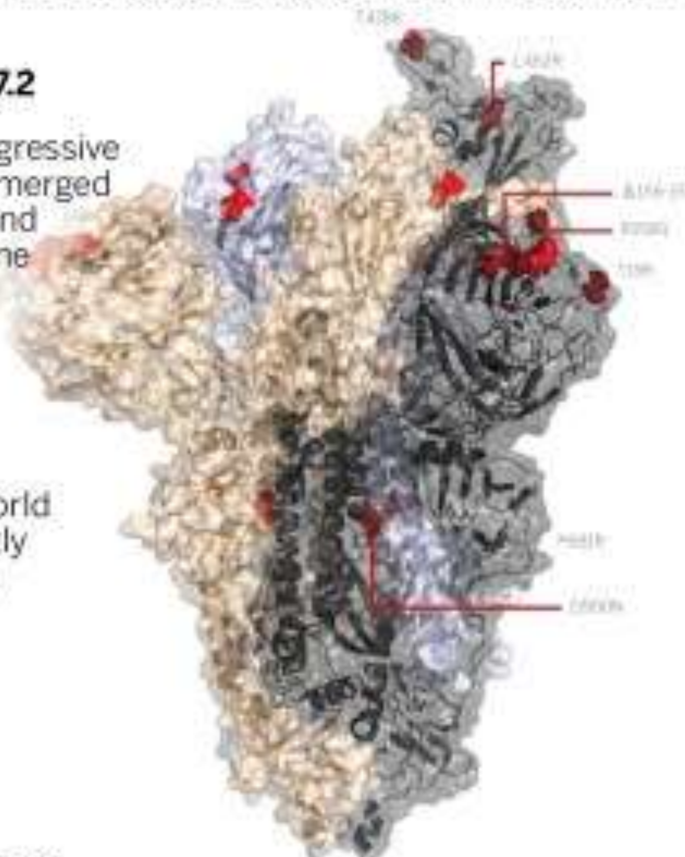
The Differences in the Covid-19 “Delta” and “Omicron” Variants are Primarily Reflected in the Amino Acid Sequence Mutations of the Three Spike Proteins

COVID-19 DELTA AND OMICRON VARIANTS

The new omicron variant has more mutations than the rampant delta variant. Scientists worry that the mutations may make omicron more transmissible, more deadly or better able to evade vaccine protections. However, there is no proof yet that the omicron mutations have those effects.

