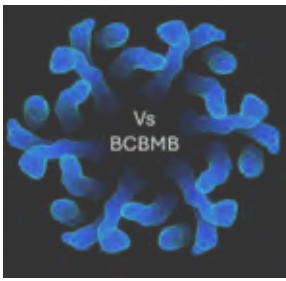


From Cell Biology to Social Media,  
the Internet, and More

# A Not So Typical Introduction to Cells

Disclaimer: **links to publications/web resources are for educational purposes only.** These resources are not owned by me. Use of these sources in this slide deck does not constitute an endorsement of the findings, nor can I guarantee their factual correctness. Reliance on these resources is at the user's discretion.



# Silent Lectures



The free PDF files you can download from here are formatted as "silent lectures"

that means: these chapters **try to engage** with you as they cover different topics

Sometimes the engagement is in the form of a "**short assignment**" (it never will take more than a few minutes, if at all that long),

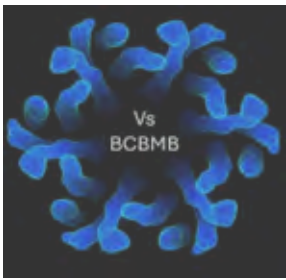
Sometimes it will be me **asking you a question** and leaving a blank space for you to think about it and come up with an answer (an answer is always provided on the next slide)

Sometimes engagement will be **inviting you to watch a short video/clip** (some made by me, some taken from YouTube) ... just follow the links in this case

Of course, I cannot force you to do any of these things, but I strongly recommend you do because it will make it more interesting, and your outcomes/retention will be MUCH better.

One advantage of this format is that you can work through the chapters at your own pace.

Adding to that: you will have the best outcomes if you turn these "silent lectures" into fully immersive experiences by playing your favorite music (at a low volume) or light some aromatherapy candles to set the mood. Even better if you invite a friend or two and work through this together because in this case, you can discuss questions that are asked and see who comes the closest to the relevant answer.



## With the Intro Comments Out of The Way – Here We Go Setting the Stage

**Google: “Cell Images”**

scroll through the search results and  
try to sum up in you own words what you see





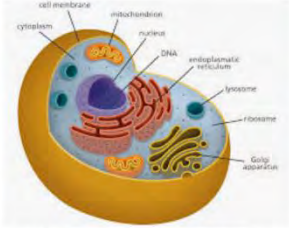
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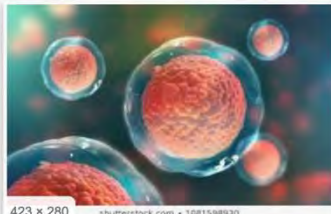
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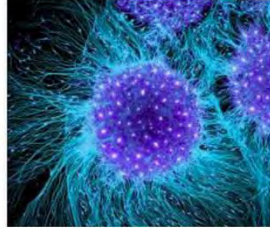
Cell Images, Stock Photos & Vectors ...  
shutterstock.com



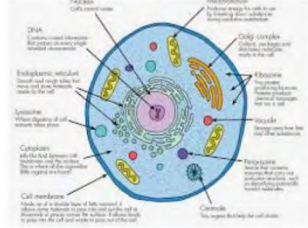
What is a cell? | Facts | yourgenome.org  
yourgenome.org



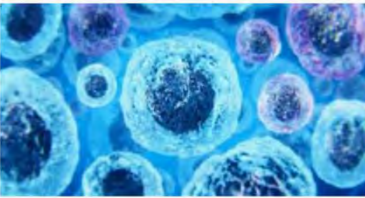
Cell Images, Stock Photos & Vectors ...  
shutterstock.com



How human embryonic stem cells spa...  
nature.com



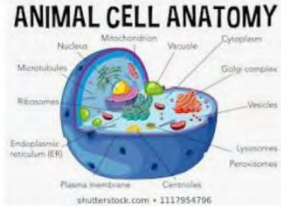
Cells - Haleo  
haleo.co.uk



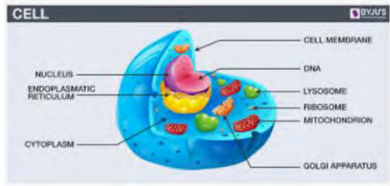
cell biology | Quanta Magazine  
quantamagazine.org



Animal Cells and the Membrane-Bound Nuc...  
thoughtco.com



Cell Images, Stock Photos & Vectors ...  
shutterstock.com



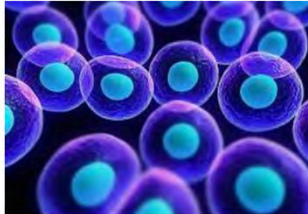
Cells: Definition, Types of Cells ...  
byjus.com



