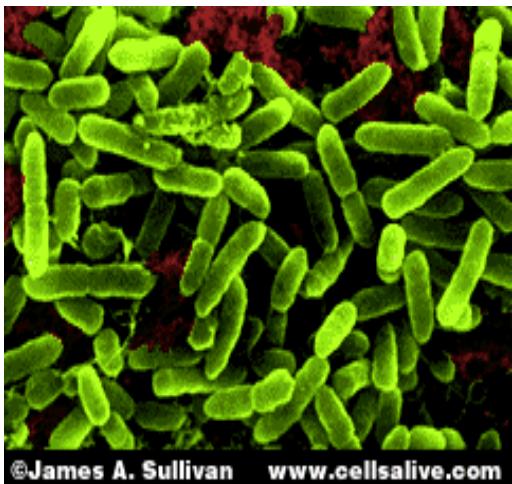


Bioscience & Bioengineering 101: BB101

Welcome to BB101!

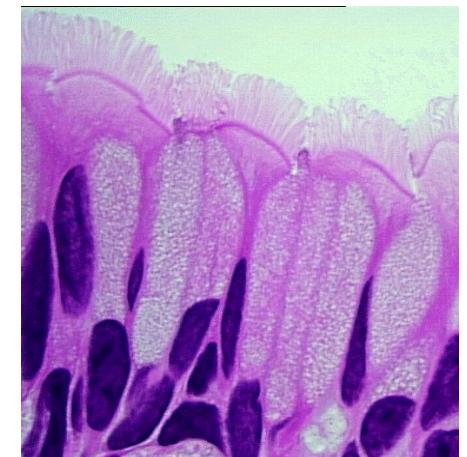
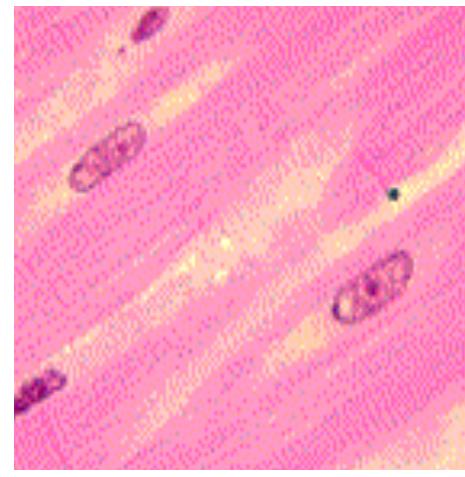
Lecture – 1
Prof. Sanjeeva Srivastava
BSBE, IIT Bombay



©James A. Sullivan www.cellsalive.com



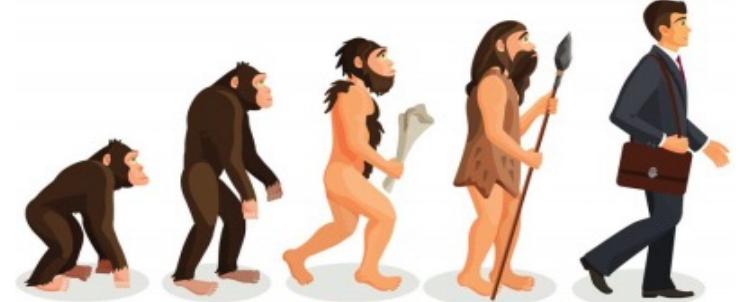
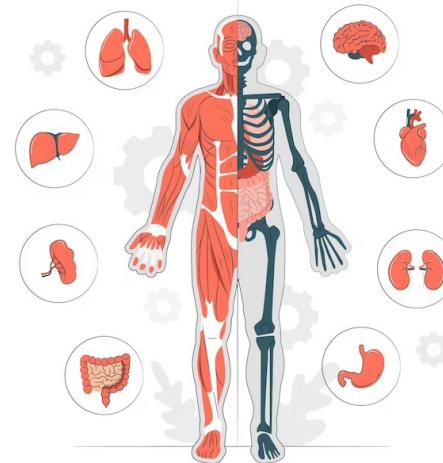
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1

Bioscience & Bioengineering 101: BB101

This is a unique course curriculum in which you are getting a broad flavor of biology. You would have to take 5-6 courses in our department to get this breadth.



Bioscience & Bioengineering 101: BB101

Sanjeeva Srivastava (SS)

Office: Room 301

Biosciences & Bioengineering

sanjeeva@iitb.ac.in

Phone: x7771



Ranjith Padinhateeri (RP)

Office: Room 306

Biosciences & Bioengineering

ranjithp@iitb.ac.in

Phone: x7761



We are friendly and approachable, but please do not harass us!

Bioscience & Bioengineering 101 (SS section)

Structure of the course

Every week:

- **Two lectures:** Will cover the topics and give you some idea/clues about the quizzes and exams.
- **One tutorial:** Will include discussions about the lecture topics and end with a quiz
- **Quizzes (5):** 5 marks each (we will take best 4 marks out of 5 quizzes, so 20 marks from quizzes)
- **Mid semester exam:** 30 marks (SS)
- **Attendance:** Not mandatory! You are grown-ups (?) and can decide whatever you want to do
- Handouts will be shared; most of the announcements on WhatsApp

Bioscience & Bioengineering 101: BB101

BB101: Teaching Assistants (BSBE M Tech/PhD students + UG students of different depts who like biology) - Intro at the end!

Textbook:

Campbell Biology: 10th edition

Introduction to Biology: before mid-sem (SS)

Before the mid-sem, we will learn about the fundamentals that enable us to think of biological organisms as living machines:

- What are they made of?
- What do they need to run?
- How do they make copies of themselves?
- How do they develop from single units into complex entities?

And most importantly, why should we care???

Introduction to Biology: after mid-sem (RP)

After the mid-sem, we will learn how to use our quantitative skills to understand the physics/chemistry/engineering principles of biological organisms as living machines:

- How do proteins fold?
- How do molecules, cells and organisms move?
- How does a heart beat?

And most importantly, why should we care???

What is your impression of Biology?

Biology is a natural science, just like Physics, Chemistry and Maths

Your impression of biology:

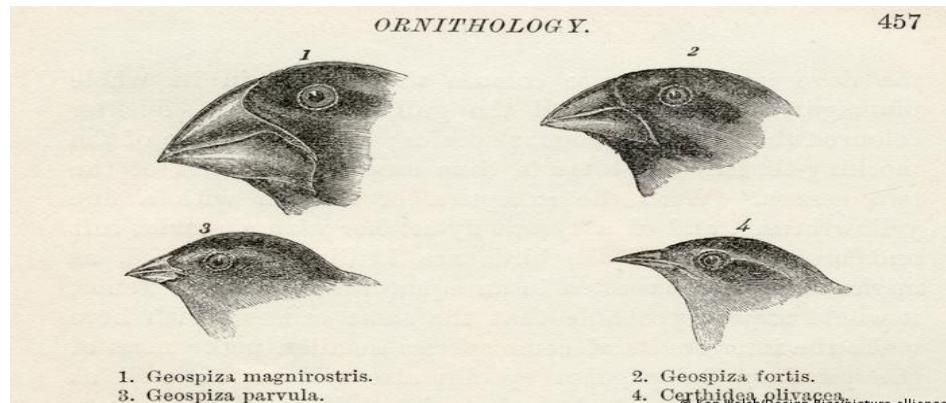
- Boring
- "Muggu"
- Drawing pictures of amoeba and paramecium
- Lots of weird names

Our job is to convince you:

- Biology has laws, rules and principles (can be understood with logic)
- Biology is highly inter-disciplinary (engineers can learn from and contribute)

Biology requires drawing skills

Charles Darwin's drawings of biodiversity



Record observations
during field visits

THEN

What is NOT sketched is even more important: coloration, texture, location, surroundings, ...



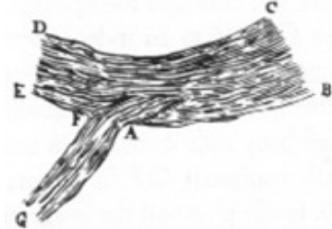
Mobile cameras, GPS, cloud servers, ...

