



**Taking inspiration from Nature to engineer tomorrow's world**

**May 2022**

**Prof Hortense**

| March 2022 | 1

# Welcome to NTU!

## Taking inspiration from Nature to engineer tomorrow's world

*Take a seat and write your name.*



*Answer the surveys if not done so already.*



# Welcome to NTU

## School of Mechanical and Aerospace Engineering

*Thank you for filling the 2 pre-surveys sent by email earlier.*

# Nanyang Technological University



Celebrating its 30 anniversary





## School of MAE

‘Laboratory for dense and multifunctional composites’.



- Additive manufacturing of ceramics and composites
- Bioinspired materials
- Multifunctional and structural (strong/hard) materials

[Hortense@ntu.edu.sg](mailto:Hortense@ntu.edu.sg)

<http://www.ntu.edu.sg/home/hortense>

# Taking inspiration from Nature to engineer tomorrow's world

## *Objectives*

- Learn what is bioinspiration and biomimicry
- How to apply bioinspiration in practice
- Discover examples from the research
- Discuss and share ideas with peers

# Taking inspiration from Nature to engineer tomorrow's world

*Outline of the module*  
*9:30 – 1 pm*

- Introduction on biomimetics and bioinspiration (ca. 1 hr)
- Be a bioinspired engineer: lab activity (ca. 1 hr)
- Share what you learned and imagined: communication activity (ca. 1.15 hr)
- Concluding words

# Wooclap



- 1 Connect to [www.wooclap.com/SEENTU](http://www.wooclap.com/SEENTU)
- 2 You can participate

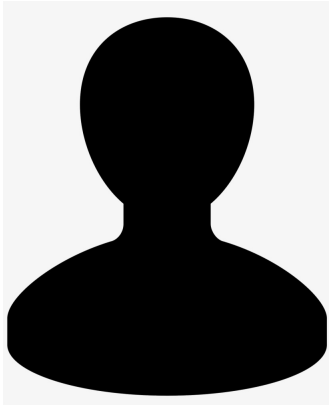
**Pictures and laptop to prepare 5 slides for sharing to the class.**



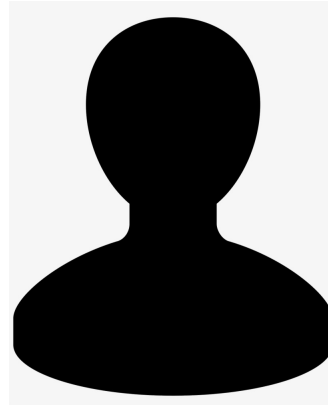
**Envelop and biomaterial for lab activity**



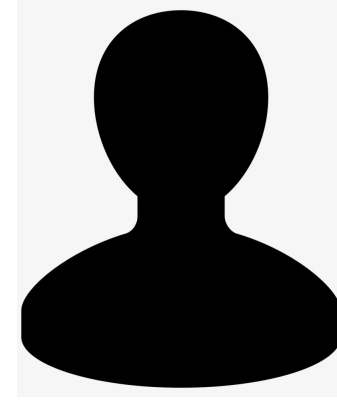
# Facilitators



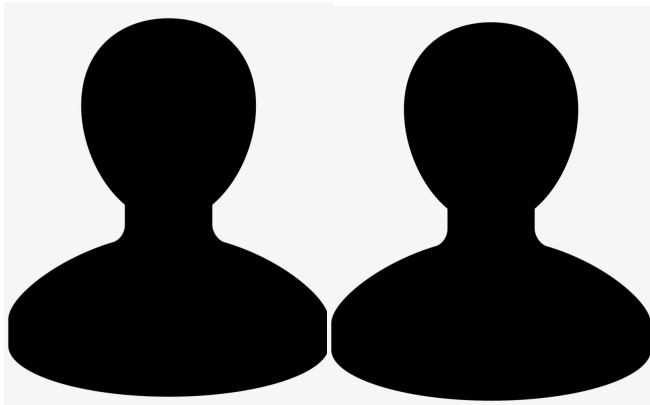
(Edamame)



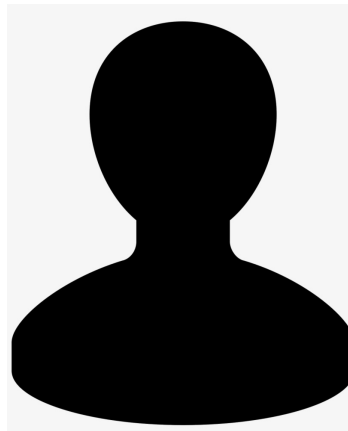
(Lotus)



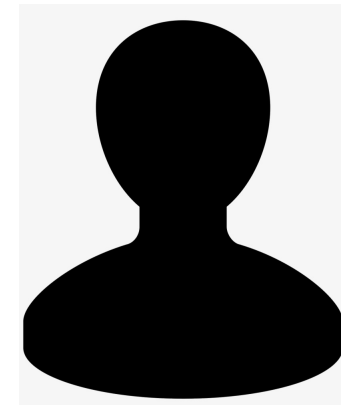
(Seashell)



(Mushroom)



(General facilitator)



(Peach gum)

# Biomimicry?

# Biomimicry



# Biomimicry

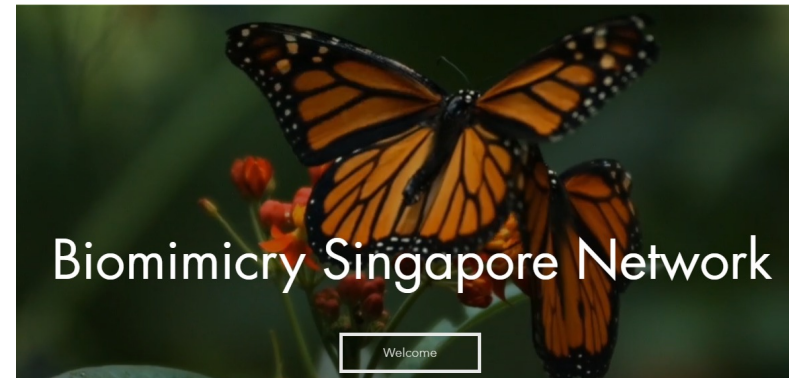
**Biomimicry is the practice of looking to nature for inspiration to solve design problems in a regenerative way.**