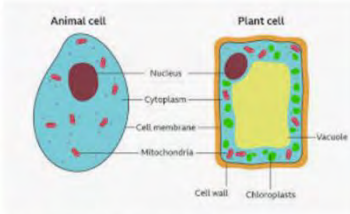
Animal Cell  
giantmicrobes.com



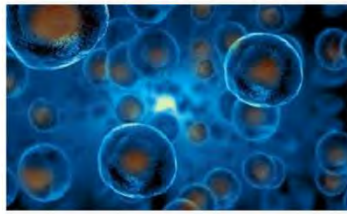
Animal Cell  
giantmicrobes.com



Stem Cell Toxicology | Asymmetrex  
asymmetrex.com



What are cells? - BBC Bitesize  
bbc.co.uk



Human stem cell combination could help ...  
drugtargetreview.com

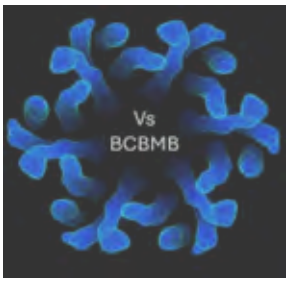


Mitochondria behind blood cell formation  
phys.org



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write down observations of what you see.  
Explicitly identify features you may recognize.

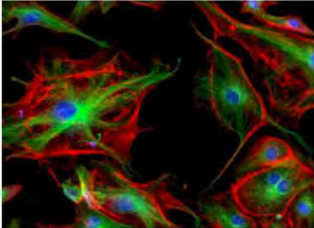
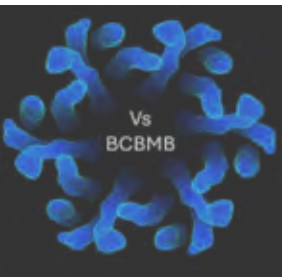




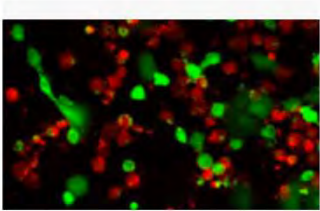
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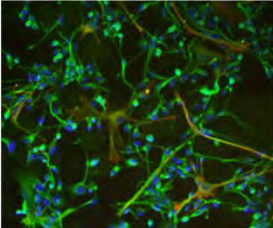
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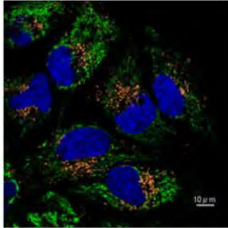
shows promise for fluorescent cell imaging  
europeanpharmaceuticalreview.com



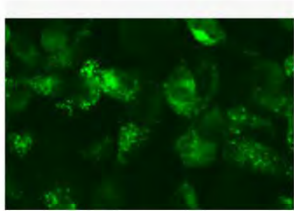
Live Cell Imaging Reagents | Sigma-Aldrich  
sigmaaldrich.com



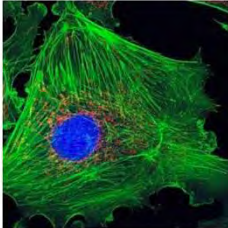
Innoprot  
innoprot.com



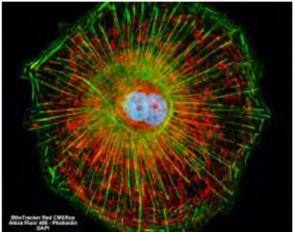
Live Cell Imaging – Monitor ...  
tebu-bio.com



Live Cell Imaging Reagents | Sigma-...  
sigmaaldrich.com



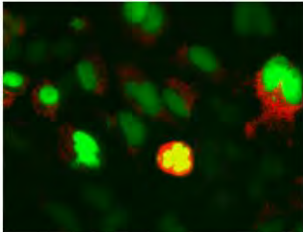
micrograph. Fluorescent dye...  
pinterest.com



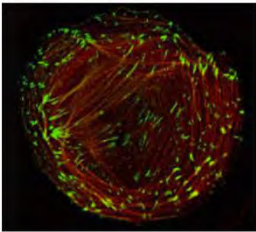
ZEISS Microscopy Online Campus ...  
zeiss-campus.magnet.fsu.edu



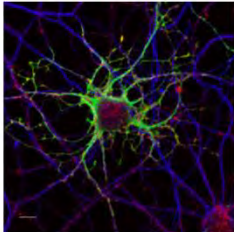
cell-sight" with Deep L...  
towardsdatascience.com



Preparing for Live-Cell Imaging ...  
thermofisher.com



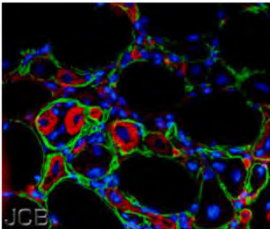
CellLight Fluorescent Protein La...  
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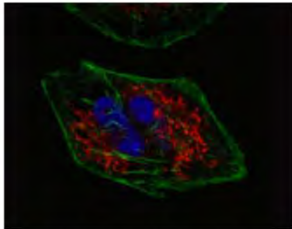
Fluorescent microscopy - LN...  
Inf-wiki.eecs.umich.edu