NOW

Biology requires drawing skills

THEN

Hand drawing of plant cells

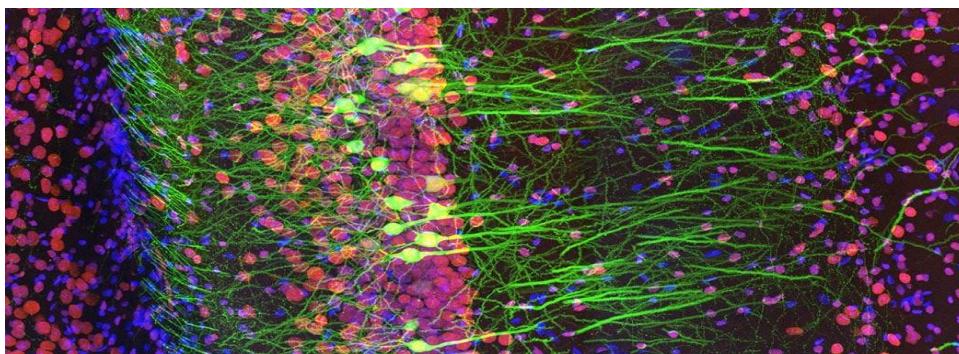


Leeuwenhoek
Microscope
(circa late 1600s)



NOW

Different cell types in the brain labeled with fluorophores



Nikon confocal microscope
(2018)



Winner of the Olympus microscopy images competition (titled: Neurogarden)

All sciences require learning names

How many components does this have?

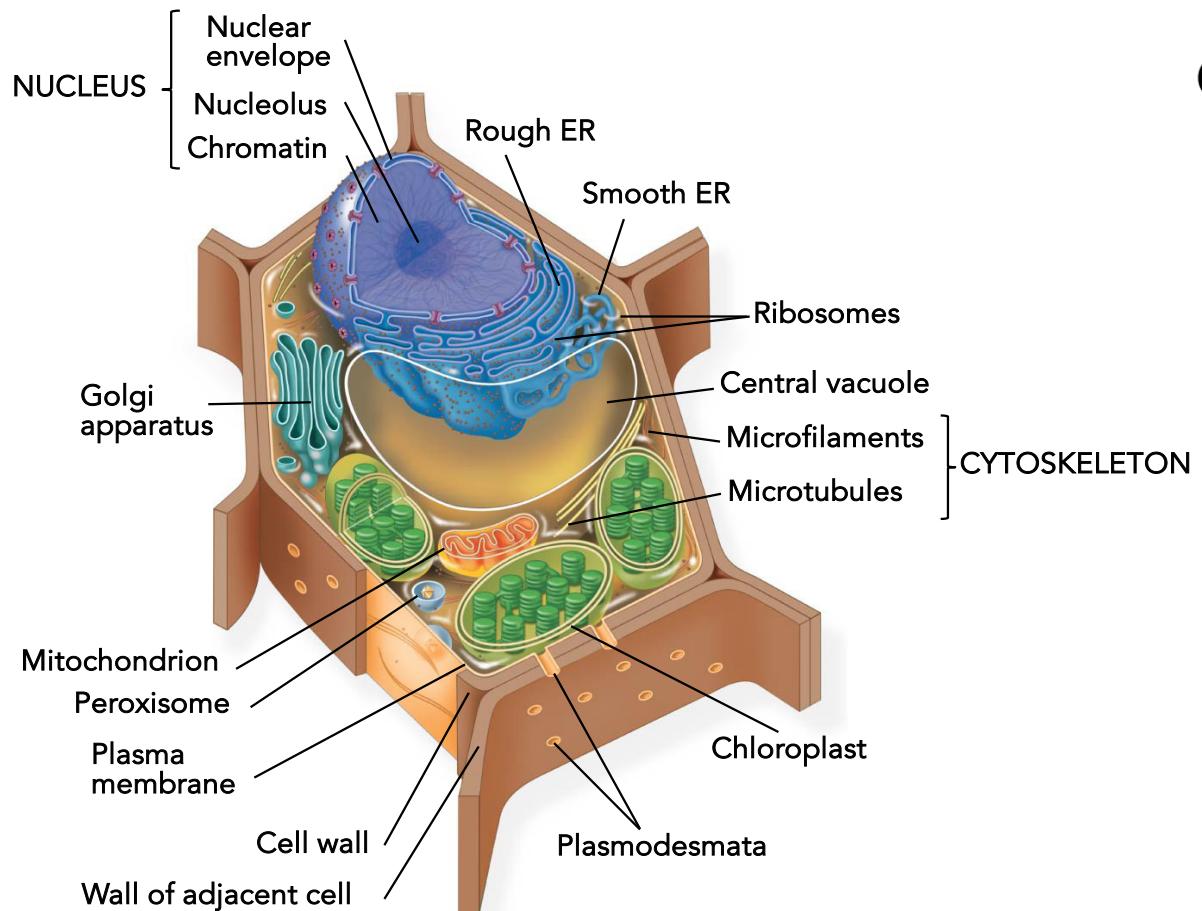


Chandrayaan-3 performed experiments using the instruments on Vikram and Pragyaan. The spacecraft was launched on July 14, 2023 on-board LVM3-M4 vehicle from SDSC, SHAR

Many students want to become space scientists... are they worried about the parts list?

Do they have to memorize the name/use of each and every component or do they learn the fundamentals and apply these?

Biology also requires learning names



Cross-section of a plant cell
that is even more complex
than a rocket

Biology is a vocabulary-rich science: *it has to be, like the study of any other complex system.*

You will not have to memorize names,
instead apply principles.

Perception versus reality!

[www.engagementaustralia.org.au/blog
/blind-men-elephant/](http://www.engagementaustralia.org.au/blog/blind-men-elephant/)

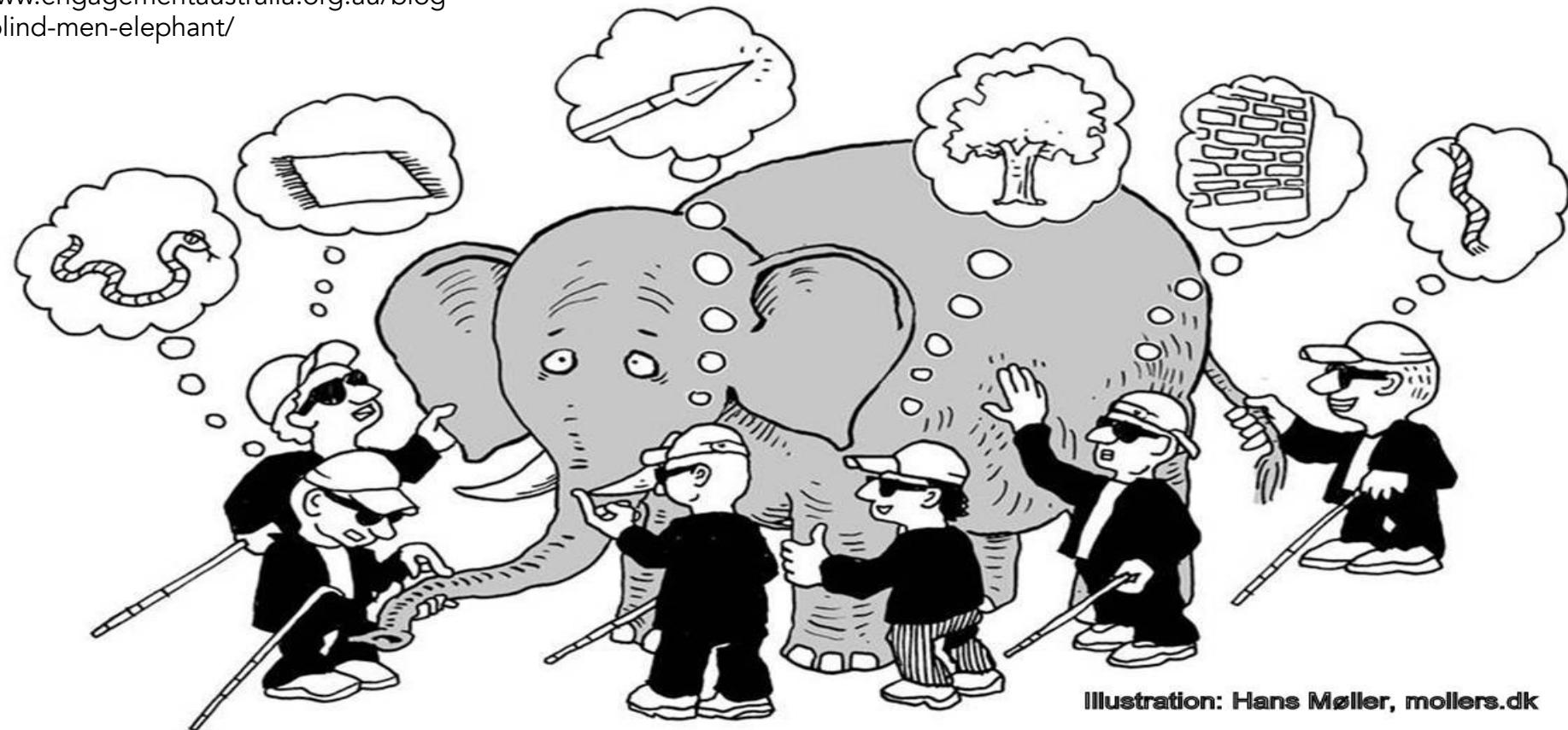


Illustration: Hans Møller, mollers.dk

Many students hate Biology: why?