2006



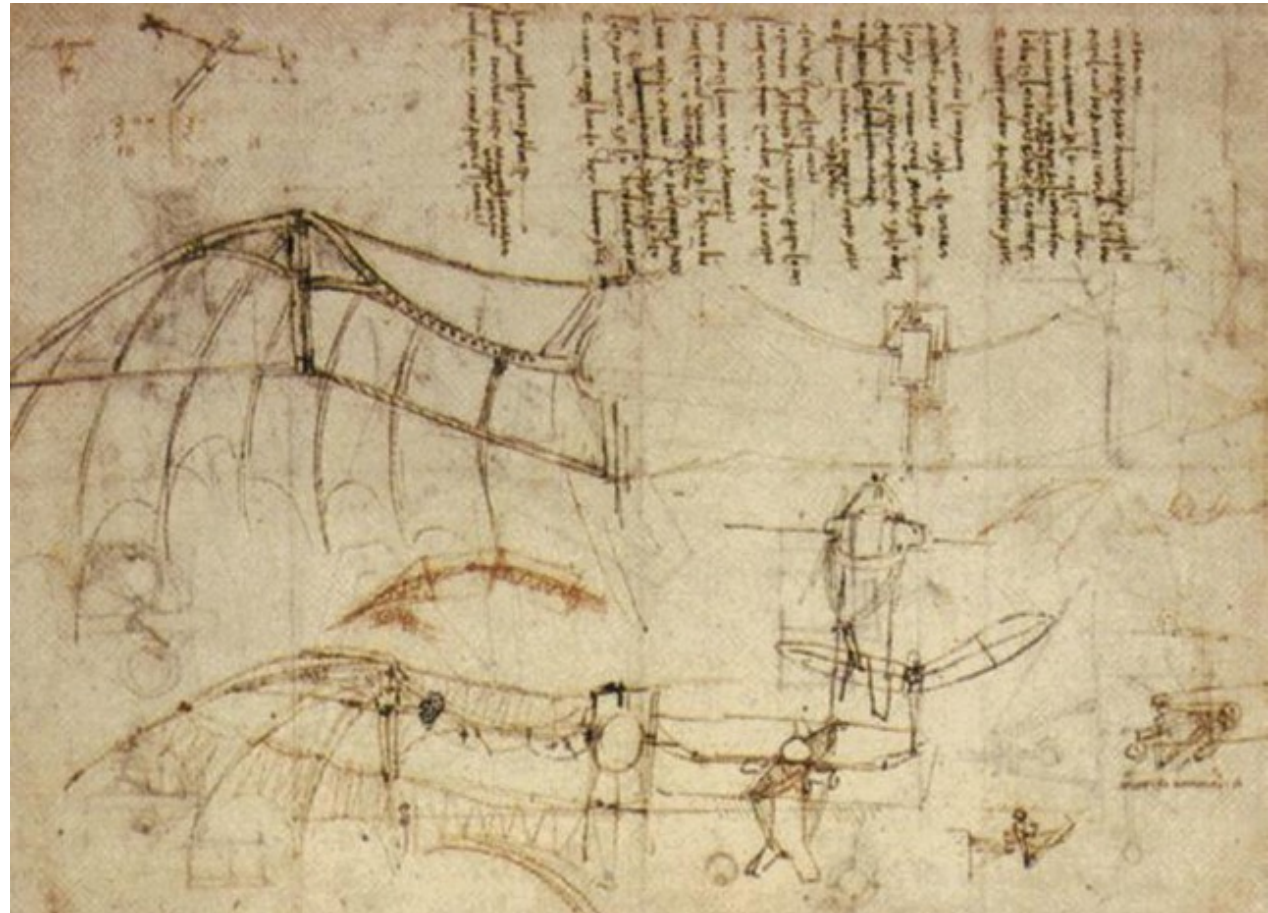
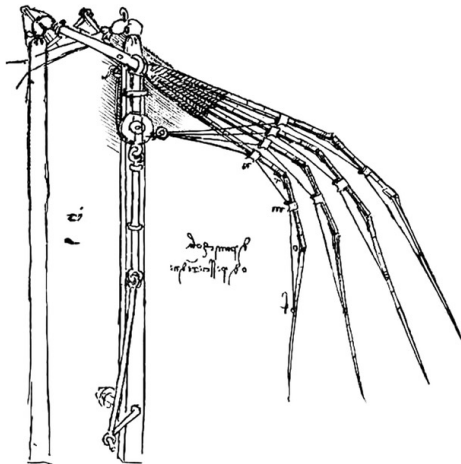
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# Biomimicry