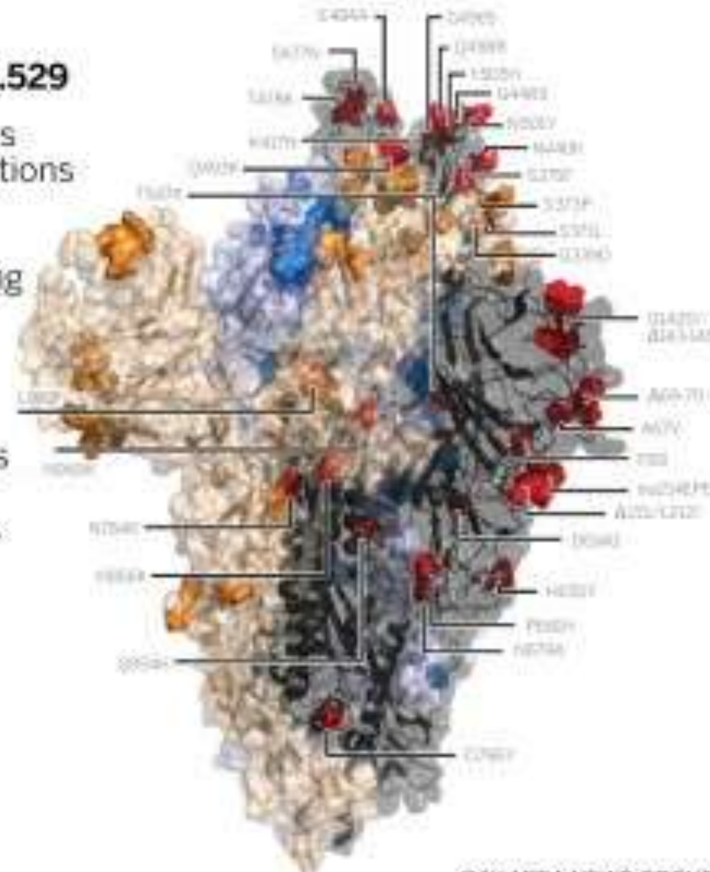
Delta: B.1.617.2

Delta is an aggressive variant that emerged in late 2020 and quickly became the most common variant in India. It continued spreading around the world and is currently the dominant variant.



Omicron: B.1.1.529

Omicron carries about 50 mutations not seen in combination before, including more than 30 mutations on the spike protein that the coronavirus uses to attach to human cells.



Source: New York Times, COG-UK Mutation Explorer; http://sars2.cvr.gla.ac.uk/cog-uk/

BAY AREA NEWS GROUP

Alarming antibody evasion properties of rising SARS-CoV-2 BQ and XBB subvariants

Qian Wang,[1,8] Sho Iketani,[1,8] Zhiteng Li,[1,8] Liyuan Liu,[2,8] Yicheng Guo,[1,8] Yiming Huang,[2] Anthony D. Bowen,[1,3] Michael Liu,[1] Maple Wang,[1] Jian Yu,[1] Riccardo Valdez,[4] Adam S. Lauring,[5] Zizhang Sheng,[1] Harris H. Wang,[2] Aubree Gordon,[4] Lihong Liu,[1,*] and David D. Ho[1,3,6,7,*]