Perception vs reality

PERCEPTION REALITY

Drawing skill Technology has made this requirement obsolete

Vocabulary Same as that for any complex system

Memorization No more than required for the study of any other discipline

HOW MODERN BIOLOGY IS CARRIED OUT AND HOW WE WILL TEACH



Biology is the study of life

The phenomenon we call life: defies a simple, one-sentence definition

The condition that distinguishes organisms from inorganic objects and dead organisms, being manifested by growth through metabolism, reproduction, and the power of adaptation to environment through changes originating internally-From Dictionary.com

Why study 'life'?

- Biology is the present: diabetes, heart attacks, drug/cigarette addiction, COVID-19 pandemic, etc.
- Biology is the future: COVID-19 vaccine, personalized medicine, genetically modified crops, etc.

It is nice to know enough to make informed decisions for ourselves.

What is Biology?



A large red 'X' is overlaid on a grid of biology sub-fields, indicating that these specific fields are not included in the scope of the slide.

Botany	Bioinformatics
Zoology	Biotechnology
Microbiology	Biophysics
Molecular Biology	Population biology
Neurobiology	Cell biology
Physiology	Genetics
Biochemistry	Evolutionary biology
Geology	Ethnobiology

What is Biology? The study of Life

Take a walk and what do you see?

Trees

Insects

Soil

Humans

Water

Birds



How do trees know when to shed their leaves?

Why do insects make a chirping noise?

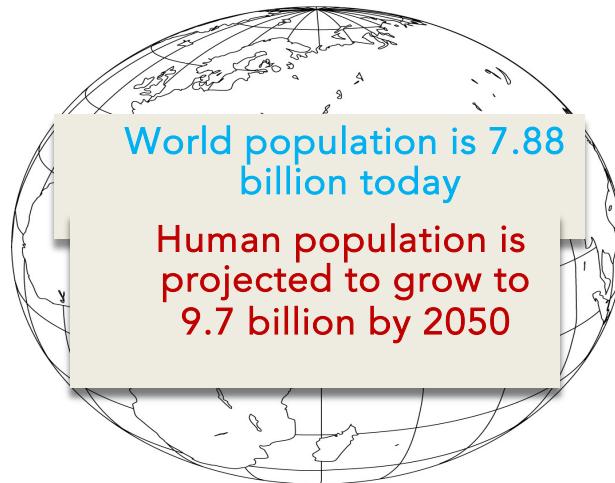
Do any creatures live in the soil?

What makes every human different from each other?

Can birds communicate with each other through song?

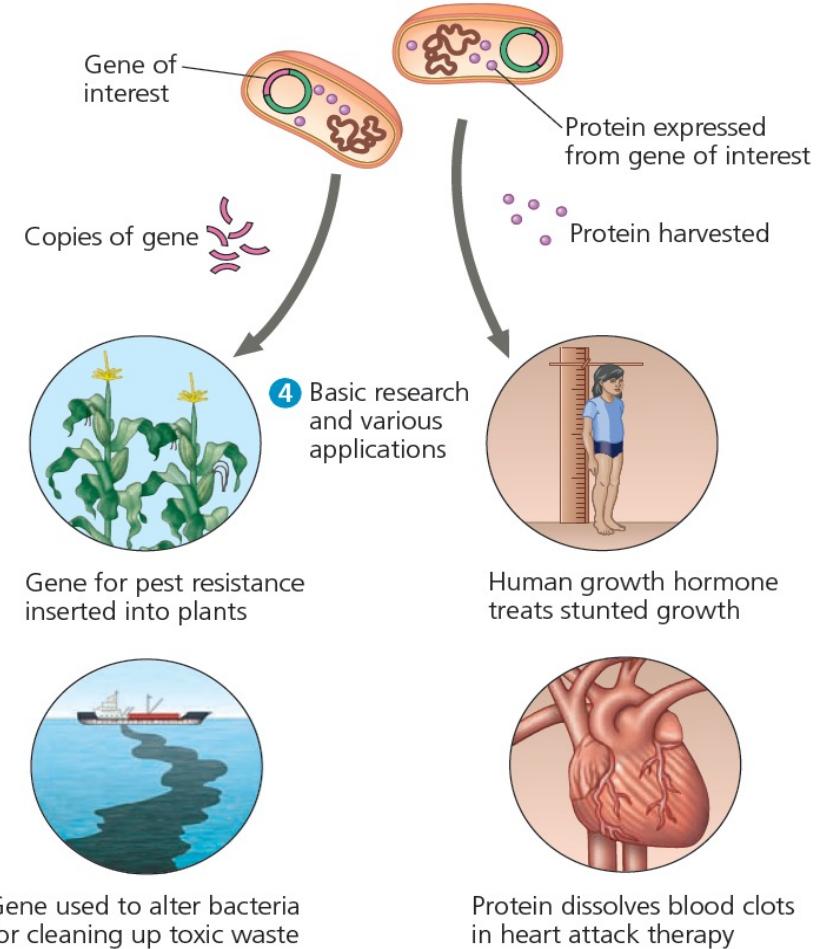
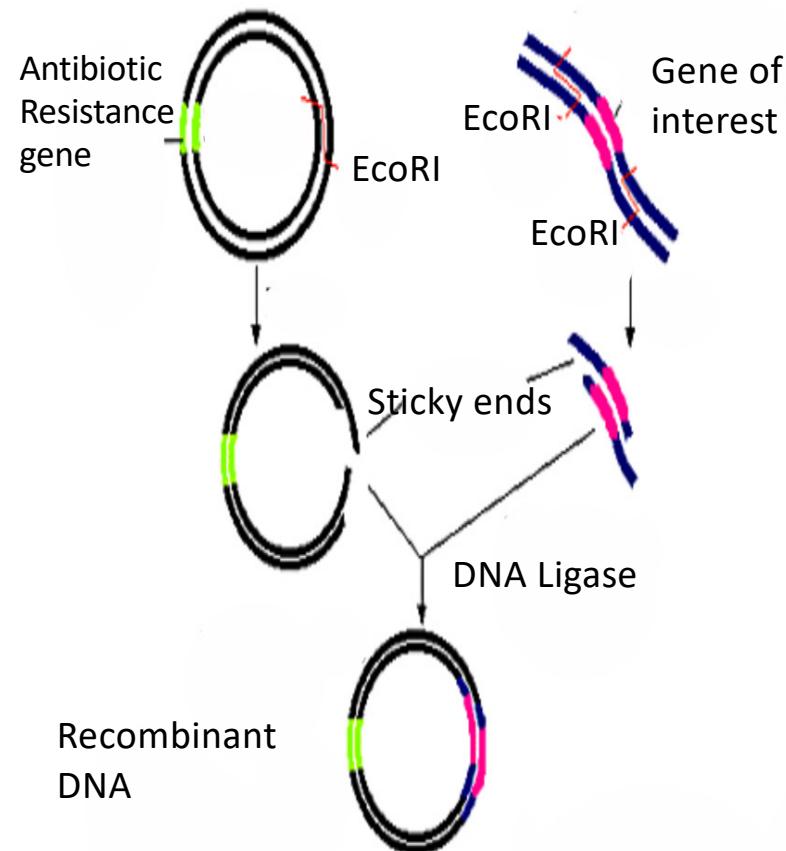
Major life problems require inter-disciplinary skills for effective solutions

How to Feed Growing World's Population?