Leonardo Da Vinci 15<sup>th</sup> century



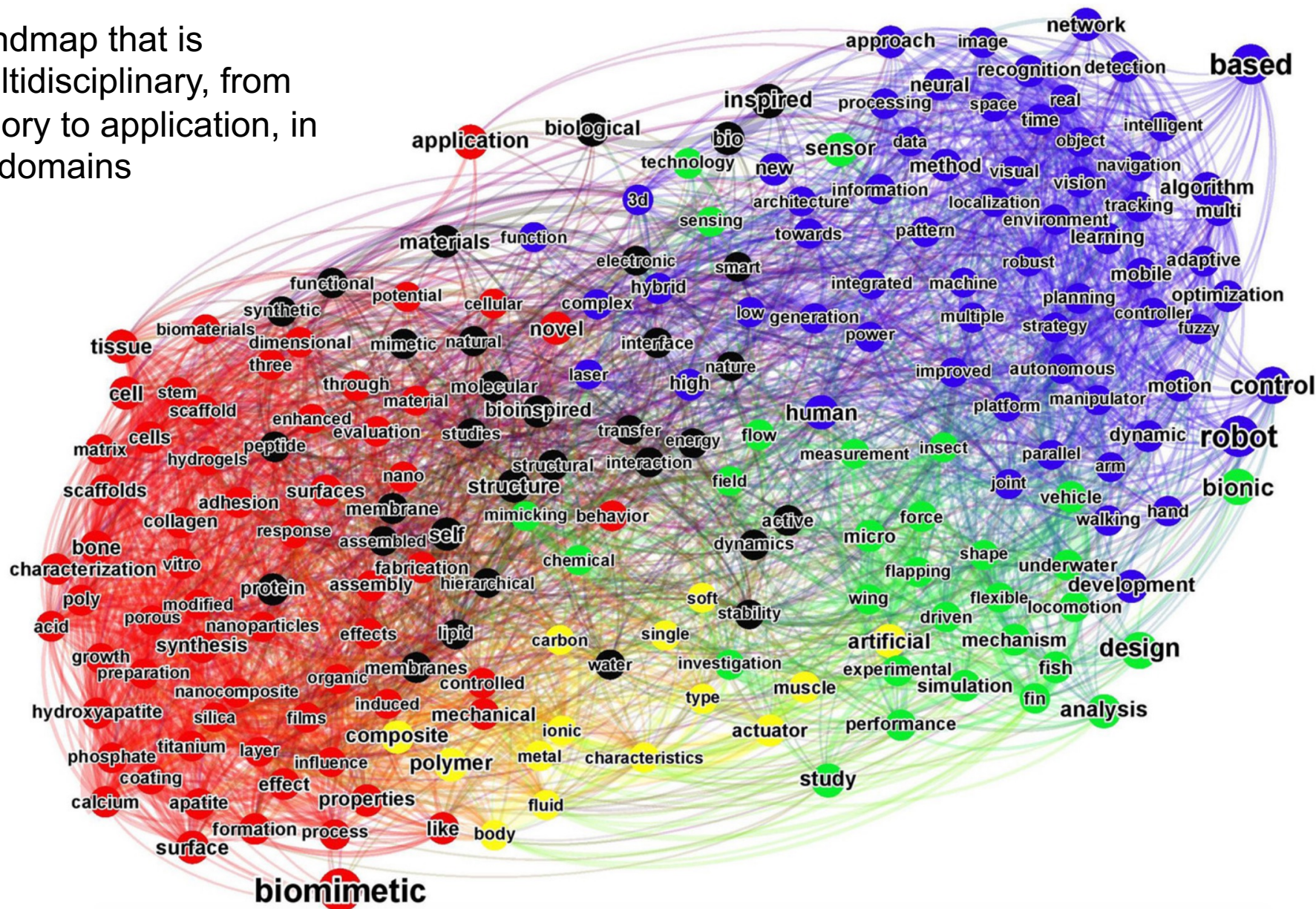
# Biomimicry – activity 1

Terms, topics associated to biomimicry?  
Where can we find biomimicry around us?  
Why can it be useful?



[www.wooclap.com/SEENTU](http://www.wooclap.com/SEENTU)







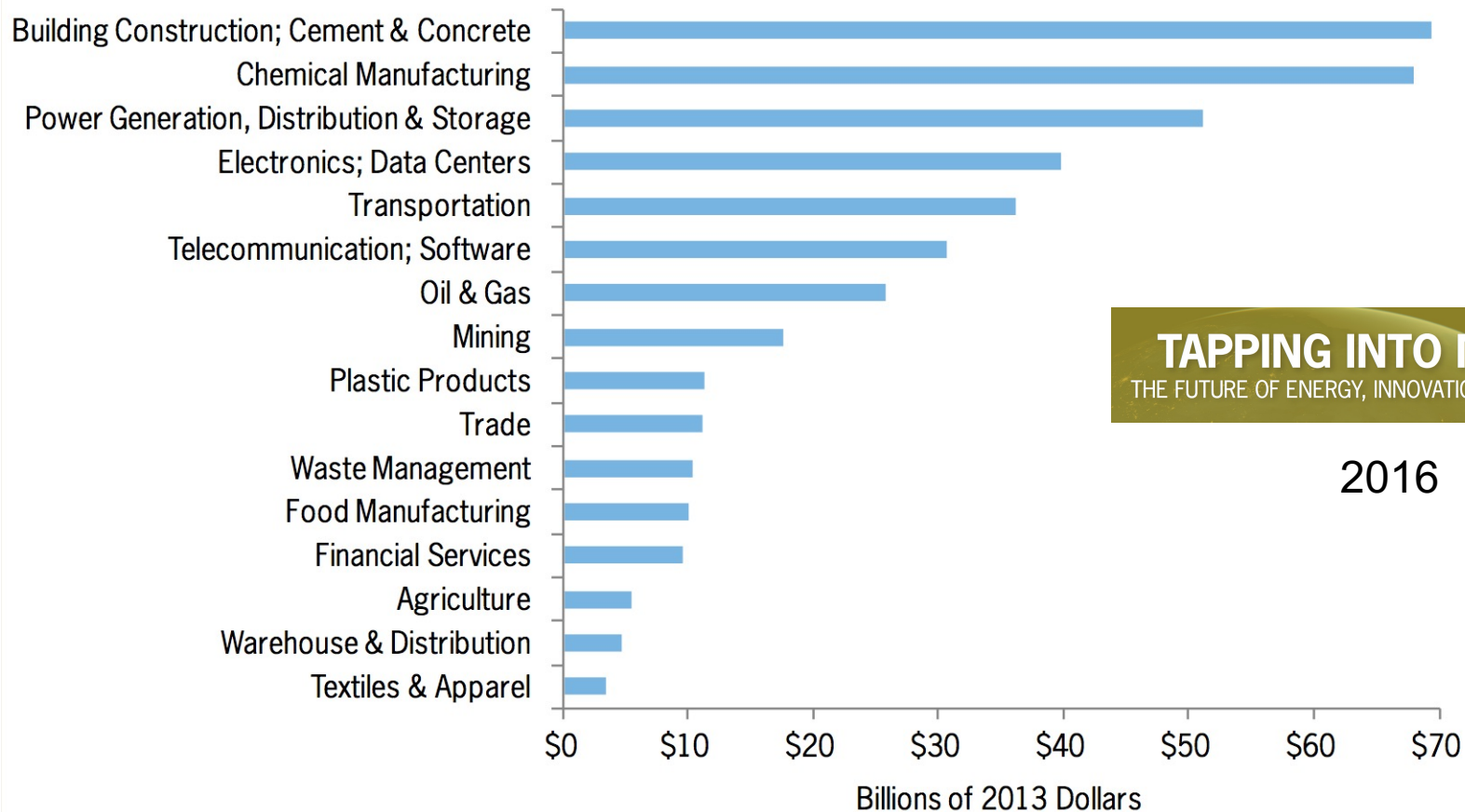
**SUSTAINABLE DEVELOPMENT GOALS**



# Bioinspiration to be one strategy to solve today's grand challenges.



Figure 1. Bioinspired Innovation's Forecasted Impact on GDP in 2030



Increased employment in bioinspired engineering.

# Bioinspiration?

Bio-inspiration goes beyond biomimicry.

It is not copying Nature, but  
**understanding** the key mechanisms and  
**applying** them to solve our engineering  
problems.