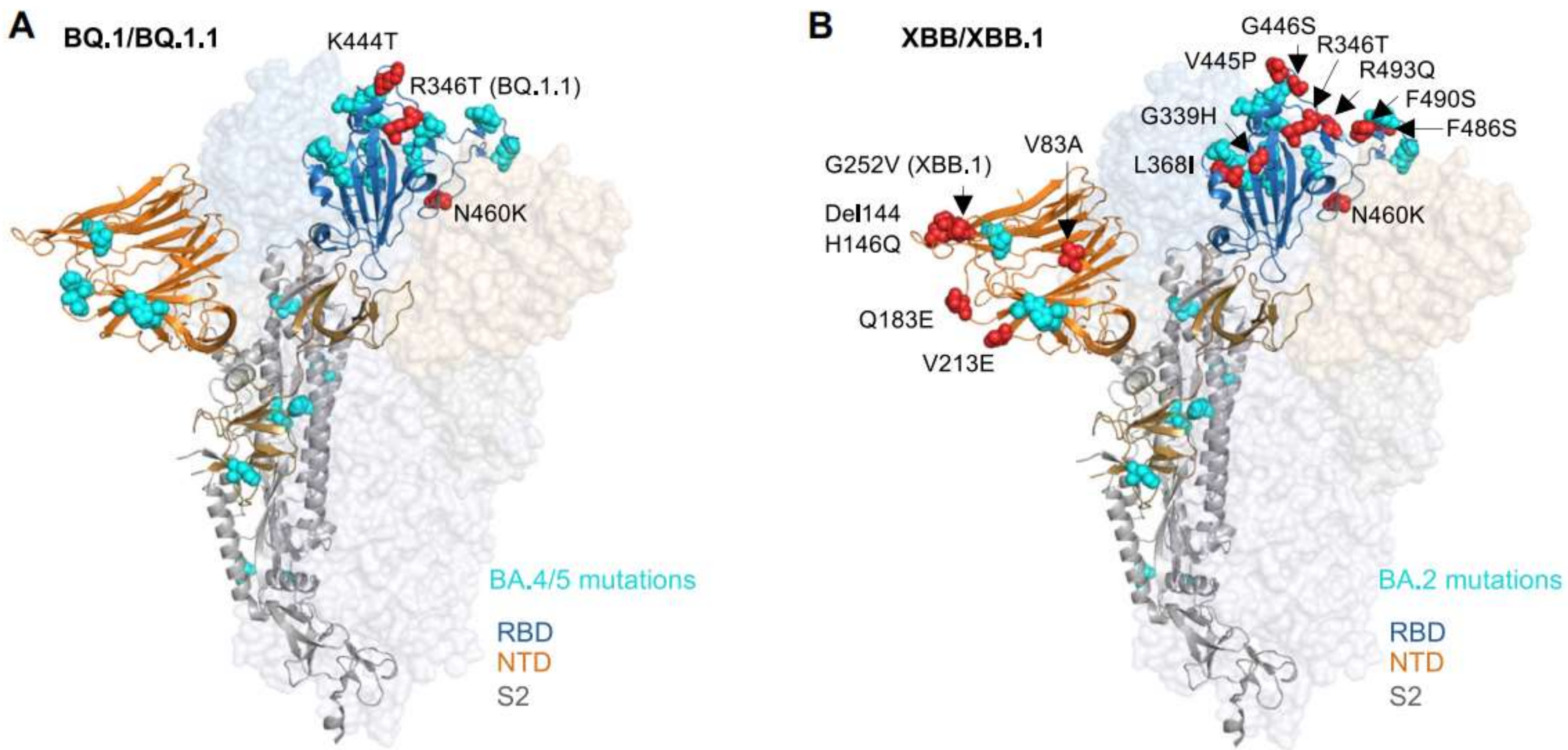


Figure S1. Key spike mutations of BQ and XBB subvariants, related to Figure 1
(A and B) Key mutations of BQ.1 and BQ.1.1 in the context of BA.4/5 (A), and key mutations of XBB and XBB.1 in the context of BA.2 (B).
See also Figure 1.

Wang et al., 2023, Cell *186*, 1–8
January 19, 2023
https://doi.org/10.1016/j.cell.2022.12.018

A Mini Review on SARS-COVID-19-2 Omicron Variant (B.1.1.529)