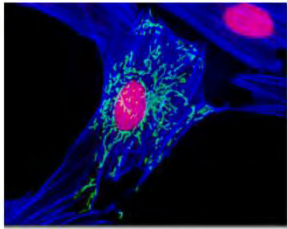
Rainbow Cell Barcoding: Fluorescent ...  
advancedsciencenews.com



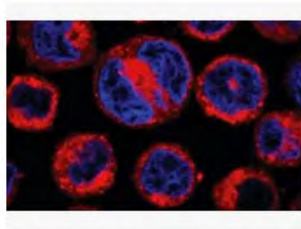
Fluorescent Nanodiamonds – the ...  
sustainable-nano.com



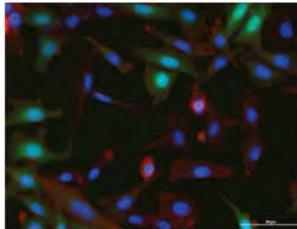
CellLight Fluorescent Protein Labelin...  
thermofisher.com



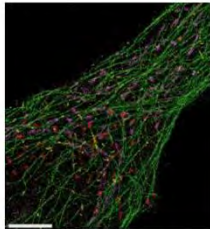
Molecular Expressions Microscopy Pr...  
micro.magnet.fsu.edu



Live Cell Imaging Reagents | Sigma-AI...  
sigmaaldrich.com



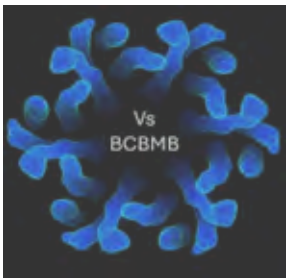
Fluorescence Microscopy ...  
biotek.com



Ultra-Sharp Images of Cel...  
wired.com

## Setting the Stage

Google: “Cytoskeleton Fluorescence Images”

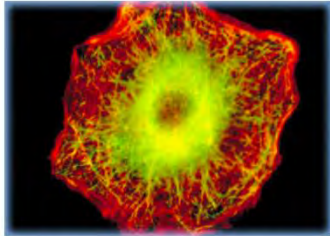
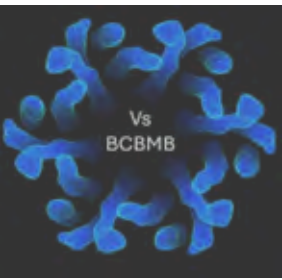




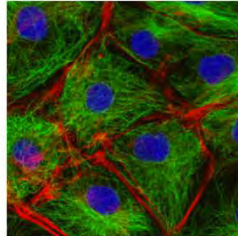
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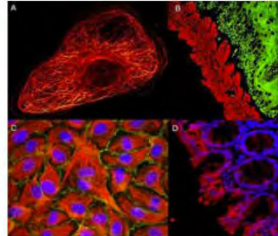
Things it showed to me....



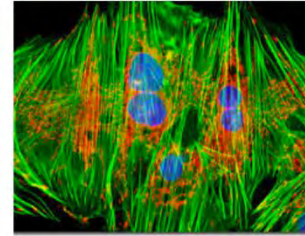
Cellular Cytoskeleton | Olympus Life ...  
olympus-lifescience.com



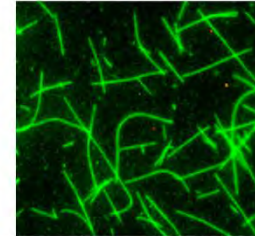
Cytoskeleton – the movers a...  
bscb.org



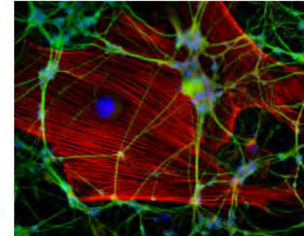
actin assays for cytoskeleton dyna...  
tebu-bio.com



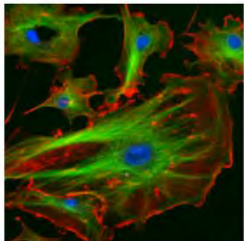
Molecular Expressions Microscopy Pri...  
micro.magnet.fsu.edu



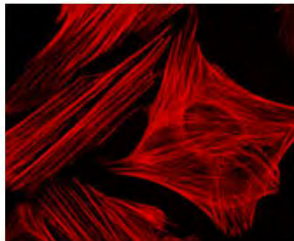
Fluorescent Tubulin Proteins  
cytoskeleton.com



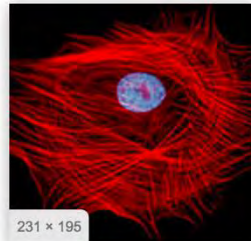
CIL:41649, glial cell, neuron. CIL. Dat...  
cellimagelibrary.org



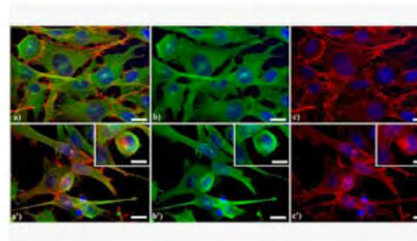
Snapshots of the Cytoskelo...  
sustainable-nano.com