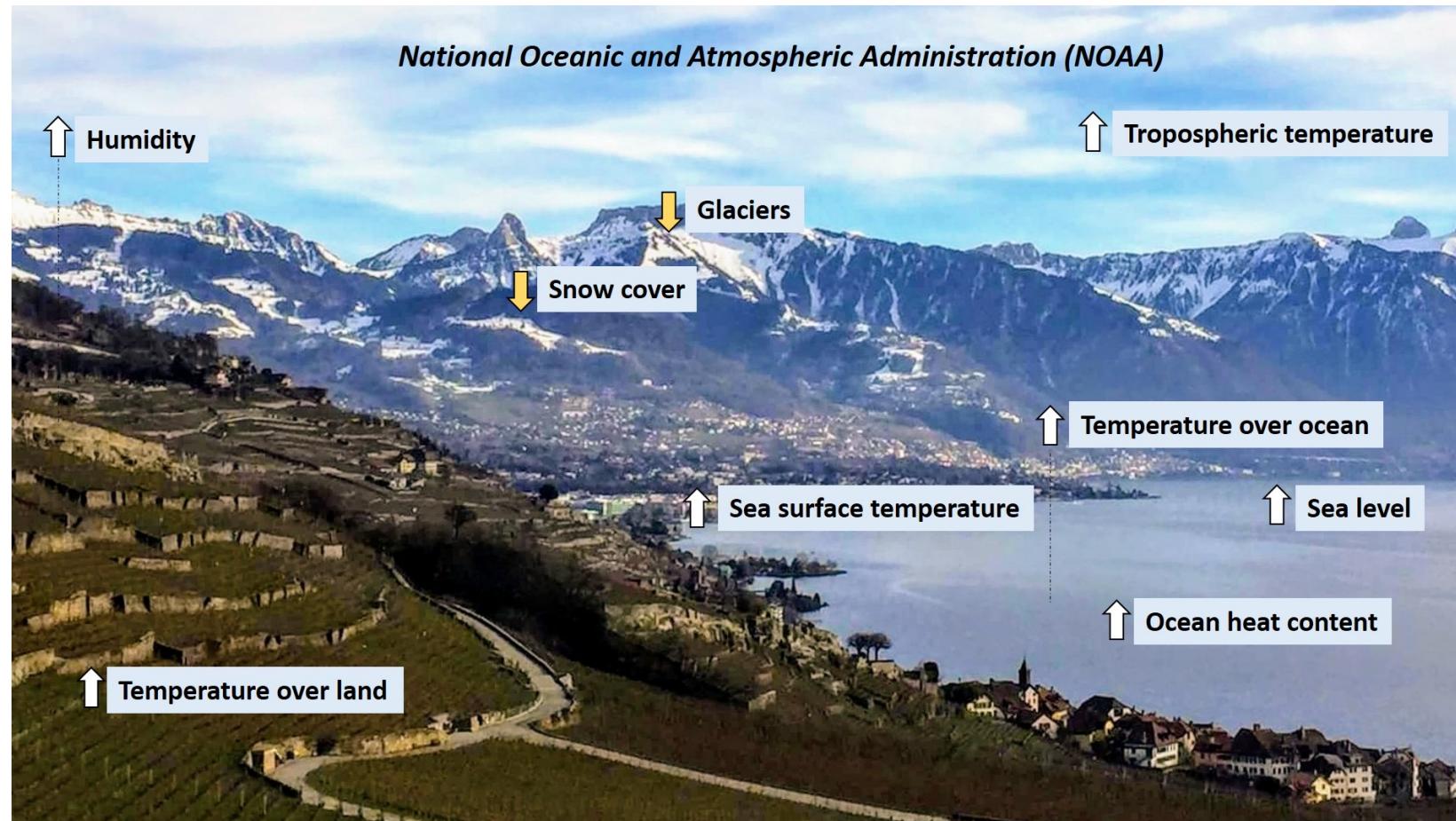


How do we feed the growing world population when most arable land on the planet is already under cultivation?

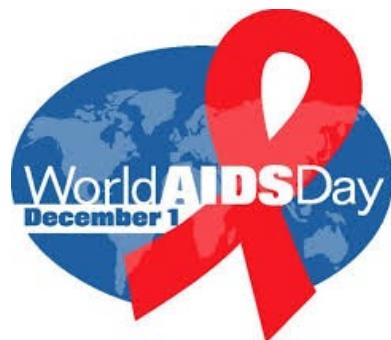
How Genetic Engineering & Biotechnology can help?



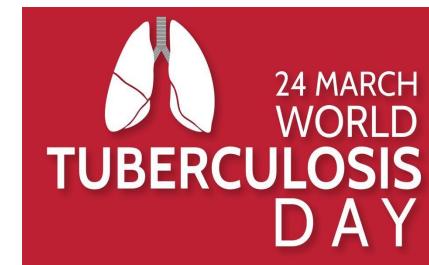
Climate Changes and Global Warming



Human Diseases



- Claimed more than 34 million lives so far.



- > 95% of TB deaths occur in low- & middle-income countries.

Bio-inspired Engineering

TRANSPORT: Learning Efficiency from Kingfisher....



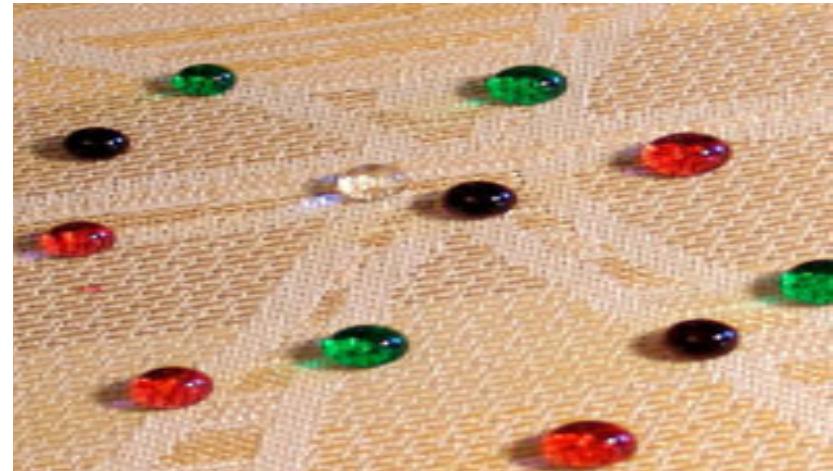
Kingfishers dive into water with very little splash to catch fish



Eiji Nakatsu, chief engineer & bird-watcher
Modeled the front-end of Shinkansen bullet train after beak of kingfisher

Result - quiet train, less electricity, travels faster

WATER PROOFING: Lotus: lessons for waterproofing....



Lotus, crevices of microscopically rough leaf surface

Traps air upon which water droplets float

Green Shield Construction Chemicals, based on "lotus effect" offers solution in Waterproofing

Result - achieves water & stain repellency

ARCHITECTURE: Creation of sustainable buildings: Lessons from Termites



- Termites, destroy building, inside maintain temp. "passive cooling"
- Cool air comes through holes, which forces hot, stale air out of vents in the top

- Air conditioning system modeled on the self-cooling mounds termites
- Mick Pearce designed Eastgate

Result – uses only 10% energy for ventilation than conventional buildings

TSUNAMI ALERT SYSTEM: Lessons from Dolphins



- Dolphins recognize calls of specific individuals up to 25 kms away
- By employing several frequencies in each transmission, find a way to cope with sound scattering behavior of their high frequency, rapid transmissions, and get their message reliably heard
- EvoLogics - high performance underwater communication and sonar, underwater robotics, fluid dynamic shape optimization



Result - high-performance underwater modem for data transmission, currently employed in tsunami early warning system in Indian Ocean

FOG HARVESTING TECHNOLOGY: Lessons from Beetle



- Namib Desert beetle (*Stenocara gracilipes*)
- Collects water droplets from morning fog on its back & let moisture roll down into its mouth

- Device consists of a fence-like mesh to attract droplet & drip into containers
- Useful for people in arid conditions