Santhosh Kumar Ettaboina, Komalatha Nakkala, K.S. Laddha

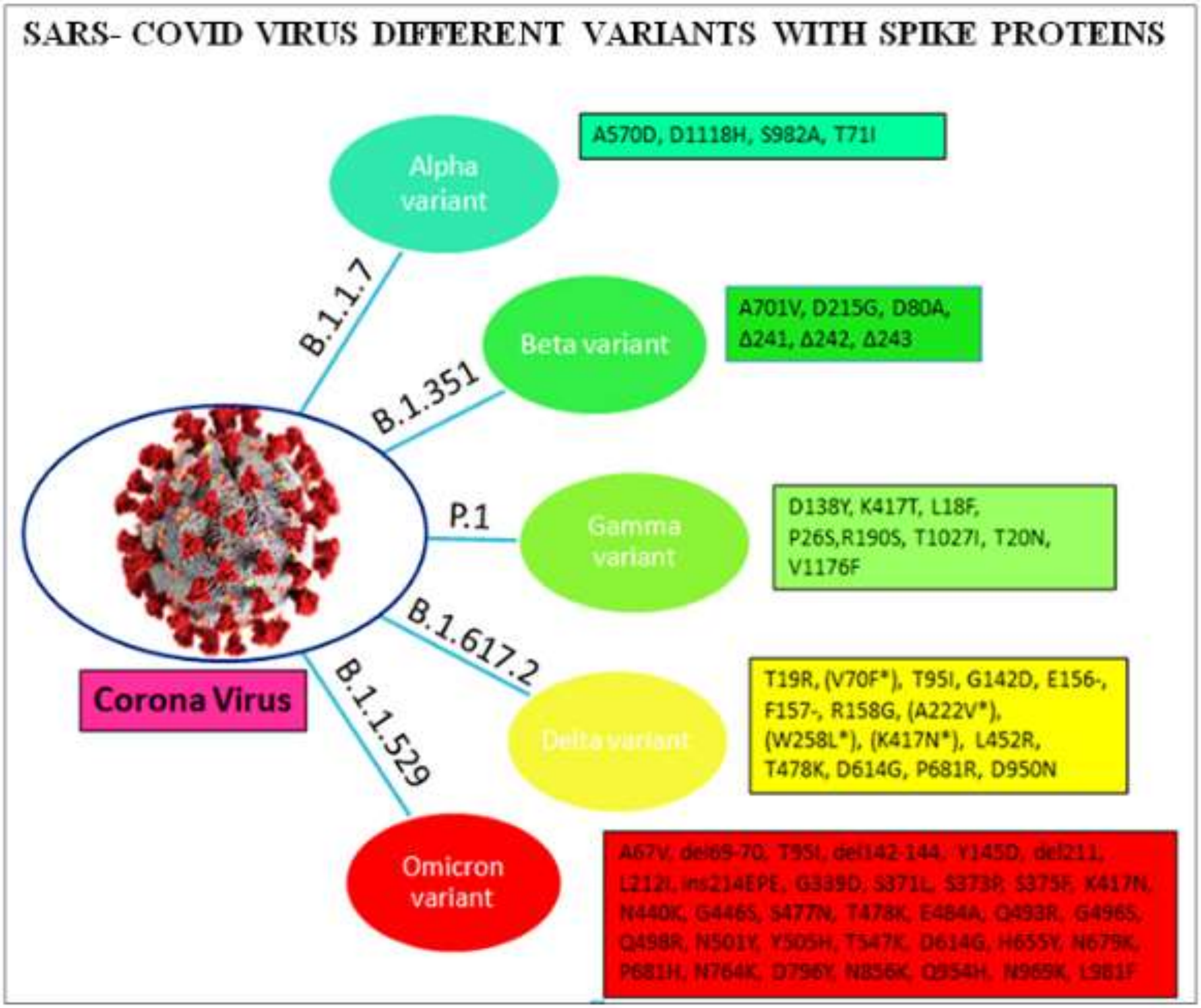


Figure 1. Different variants with their spike proteins

SciMedicine Journal

(ISSN: 2704-9833)

Vol. 3, No. 4, December, 2021

http://dx.doi.org/10.28991/SciMedJ-2021-0304-10

A Mini Review on SARS-COVID-19-2 Omicron Variant (B.1.1.529)