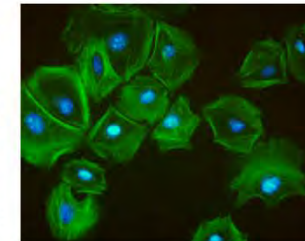
Indian Muntjac Actin Cytoskeleton ...  
microscopyu.com



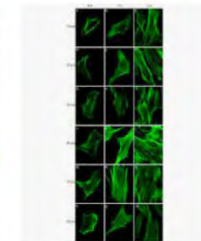
Cytoskeleton Structure | Ther...  
thermofisher.com



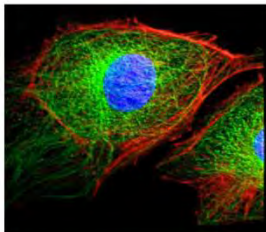
Fluorescence microscopy after double ...  
researchgate.net



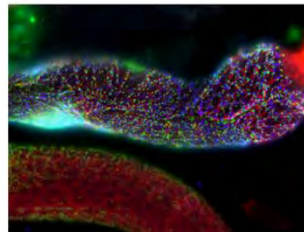
micrograph showing cell nuclei ...  
pinterest.com



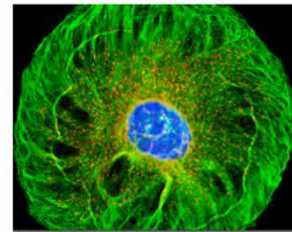
actin cytoskeleton of t...  
researchgate.net



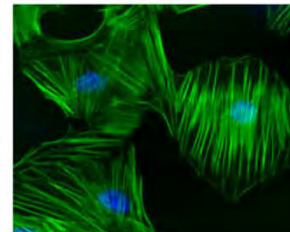
Flickr Hive Mind



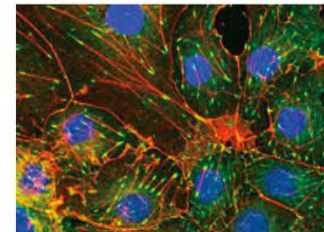
C. elegans Gonad by Dr. Shoichiro On



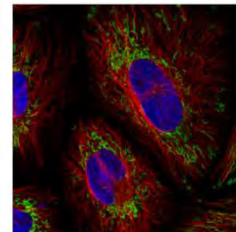
Molecular Expressions Microscopy



News



Enrichment & Staining | Life Science

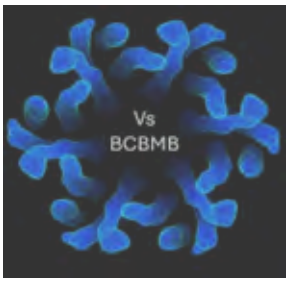


Solved: Fluorescence Micro

https://www.google.com/images?maurl=https://www.thermofisher.com/content/dam/LifeTech/global/life-sciences/cellanalysis...-d&bih=767&biw=1440&q=cytoskeleton fluorescence images&ved=0ahUKEwi9-zN4brkAhXCI-AKHTVBErEQMwhqKA4wDa&iact=mr&uact=8

## Setting the Stage – Last One

Google: “Neuron Fluorescence Images” .....

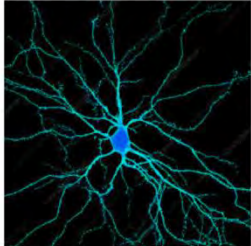
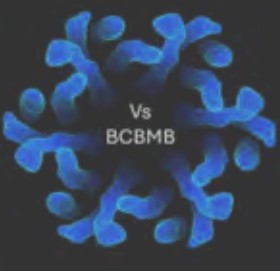




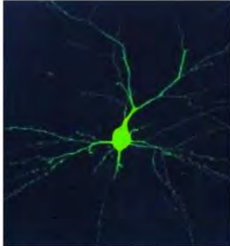
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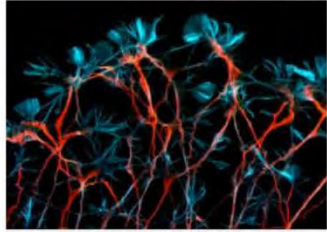
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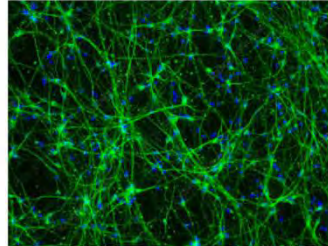
Neuron, fluorescence microgra... sciencephoto.com



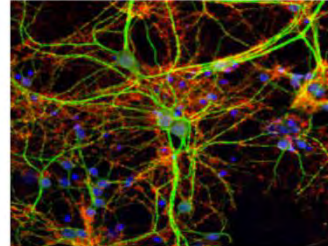
A morphology of a single ne... researchgate.net