Result – development of fog harvesting technology

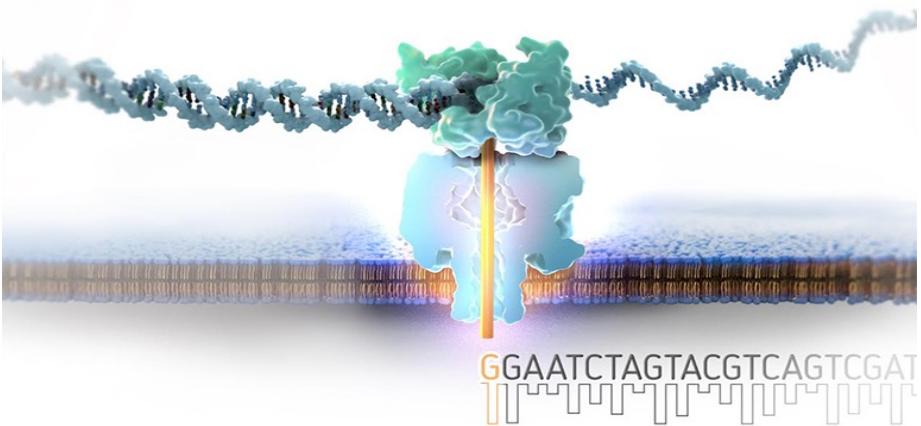
GECKO TECHNOLOGY



- An Invention Inspired by Gecko Allows humans to scale walls in same way that Spider-Man does.

Robert full, PNAS March 18, 2008 105 (11) 4215-4219

NANOPORE DNA SEQUENCING

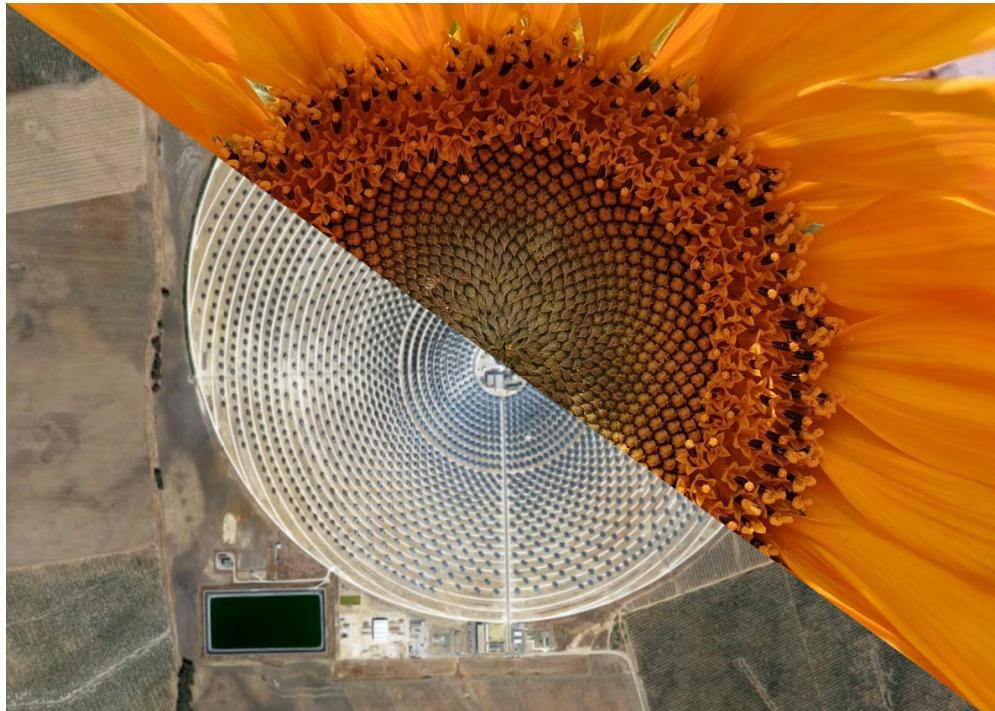


- How does nanopore DNA sequencing work?
- Operates by tracking how an electrical current changes as nucleic acids flow through a protein nanopore

*Result – One-of-a-kind sequencing technique for analysing
DNA or RNA segments in real time*

<https://nanoporetech.com/>

RENEWABLE ENERGY SOURCES



- World's Largest Concentrated Solar Power Plant is in Dubai - Inspired by Sunflower
- Rows of mirrors reflect the rays of sun to a central generator tower and work like a field of flowers

<http://edition.cnn.com/2014/05/07/tech/incredible-new-tech-inspired-by-biology/index.html>

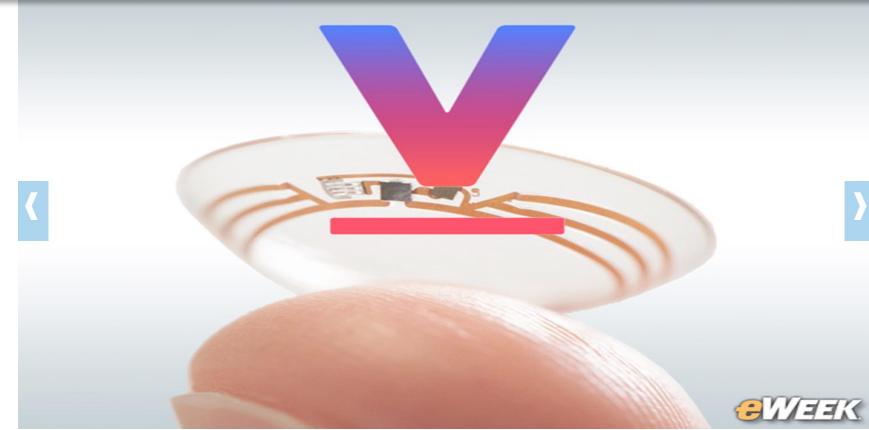
Technology Giants Investing in Mega Biology Projects



Google X Projects: Google Brain



Computational Biology - IBM



Google X Projects: Smart Contact Lens



IBM WATSON



VIVEK JAYARAMAN

Lab Head

[Jayaraman Lab](#)

[Contact Me](#)

Vivek studied to be an aerospace engineer, and spent a few fun years developing numerical simulation software for The MathWorks. A couple of excellent neuroscience courses at Brandeis University convinced him to study brains instead. He now spends his time trying to understand bugs that are a bit more fun to work on than the ones he encountered in his previous career.

B.Tech., Indian Institute of Technology, Bombay (1994)

MS, University of Florida, Gainesville (1996)

PhD, California Institute of Technology, Pasadena (2006)



Projects

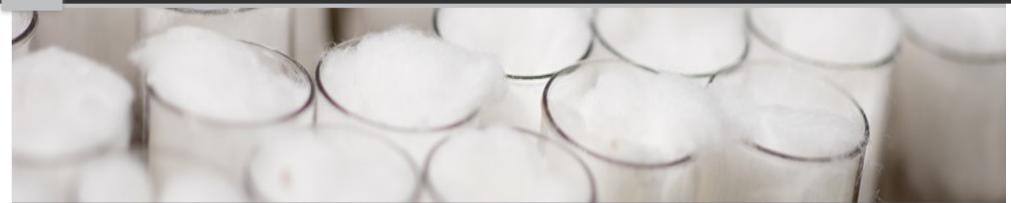
Lab Members

Publications

Joining the Lab

Lab News

Contact Us



Malik Lab Members

Dr. Harmit Malik

Harmit Malik grew up in the city of Bombay (now renamed Mumbai) in India. He attended the Indian Institute of Technology where he received a degree in Chemical Engineering. There, he was introduced to molecular biology thanks largely to the generous mentoring of Dr. K. Krishnamurthy Rao in the nascent Biotechnology Center. He then joined the Ph.D. program in Biology at the University of Rochester, under the mentorship of Tom Eickbush, studying the evolutionary origins of retrotransposable elements. He then arrived in Seattle to work on the evolution of centromeric histones and other assorted problems in Steve Henikoff's lab, funded by a postdoctoral fellowship from the Helen Hay Whitney Foundation. Tired of moving and because he is such a Mariners fan, he decided to stay at the Hutch after his postdoctoral term and started his lab in fall of 2003!