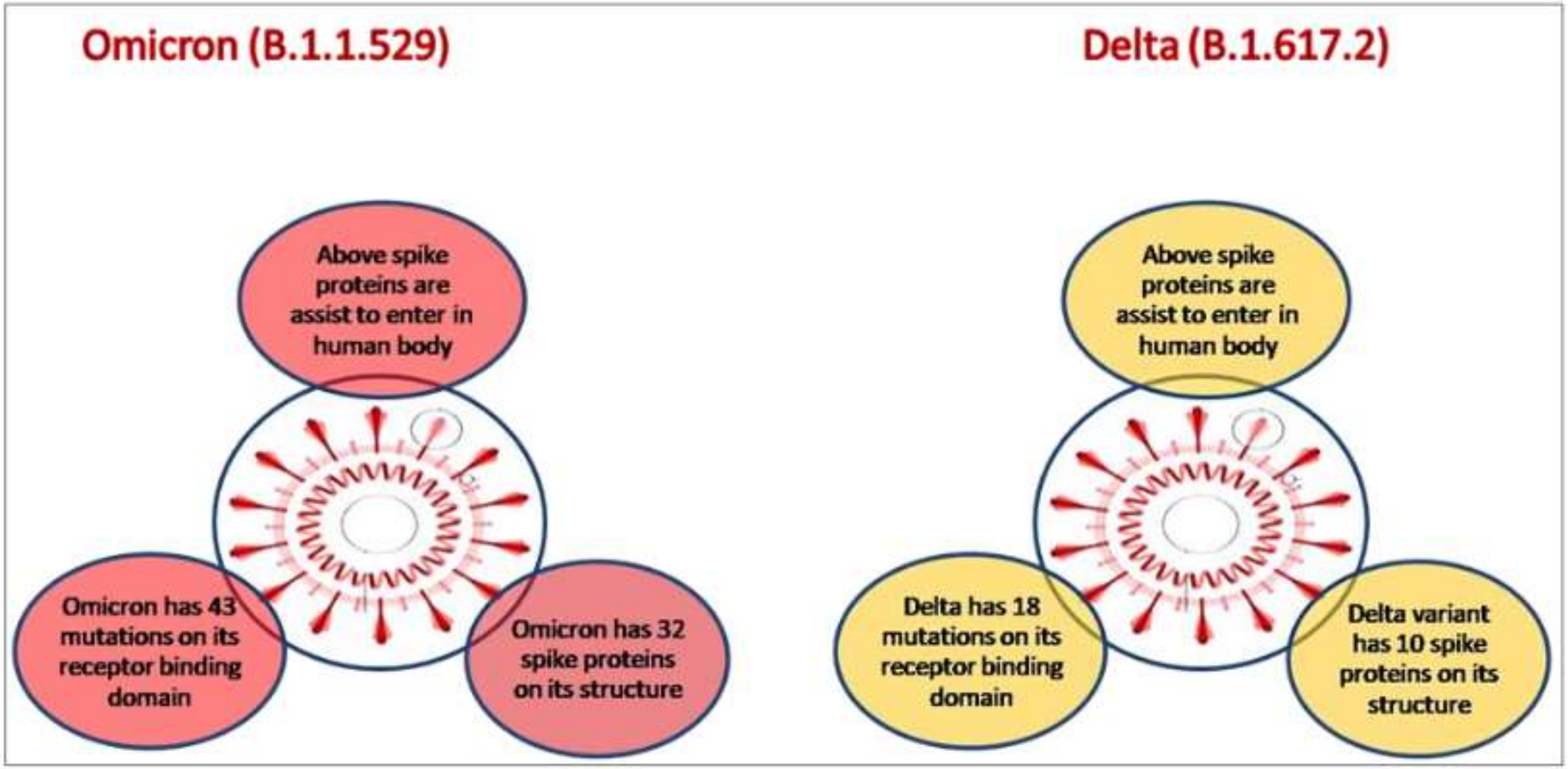


Figure 2. Different spike proteins between delta and omicron variants of SARS-COVID-19-2