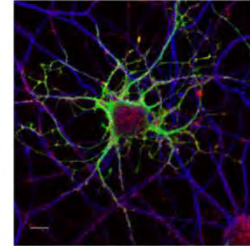
Neurons Fluorescence Images, Stock ... shutterstock.com



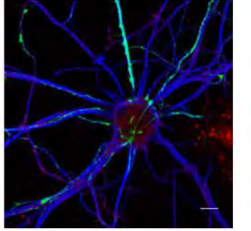
Neurons from stem cells, fluoresce ... sciencephoto.com



Fluorescent Probes | Thermo Fisher ... thermofisher.com



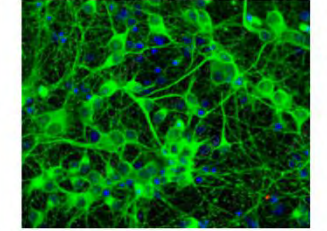
confocal fluorescence microsc... flickr.com



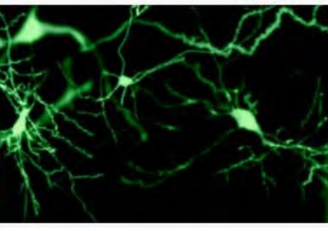
Neurons, confocal fluoresce... flickr.com



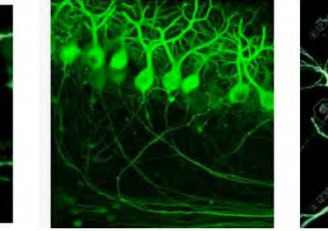
Pyramidal Neuron, Fluorescence... 123rf.com



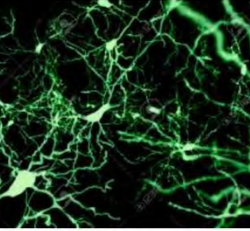
Brain hippocampus neurons, fluore... sciencephoto.com



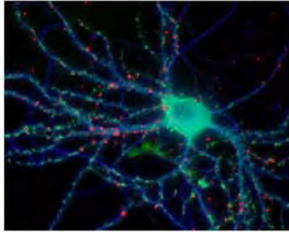
Fluorescence Stock Footage ... shutterstock.com



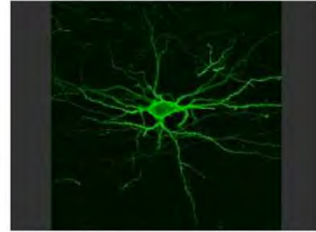
Fluorescence microscopy im... pinterest.com



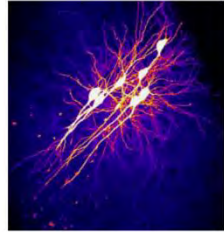
Marked By Fluorescence Stock Photo ... 123rf.com



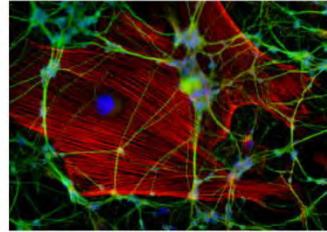
science biology microscopy neuron ... rebloggy.com



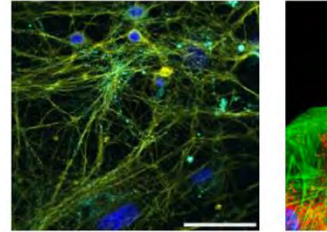
Seeing the brain's electrical activity ... news.mit.edu



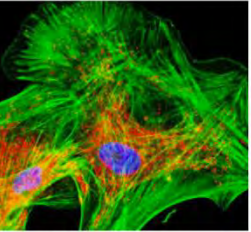
science biology neuroscie... rebloggy.com



CIL:41649, glial cell, neuron. CIL. Dataset cellimagelibrary.org



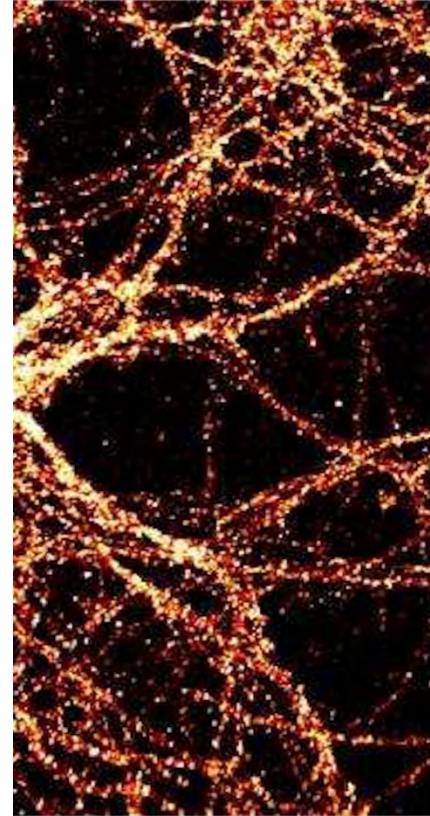
Confusion at the neuronal leve... fau.eu