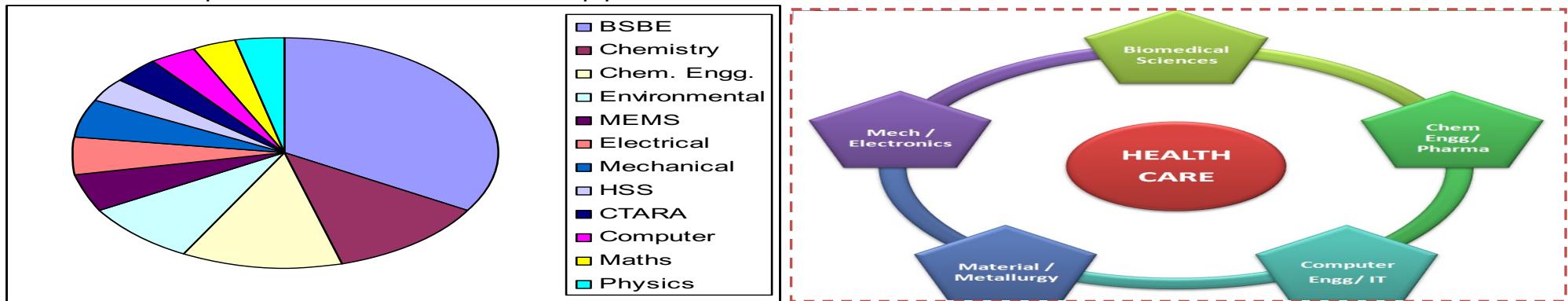
Harmit is interested in a variety of problems that could all be classified under the genetics of evolutionary conflict. He studies rapidly evolving proteins as a hallmark of this kind of conflict, hoping to better understand the molecular nature of the conflict, as well as uncover previously unrecognized sources of conflict. His lab is currently working on several rapidly evolving projects—including centromeres and heterochromatin, nuclear import and variant histones, and innate defense strategies against retroviruses. Harmit's role in the lab ranges from supervising the projects of other lab members to serving as their glorified technician.

Harmit is married to Chandni and has two young sons, Aman and Vivek. He used to be an avid reader of comic books and graphic novels. After Aman and Vivek, he is getting interested in linguistic studies of toddlers!



IIT Bombay: Faculty involved in Bioresearch

- 15% faculty of institute actively involved in bio-research
- A wide-spectrum from basic to applied & translational research



IIT Bombay
Healthcare Research @ IIT Bombay

Home About Us Workshops Presentations Photo Gallery Facilities Seed Funding Forum Shu

Home » Home

Healthcare Research @ IIT Bombay

IIT Bombay has taken an initiative to strengthen biology related activities under the umbrella of the Healthcare Initiative. Given the critical mass of faculty at IIT Bombay in this area, the Initiative aims to

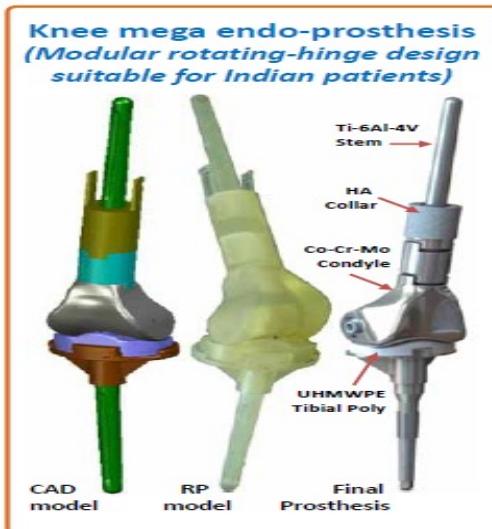
Healthcare consortium consists of IIT Bombay, TMC, KEM, Hinduja, Strand Life services & Span Diagnostics Ltd.

IITB Faculty Pursuing Interdisciplinary Bio Research



<http://www.bio.iitb.ac.in/people/faculty/srivastava-r>

Mobile based diagnostic system -
urine analysis to blood sugar test



<http://orthocad.iitb.ac.in/betic/>



www.bio.iitb.ac.in/~dpaul/research.html
Mobile based diagnostic platform to detect
sickle cells in blood at point-of-care



As with all science, in biology there are interesting questions....

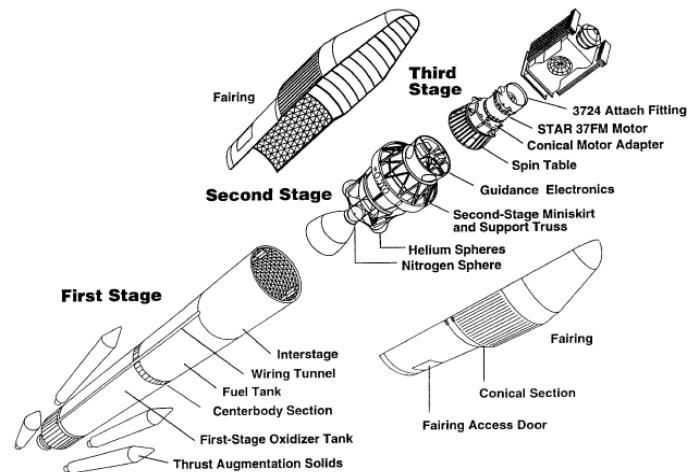
We try and find the answers by using different approaches that could involve study of behavior, populations, tissues, molecules, and even physics and chemistry.

**Before we can begin to answer
interesting questions....**

Let us look at the approaches used

Approaches to studying complex systems: bottom-up approach

(used in engineering)



(stardust.jpl.nasa.gov)

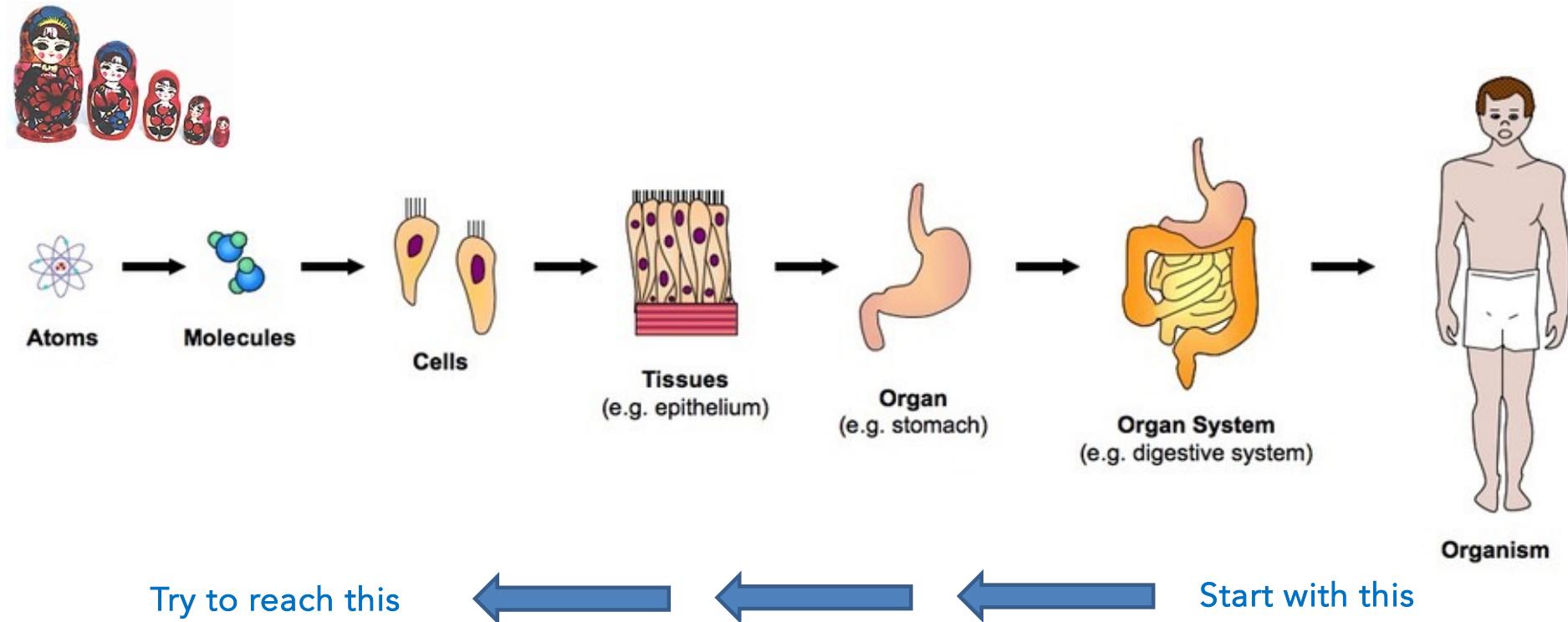


(www.orbital.com)