(eg: there is no example of space shuttles  
in Nature)

# The principle of applying bio-inspiration – activity 2

1. Determining the problem to solve/ aims.

*E.g. hot Earth to cold space*

2. Identifying a natural system where the problem is solved and understanding the concepts

*E.g. a species that lives in hot and cold*

3. Developing a method to apply this solution to the engineering problem.

*E.g. apply to different ranges of temperature*



# The principle of applying bio-inspiration – activity 2

Let's look at some examples

# Example in architecture

(1) Problem/ aims

(2) Natural system

(3) Apply

- Energy Efficiency
- Insulated greenhouse
- Isolation of indoor and outdoor environment
- Natural lighting



- Energy reduction by 30%
- Capturing solar energy
- Reduction of artificial lighting by 55%



# Example in transportation



Stop at 2:08

# Example in transportation

(1) Problem/ aims

(2) Natural system

(3) Apply



[www.wooclap.com/SEENTU](https://www.wooclap.com/SEENTU)

3 - 5 min

# Example in transportation

(1) Problem/ aims

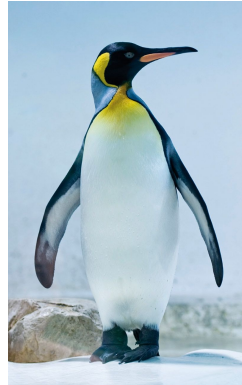


Fast and  
low noise

(2) Natural system



Feathers, belly  
shape, and  
beak of birds.



(3) Apply



New design shapes

Achieve: 10% faster,  
15% less electricity, and  
below the sound limit



# Example in water treatment (desalination)



Stop at 1:23



# Example in water treatment (desalination)

(1) Problem/ aims

(2) Natural system

(3) Apply



[www.wooclap.com/SEENTU](https://www.wooclap.com/SEENTU)

3-5 min

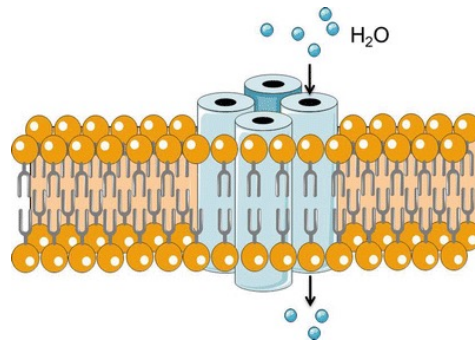
# Example in water treatment (desalination)

(1) Problem/ aims



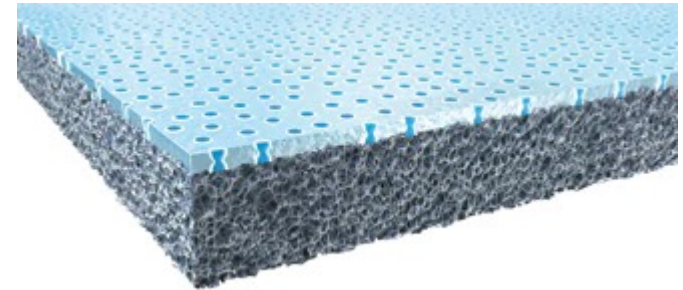
Separate salt and water, purify water

(2) Natural system



Aquaporin protein in all living cells

(3) Apply



Membrane



## Benefits of bio-inspiration:

Realize functionalities that we cannot do traditionally, in much faster, efficient and sustainable manner.


We have seen the top-down process of  
applying bioinspiration:

Technical challenge



“Ask Nature”





It's time to  
ask nature.

[Asknature.org](https://asknature.org)

We have seen the top-down process of applying bioinspiration:

Technical challenge  “Ask Nature”

There is also the bottom-up process :

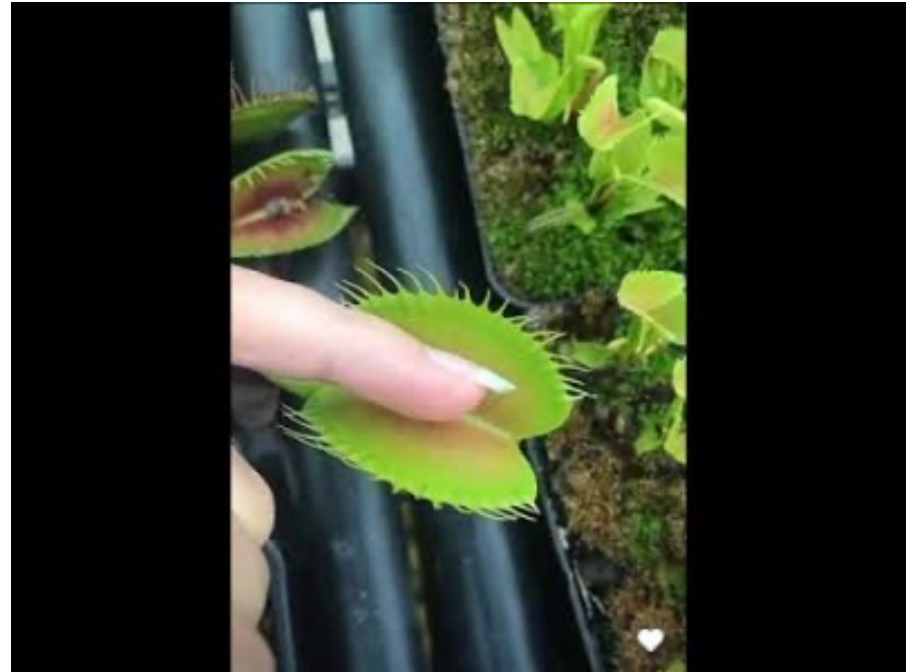
Discovery in biology  Developing new technology