Human Cortical Neuronal Cells (HCN-1... microscopyu.com

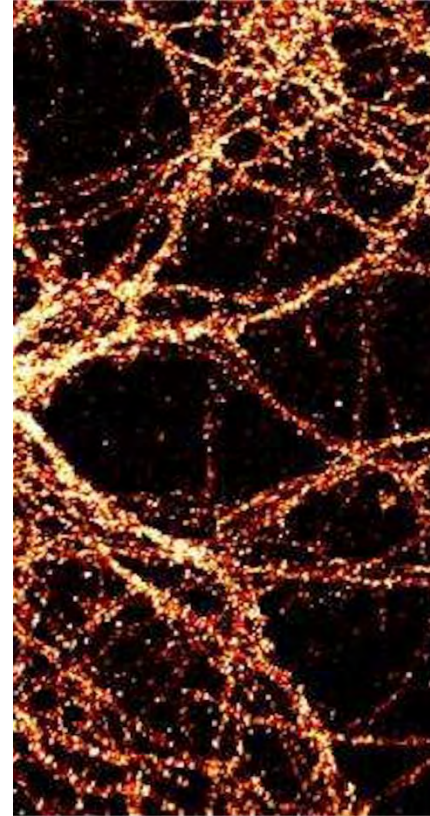
# Test Your Knowledge

Based on what you looked at so far and using what you know/remember from previous encounters with biology – take a guess what the following images show



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Based on what you looked at so far and using what you know/remember from previous encounters with biology – take a guess what the following images show



## Hippocampal Neurons

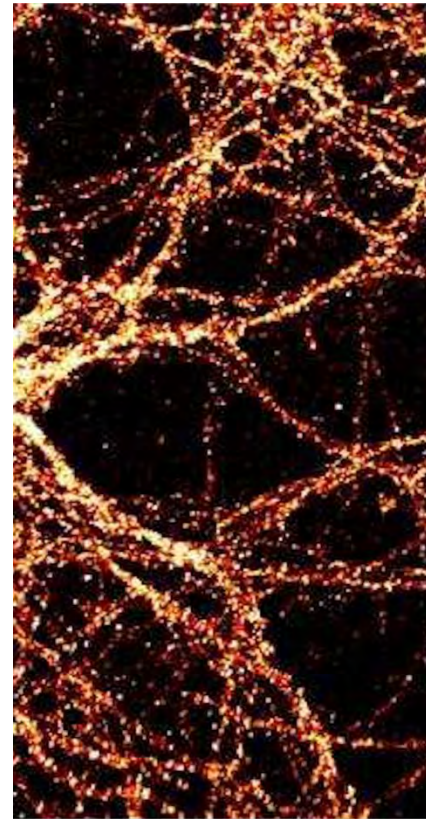
© Yu, H et al (2015)  
Nat Neurosci 18:836-43

© <https://medicalxpress.com/news/2015-04-neurons-constantly-rewrite-dna.html>

# Test Your Knowledge

Based on what you looked at so far and using what you know/remember from previous encounters with biology – take a guess what the following images show

Now this one....



## Hippocampal Neurons

© Yu, H et al (2015)  
Nat Neurosci 18:836-43

© <https://medicalxpress.com/news/2015-04-neurons-constantly-rewrite-dna.html>

# Test Your Knowledge

Based on what you looked at so far and using what you know/remember from previous encounters with biology – take a guess what the following images show  
...start on the right.....

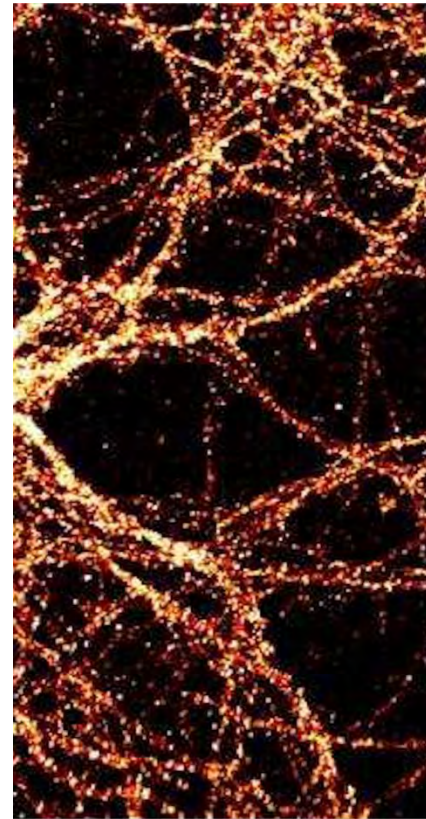
## Dark Matter/Energy Simulation



[https://www.youtube.com/watch?v=Ssxd\\_dvnuYo](https://www.youtube.com/watch?v=Ssxd_dvnuYo)

(this video is amazing)  
Illustris project

Yellow: normal matter  
Purple: dark matter  
Black: Dark Energy



## Hippocampal Neurons

© Yu, H et al (2015)  
Nat Neurosci 18:836-43

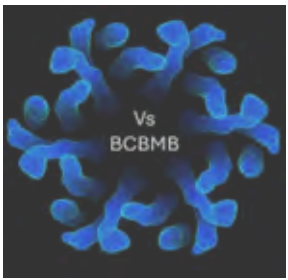
©  
<https://medicalxpress.com/news/2015-04-neurons-constantly-rewrite-dna.html>

The resemblance between the structure of the Universe and biological structures at the microscopic level is stunning (to me), loudly broadcasting one message: “**fundamental patterning in nature is independent of scale**” = you will find recurrent organizing principles in things that may seem completely unrelated ...let say: quantum mechanics, biology, sociology, or urban planning.