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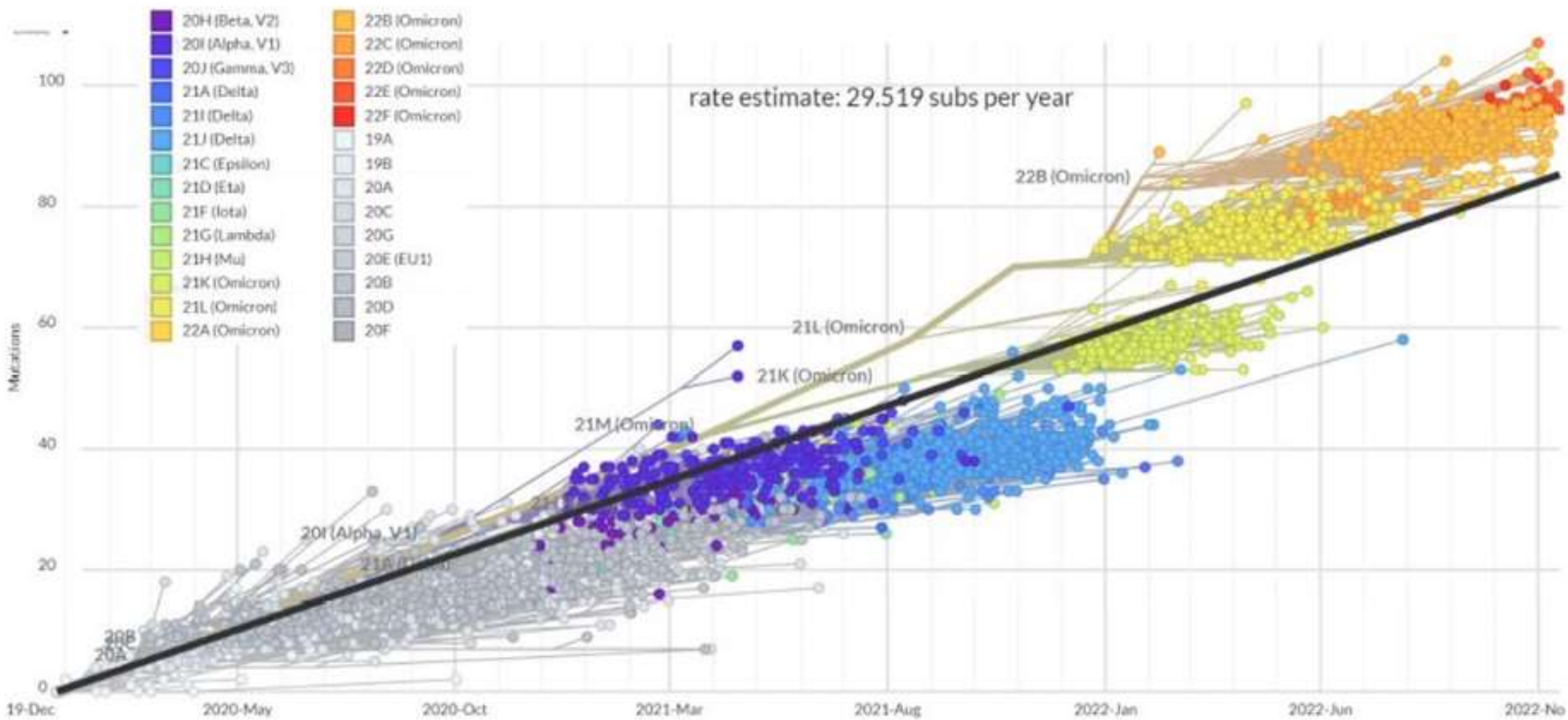
http://dx.doi.org/10.28991/SciMedJ-2021-0304-10

Convergent evolution in SARS-CoV-2 Spike creates a variant soup that causes new COVID-19 waves.

Daniele Focosi, Rodrigo Quiroga, Scott A. McConnell, Marc C. Johnson, Arturo Casadevall

Figure 2

Clock tree of SARS-CoV-2 evolution, with regression line showing an increase in the estimate rate of substitutions per year across 3045 genomes sampled between Dec 2019 and Nov 2022. Accessed online at https://nextstrain.org/ncov/gisaid/global/all-time?l=clock&m=div on November 26, 2022.



When is a COVID mutation a new variant, and when is it a subvariant? And what's a recombinant?

First, what are mutations?

When cells reproduce, they use a set of genetic instructions (made of DNA or RNA) to replicate. But given this is happening at such a rapid rate, sometimes errors can occur.

These errors, or changes in the genetic code, are also called mutations.

What are variants? Are they different to strains?

A variant is where the genetic code has changed due to a mutation, or a number of mutations.

A variant, while different genetically, does not necessarily differ in its behaviour from the parent virus.

The virus that causes COVID is a single species of coronavirus named SARS-CoV-2.

What are subvariants?

Omicron has been shown to be more infectious than its predecessors, hence has spread swiftly worldwide. Given the resulting abundant opportunities to reproduce,

Omicron has had the opportunity to acquire specific mutations of its own.

These have not been deemed significant enough to satisfy the definitions to call them new variants. However, they have had some slightly different properties. For this reason they have been referred to as "subvariants". Initially we saw BA.2 arise, which was found to be slightly more infectious than the original Omicron, BA.1

What are recombinants?

There are now a large number of Omicron subvariants. BA.4 was detected in January and is essentially a mixture of BA.1 and BA.3 with some new mutations, making it slightly more infectious than preceding subvariants.