# Applying the bioinspiration process – activity 3

Let's look at some examples  
from our research

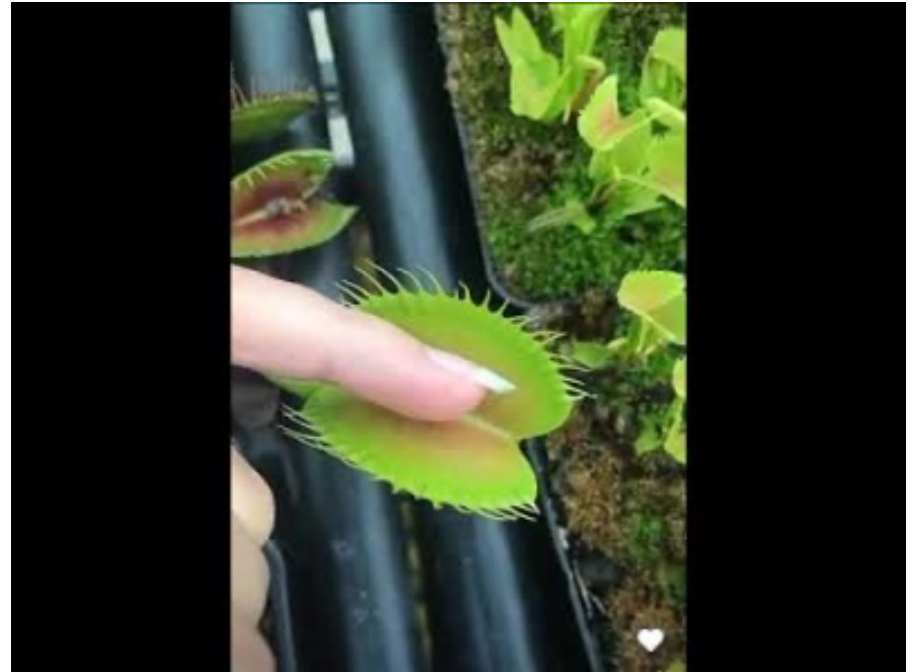
# Example of Venus inspired-inspired materials



What mechanism or principle could we learn from the Venus Fly trap?



# Example of Venus inspired-inspired materials



What mechanism or principle could we learn from the Venus Fly trap?

*Fast morphing, complex shapes*

# Example of Venus inspired-inspired materials

Part of the fast closing of the Venus flytrap results from a mechanical instability which results in 2 positions: on and off.





# Example of Venus inspired-inspired materials

This is because there is energy stored in the material. This is called pre-stresses and they are due to the microstructure.



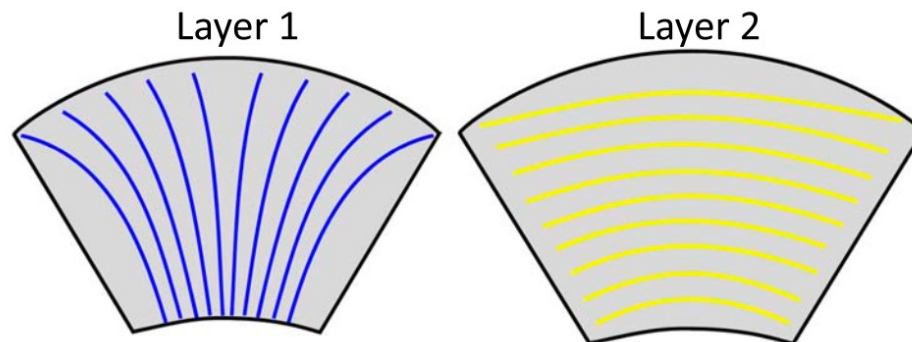
# Example of Venus inspired-inspired materials

We are now applying the same principle in other materials systems.

## Venus Flytrap Bioinspiration



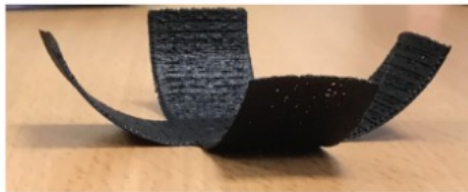
## Synthetic Composite



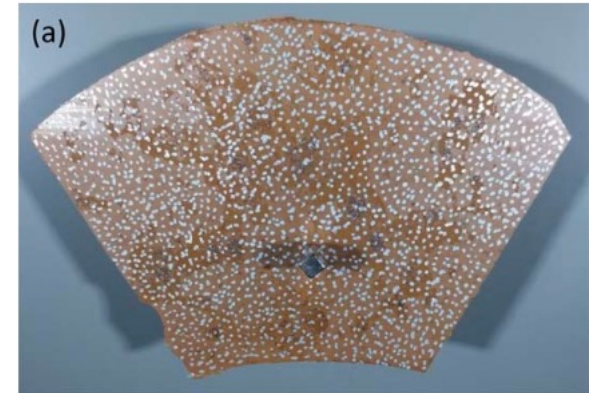
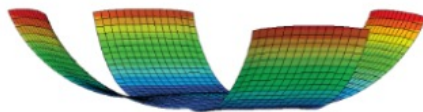
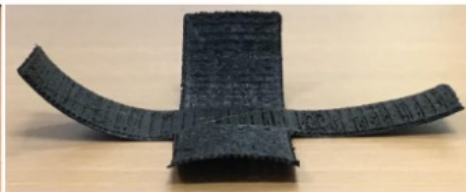
# Example of Venus inspired-inspired materials



state 1



state 2



	Sample 0 (conventional reinforcements)	Sample 3 (magnetically aligned reinforcements)
State 1 (Open)		
State 2 (Closed)		

What could be an application for these kind of materials?





# Example of Venus inspired-inspired materials

## (1) Biological system



The Venus Flytrap that closes in less than 100 ms upon mechanical input.

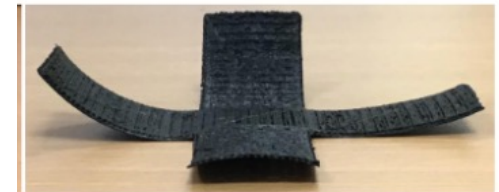
## (2) Understanding the principle behind



The leaves have perpendicular reinforcements that store energy and lead to bistability.

## (3) Apply to innovate

state 2



Create materials that are actuated in a very short time, repeatedly, in **other compositions**, shapes, for robotics, machines, etc.



# Applying the bioinspiration process – activity 4

Each table has: (1) a biomaterial, (2) a testing procedure, (3) 2 envelopes



Edamame



Lotus leaf



Seashell



Peach gum



Mushroom

**Download the PPT slides template. You will have to present the slides in 5-10 min at the end of the workshop**

# Group No.-

Name of the group members-

# Preliminary thoughts

Insert Image of the object

Initial thought that came to your mind when you saw the object:

# What you learned from the experiments

Insert Images/Videos

Brief description about what you did in the lab and what key concept you have learned.

# Biomimicry/bioinspiration in application

For what application could the mechanism learned be used?  
Suggest a problem and how biomimicry from your object can be used to solve this problem?

- Problem/Aim:
- Natural System:
- Method of implementation:



# Applying the bioinspiration process – activity 4

1. Discuss in groups about the object
2. Download the slides
3. Follow your facilitator to the lab. Take notes and pictures
4. Come back to the room to prepare the slides

It is ...