## Setting the Stage

Likening the structure of the Universe to that of biological structures based on phenomenological similarity creates an interesting puzzle. **Why?**

*...what are your thoughts ...?*



## Setting the Stage

Likening the structure of the Universe to that of biological structures based on phenomenological similarity creates an interesting puzzle. **Why?**



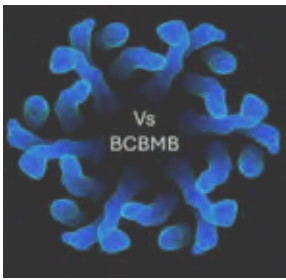
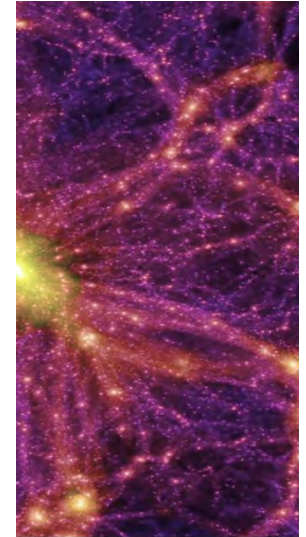
**Answer:** analogy calls for equating visible matter (5%) **and** invisible dark energy/matter (95%) with macromolecules in living systems ...

....dark matter is called "dark" because we cannot directly see it = **the analogy implies that in a living system, any given molecule sees mostly "nothing/empty space"**.

→ this not only is true, but life is even more extreme in that most molecules "see" only a tiny fraction of 1% of all other molecules (in most cases don't even see identical copies of themselves).

→ **How then can biology work if any one molecule "sees" mostly nothing/"empty" space?**

....what do you think?



## Setting the Stage

Likening the structure of the Universe to that of biological structures based on phenomenological similarity creates an interesting puzzle. **Why?**



**Answer:** analogy calls for equating visible matter (5%) **and** invisible dark energy/matter (95%) with macromolecules in living systems ...

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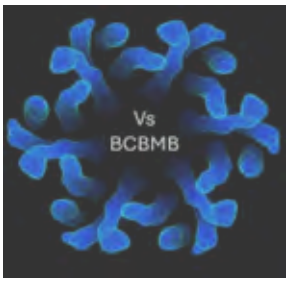
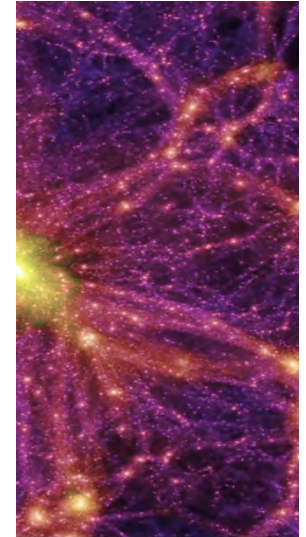
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→ **How then can biology work if any one molecule "sees" mostly nothing/"empty" space?**

**Answer:** works because what may look like "empty" space **is not really** empty = we don't see dark energy/matter directly....but....it's still there, and it sure impacts us!

→ Same holds in biology: any one molecule doesn't see most of what is around it ...but...that "something" is still there and impacts all the things that can't see it (and that it cannot see either).

→ **In other words:** components of a complex system neither need nor want to "see" everything (in fact, they must not "see everything") to know what to do because **operating instructions are issued AND moderated by the entire ensemble.**





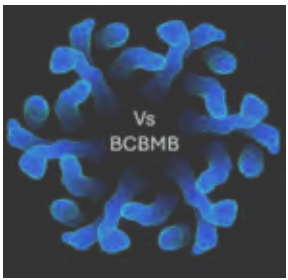
## Setting the Stage

The importance/role of ensembles is something you can understand through your own life experience.....

→ For instance: teamsports – your team cannot win if **everybody ALWAYS** wants to drive the action.

→ Or: in the armed forces – a Private neither needs to know nor will they discuss the logic behind orders issued by the commander in chief ...

Another example, but at a much larger scale, is related to “**six degrees of separation**”....do you know what that refers to?





## Setting the Stage

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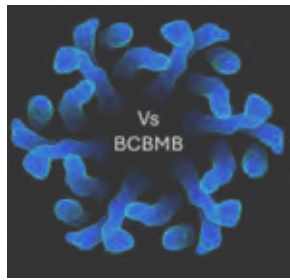
Another example, but at a much larger scale, is related to “**six degrees of separation**”....do you know what that refers to?