When viruses reproduce inside host cells,

they can randomly collect pieces from multiple strains or variants when they reproduce,

Given this is basically forming a combination of both virus this process is called recombination. When this happens, the resulting "recombinant" can have properties of either or both viruses.

Variant Sequence

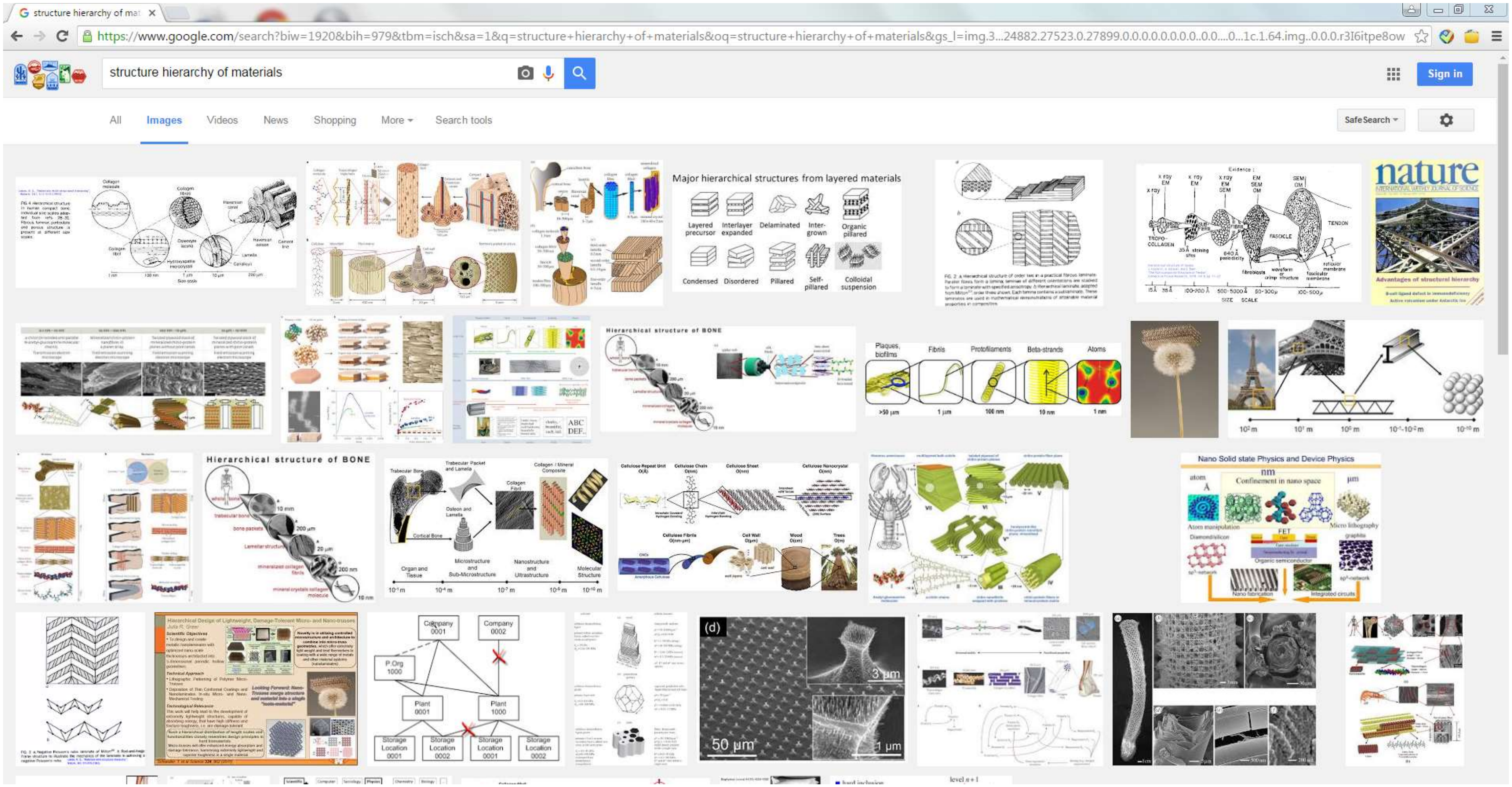
There are Ten Greek Letters between Delta and Omicron. Why Skip?