Will have the presentation at 12...

# Summary from our examples



→ Aligned bricks

→ Strong & tough

→ Unbreakable ceramics



→ Chemical bounds

→ Sticky & self-healing

→ Adhesives



→ Bilayer

→ Morphing

→ Sensing



→ Nanopillars

→ Super-hydrophobic

→ Anti fouling



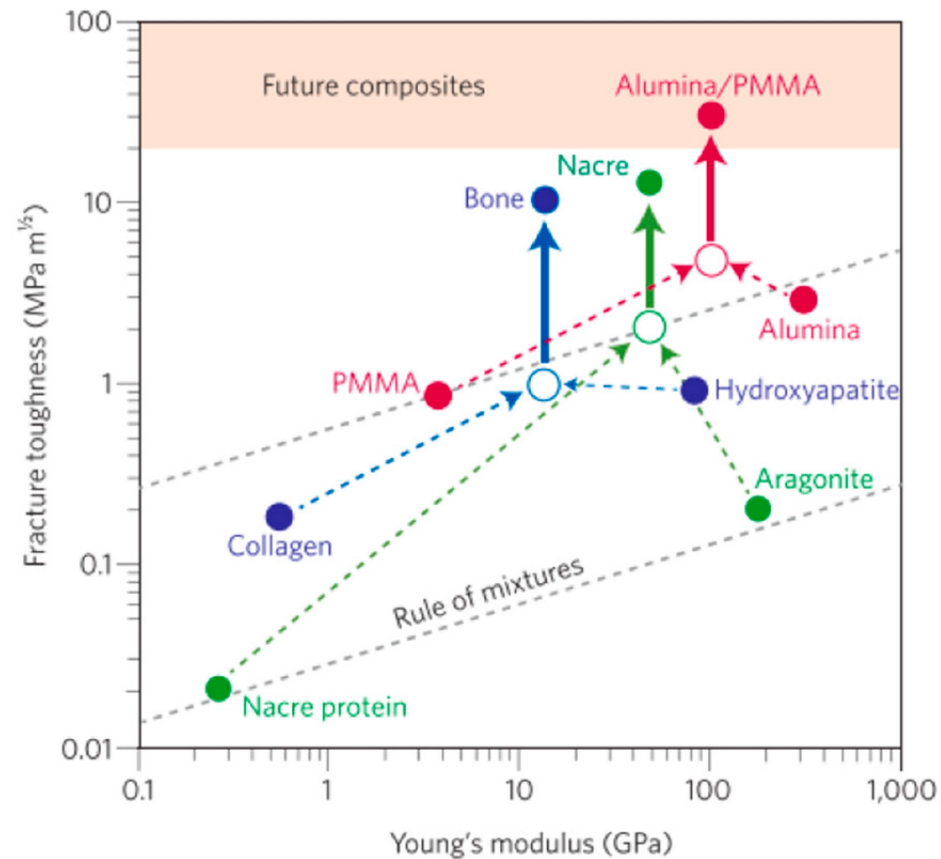
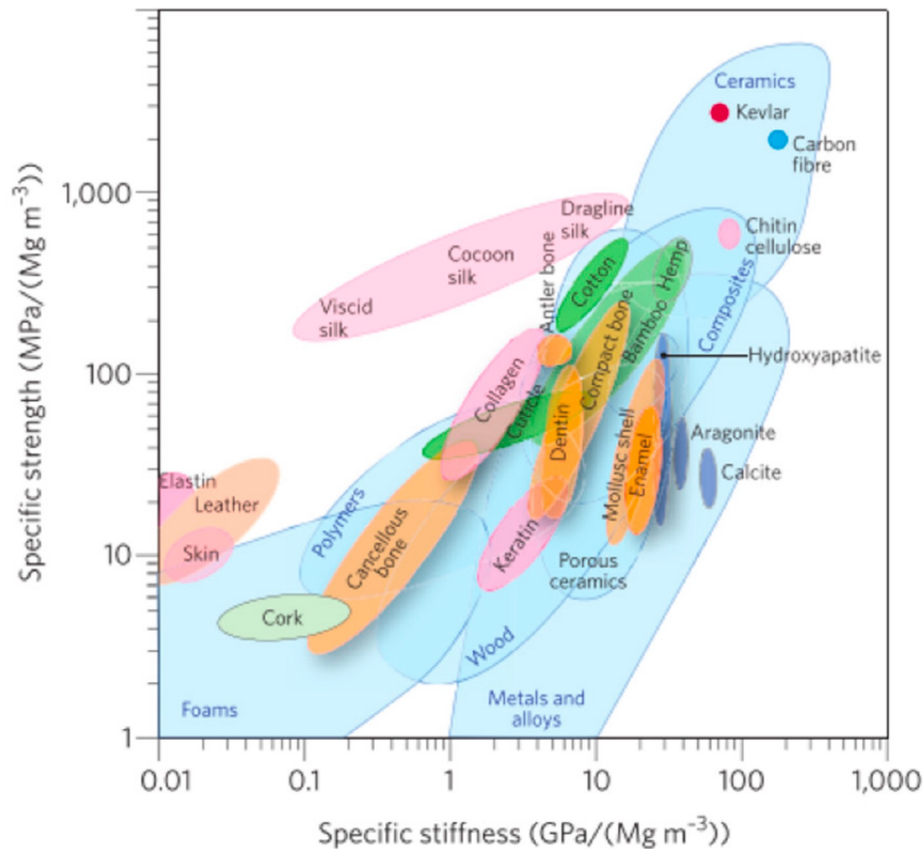
→ Gradient