Information on parts and
design available in a manual

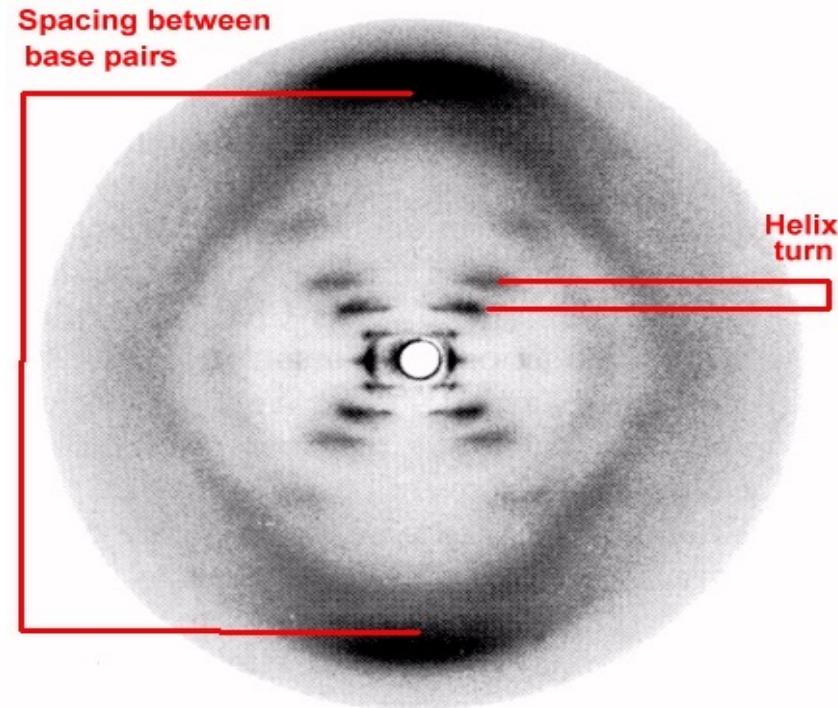
Use manual to
construct rocket

Approaches to studying complex systems: top-down approach

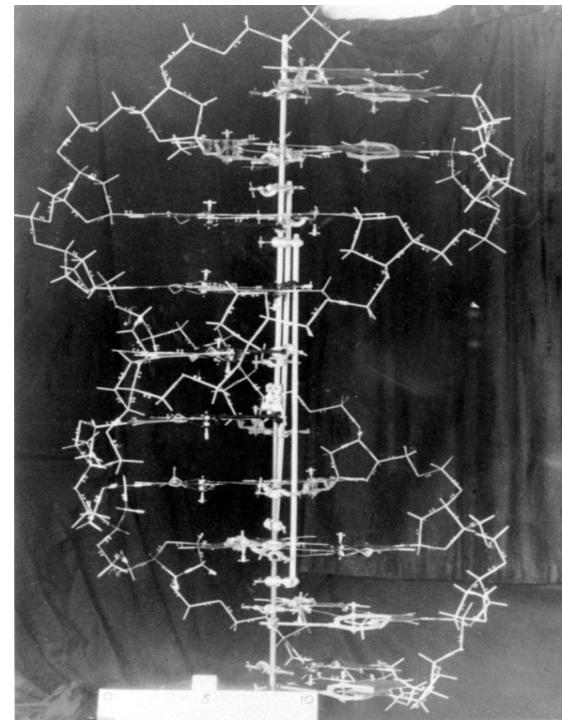


Living organisms are more complex than the rocket!
Do they have a manual (instruction booklet) as well?

Solving the structure of DNA: X-ray diffraction (physics) combined with models (chemistry)

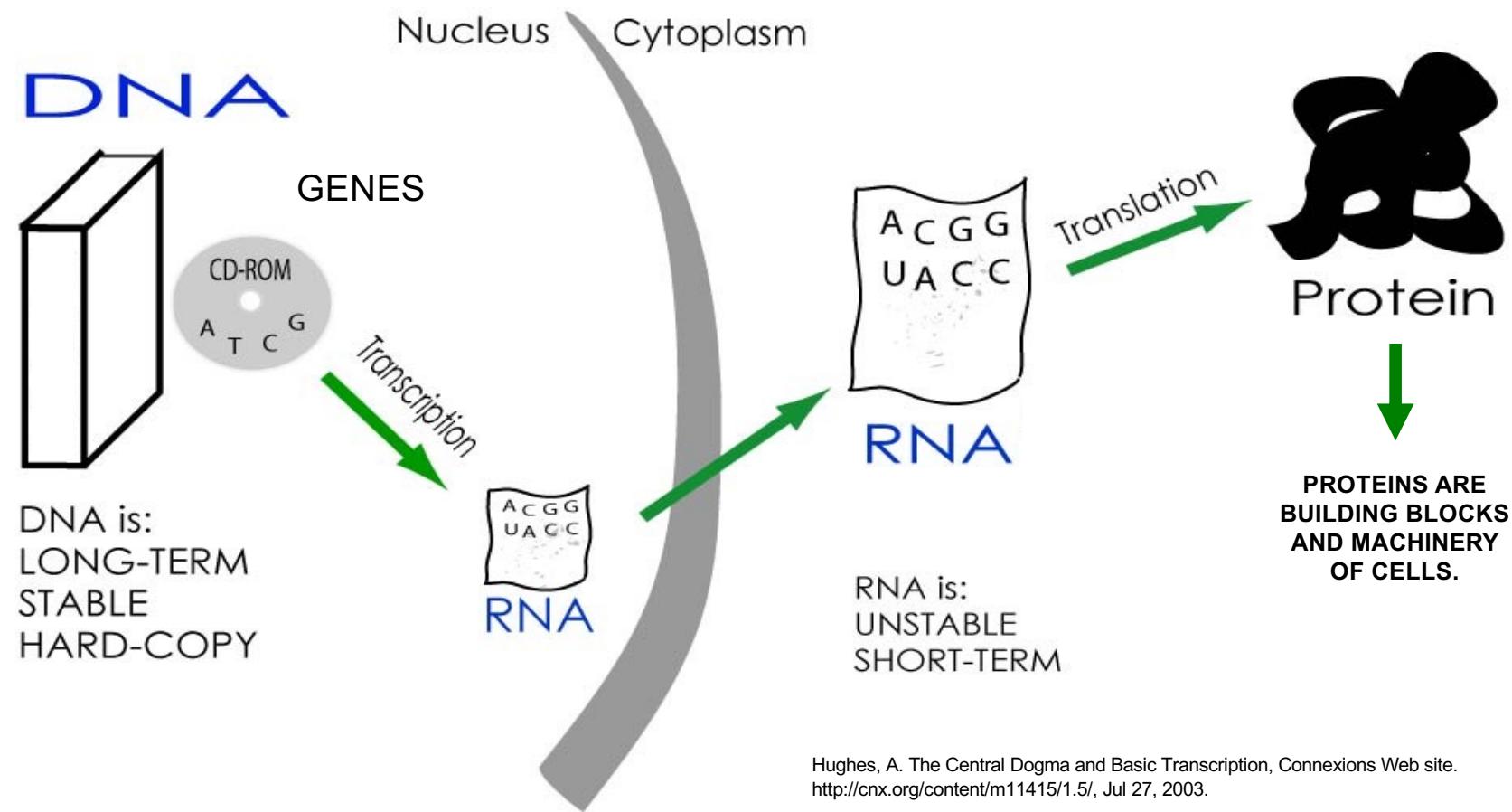


X-ray diffraction data: Rosalind Franklin and Maurice Wilkins



Ball and stick models: Watson and Crick

How can DNA be a manual? The Central Dogma



Hughes, A. The Central Dogma and Basic Transcription, Connexions Web site.
<http://cnx.org/content/m11415/1.5/>, Jul 27, 2003.