There have been Eight "***Variants of Interest***" between Delta and Omicron. Delta and Omicron are Both ***"Variants of Concern"***.

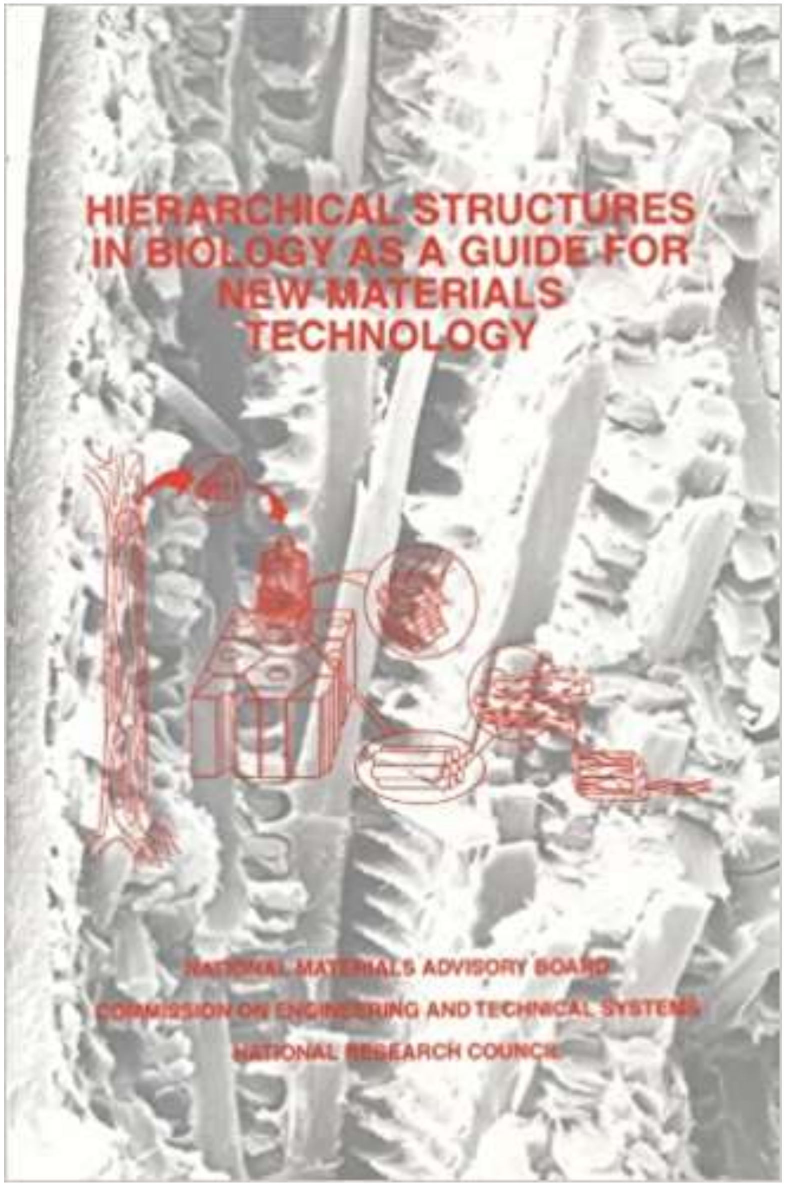
There have been Two Skipped Greek Letters between Delta and Omicron.

Hierarchical Structures Are Everywhere

Search results from Images.google.com



Recommended Reference



HIERARCHICAL STRUCTURES IN BIOLOGY AS A GUIDE FOR NEW MATERIALS TECHNOLOGY

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Hierarchical Structures

Questions?

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"It's probably my age that tricks people into thinking that I'm an adult."