→ No delamination

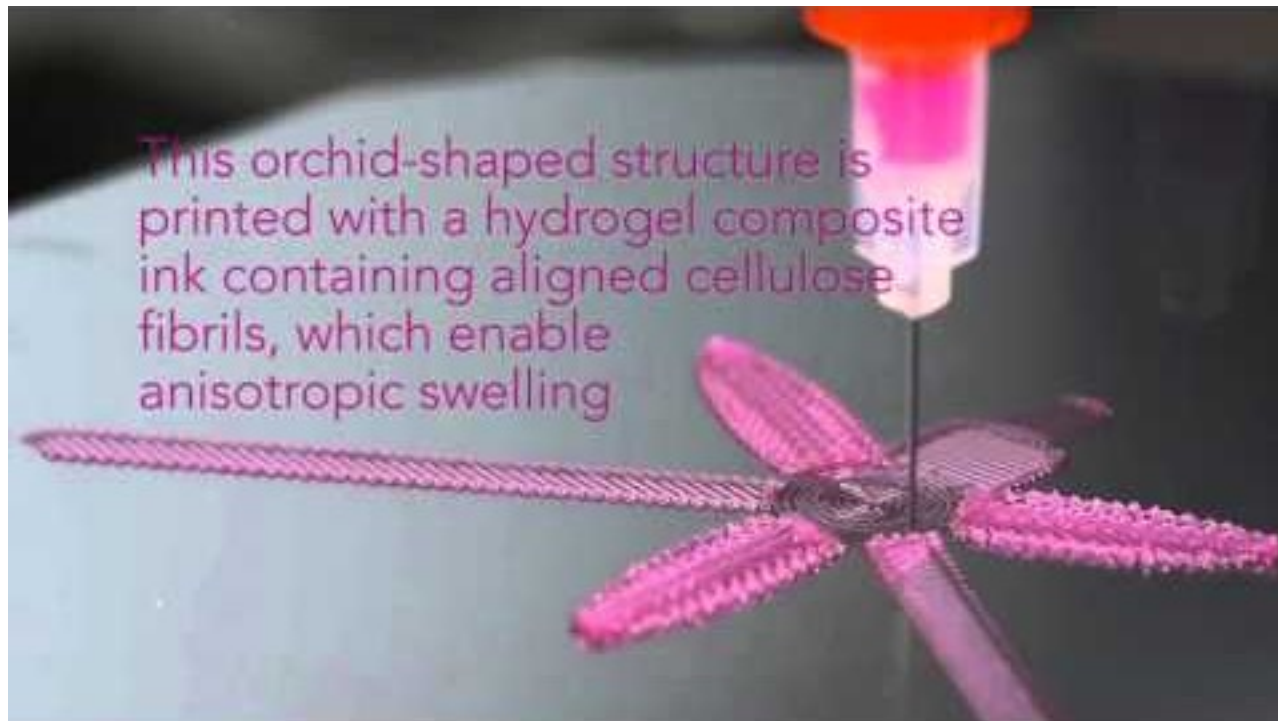
→ Orthopaedics

# Strength and toughness challenge

Ashby plots

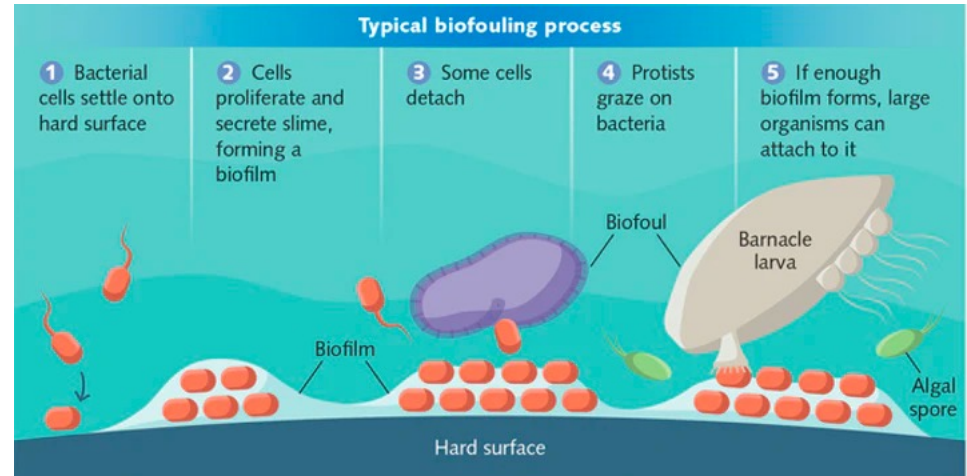


# Morphing and manufacturing



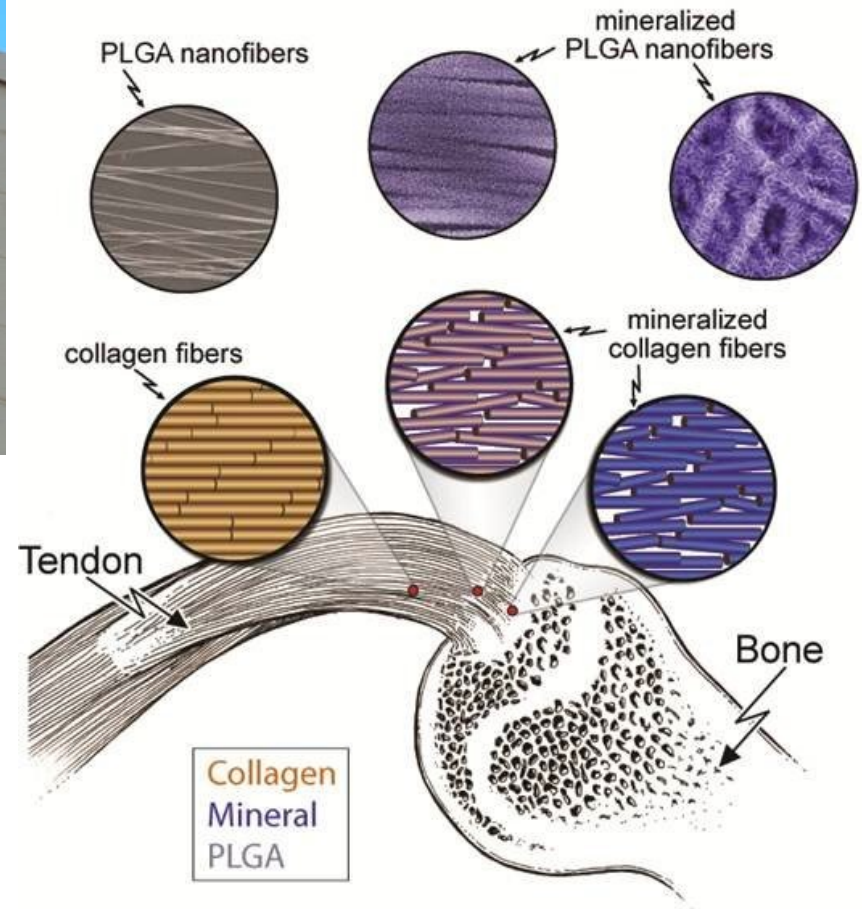
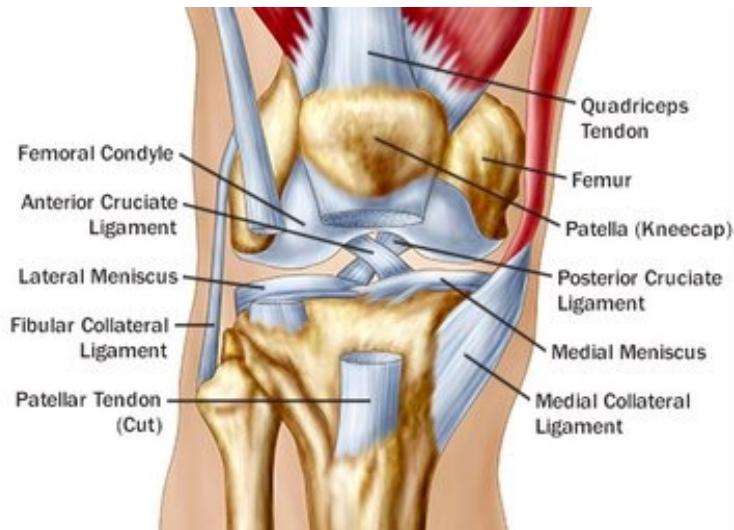