Our (human) DNA manual is huge: \sim 3 billion base pairs



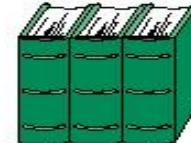
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50 kb
2 pages



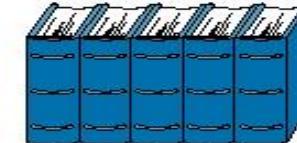
Escherichia coli
(bacteria)
4.7 Mb
200 pages



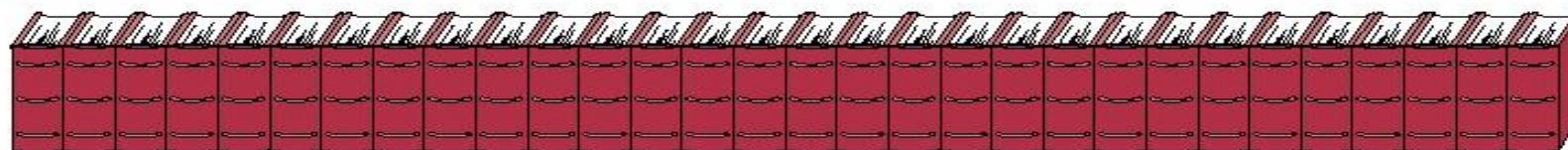
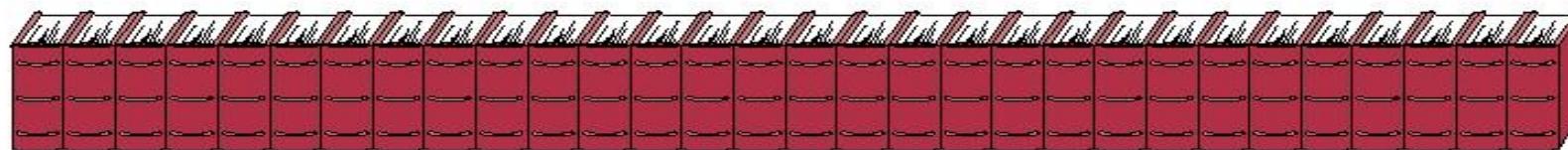
Saccharomyces cerevisiae
(yeast)
12.5 Mb
500 pages



Caenorhabditis elegans
(nematode)
Arabidopsis thaliana
(plant)
100 Mb
3 volumes



Drosophila melanogaster
(fruit fly)
165 Mb
5 volumes



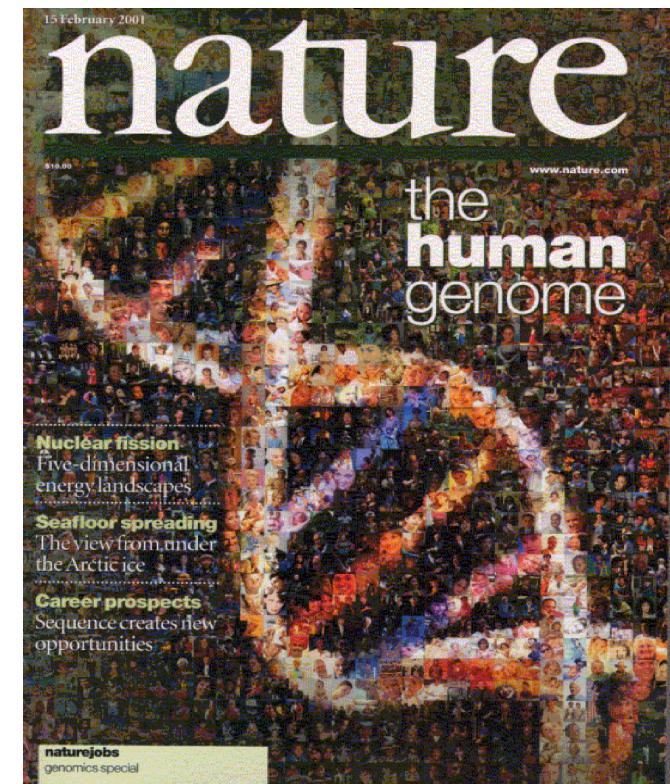
Human being
3000 Mb
80 volumes



25 kb per page
1500 pages
per volume
(2 inches thick)

Sequence of the human genome is known

- Human genome ~ 3 billion bases
...ATGCAATCCGTGCAT...
- We now know the DNA sequence of the entire human genome
- Joint effort between Celera Genomics and Human Genome Sciences



A modern crime thriller



(Photo credit: BBC News)

Latha Reddy

Delivers a baby boy in Nayapul Government Maternity Hospital, Hyderabad (2003)

Is given a baby girl on discharge from the hospital

Baby swapping racket uncovered

Can we say with certainty that a child is the offspring of his/her parents?

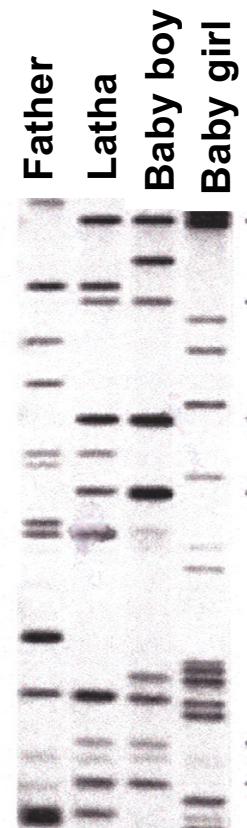
DNA fingerprinting

An example of DNA fingerprinting
(using variable repetitive elements)

A 'bar code' for each of us!



Latha's biological offspring?





Using this information can Latha Reddy's son be identified?

A nurse in the hospital confessed that a baby boy was Latha's son. Analysis of variations in the DNA of Latha and the baby boy showed that he was her biological offspring.



This is known as DNA fingerprinting.

We've talked about one interesting question in biology

What makes all of us different from each other?

- Variations in our DNA
- Applications in forensics,
- Study of the cause of various diseases,
- Population biology and ethnicity,
- And many more ...

Today we can sequence whole genomes



Per genome: the cost has dropped from USD 10 million for the first genome, to ~USD 1000 today; the time has dropped to days



Oxford Nanopore DNA sequencer can be plugged into your laptop and has been used in space!

Engineering and instrumentation

47

DNA can be a business: 1000s of genome sequencing companies in the UK and USA



Illumina: sequencing services, instruments and reagents for genome sequencing; 2021 revenue of \$4.52 billion and a market cap of \$28.92 billion.

Services: Ancestry, Traits, Health



Proteins can also be a business!



Genome companies in India

[Indian Biosciences](#) (genealogy, health, immigration paternity, relationships)

[GeneSupport](#) - a collaborative venture of [geneOmbio Technologies](#) and Resilient Cosmeceuticals Pvt Ltd, with international ties with [DNALife](#) (health, lifestyle, nutrigenomics, pharmacogenetics)

[Mapmygenome](#) (health, inherited cancer gene screening, pharmacogenetics, pre-natal screening, preconception screening, exome sequencing)

[Meragenome](#) (health)

[X Code Life Sciences](#) (health)

Haystack Analytics (infectious diseases), Proteomica (OMICS-based wellness & biopharma applications) - go visit them at the IITB incubator (SINE)!

Objectives of this course

90% of you

Give most of you enough biology background so that you have a decent understanding as you move ahead in life

- WHY? Today and tomorrow's world is one where advances in biology will affect you every day
- We will use these futuristic scenarios in class and tutorials

10% of you

Convey to some of you the excitement of biology

- WHY? You can use your engineering background to contribute to biology and biomedical research

Biology is interdisciplinary

Some examples from this lecture:

- Structure of DNA (chemistry, physics)
- Sequencing (instrumentation and engineering, computational skills)
- Other examples (from IITB):

Covid-19 point of care diagnostics

Covid-19 pooling of samples for rapid diagnosis

And many more.....

So, want to know more about modern biology?

- What is the difference between Covaxin and Covishield?
- My cousin has leukemia and there is a new treatment based on immunotherapy. Should she take this?
- My uncle has diabetes. Why is the home test for blood glucose so expensive? Can I make a cheaper test?
- **If you want to know the answers, you are ready for BB101!**

Next lecture...

- Domains of life
- Cells as the smallest units of life
- Cell compartments: functionalization
- How do we study cells?