# Problem of biofouling & self-cleaning





# Problem of delamination



# Biomimicry@Singapore

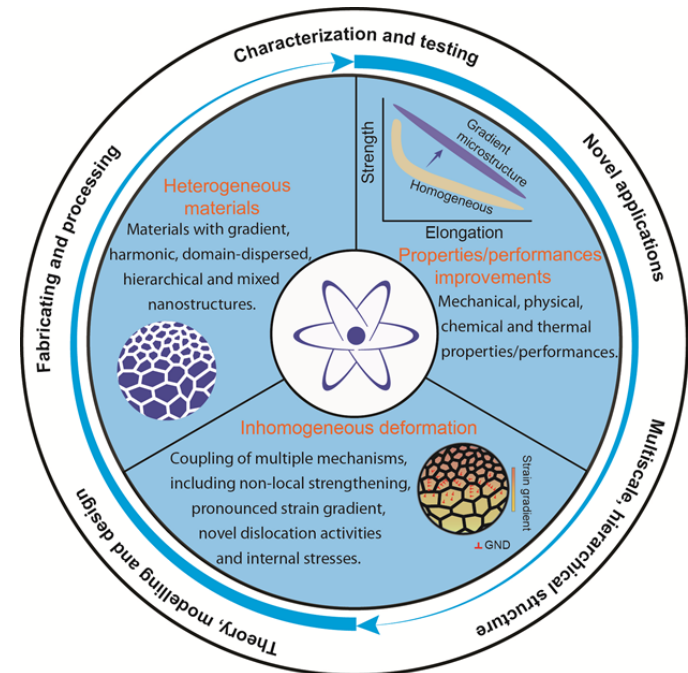
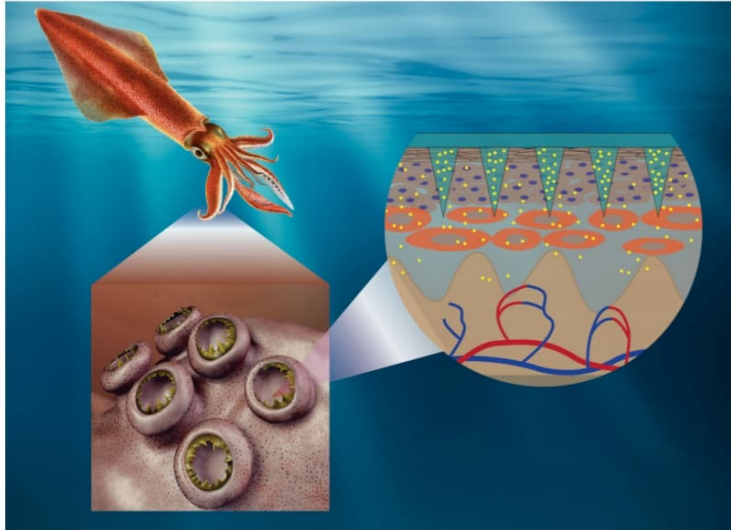
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## Biomimicry Singapore Network

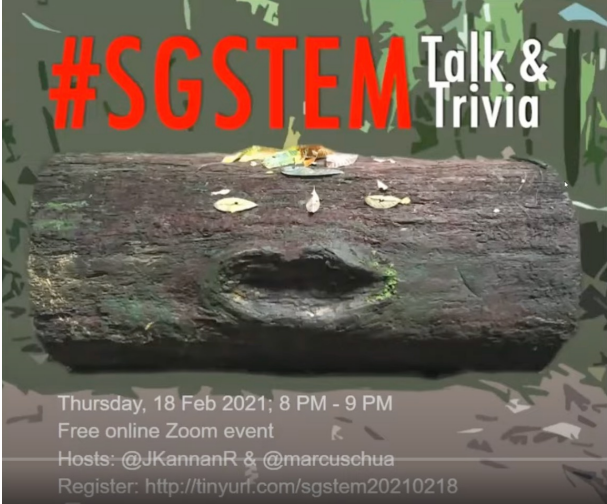
Welcome

# Bioinspiration@NTU






# Bioinspiration@Singapore



**#SGSTEM Talk & Trivia**

Thursday, 18 Feb 2021; 8 PM - 9 PM  
Free online Zoom event  
Hosts: @JKannanR & @marcuschua  
Register: <http://tinyurl.com/sgstem20210218>

Speaker: Dr Anuj Ja  
Biomimicry Singapore



**Biomimicry Education and Outreach in Singapore**

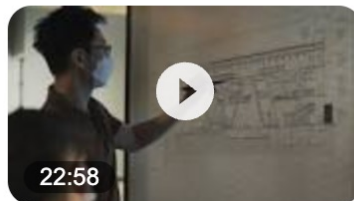
Come and learn with Anuj on how nature and technology can be intertwined to solve local and global problems through the lens of biomimicry.

Take part in an online trivia and play for an environmental or animal charity of your choice.

[https://www.youtube.com/watch?v=9j6B8B6C8O0&ab\\_channel=SGSTEM](https://www.youtube.com/watch?v=9j6B8B6C8O0&ab_channel=SGSTEM)

[www.channelnewsasia.com](http://www.channelnewsasia.com) › watch › building-nature-244...

## Building With Nature - S1 - CNA



Drawing parallels between **Singapore's** greening journey and the futuristic design of the **Singapore** Pavilion ...

CNA · 1 month ago

# Any Question?

## Can you take some time to fill in the following?



# Thank you!