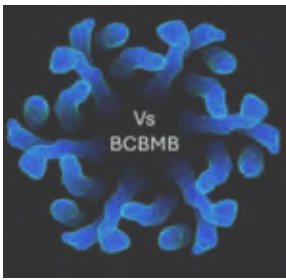
**Answer:** it's the idea/theory that each person is related to each other person on the planet through at most six social interactions/intermediaries (yes... even YOU and I)

**Does this apply to molecular systems too?**

**If so: what does “six degrees of separation” mean in terms of microscopic biology and what is the impact of this on the dynamic behavior of a biological system?**

**Thought Experiment:** imagine you stand in a room with 100 people. Now imagine moving around as you see fit with your eyes closed. What would you experience?





## Setting the Stage



Another example, but at a much larger scale, is related to “**six degrees of separation**” ....do you know what that refers to?

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**Thought Experiment:** imagine you stand in a room with 100 people. Now imagine moving around as you see fit with your eyes closed. What would you experience?

Other than bumping into other people and the wall ... you can move as you please

**Thought Experiment – Step 2:** at some point, randomly grab the hands of two people close to you – if you are first or last person in the chain...put your free hand on the shoulder of anyone in the chain that you can reach within a few steps. Now, close your eyes and try again to move exactly like **YOU** want.

**What do you experience?** ...don't really need to answer that ... you know that you will be restricted in your movements ... and will feel if somebody in the chain starts to push/pull ....even if you are not close by

## Setting the Stage

**How does this thought exercise look in terms of molecules?  
instead of people?**

*...try to form a mental image of it .....*





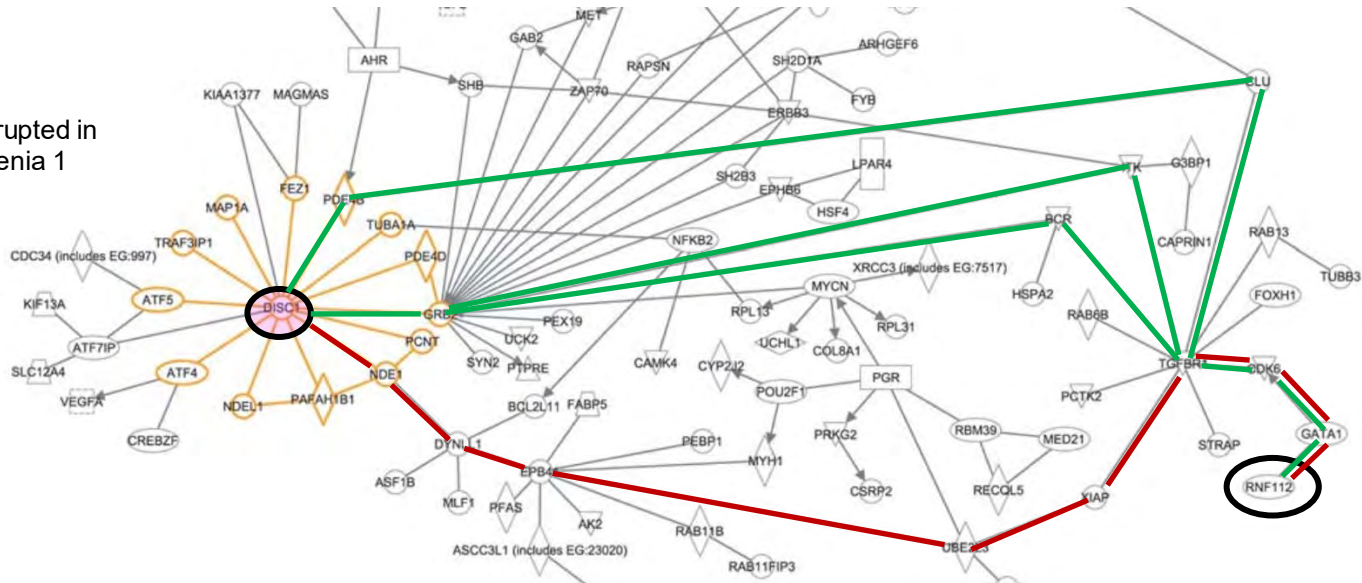


# Setting the Stage

How does this thought exercise look in terms of molecules? instead of people?

Here is a worked example

DISC1 – Disrupted in Schizophrenia 1



The three paths that are colored in green have indeed "six segments"

This is not to say that **all** possible paths from DISC1 to RNF112 (whatever that one does) have six intermediaries – you will find paths that are longer (in the spirit of full disclosure...I've shown one in red [9 steps], and you could make this one even longer if you take detours ...)

**BUT** that is not really the point. The principle still holds = even though DISC1 does not at all interact with RNF112 directly, it **indirectly "knows"** (and can respond to) what happens in RNF112's neighborhood because all these components are part of the same, coupled network of molecules .. and it does not stop there.....

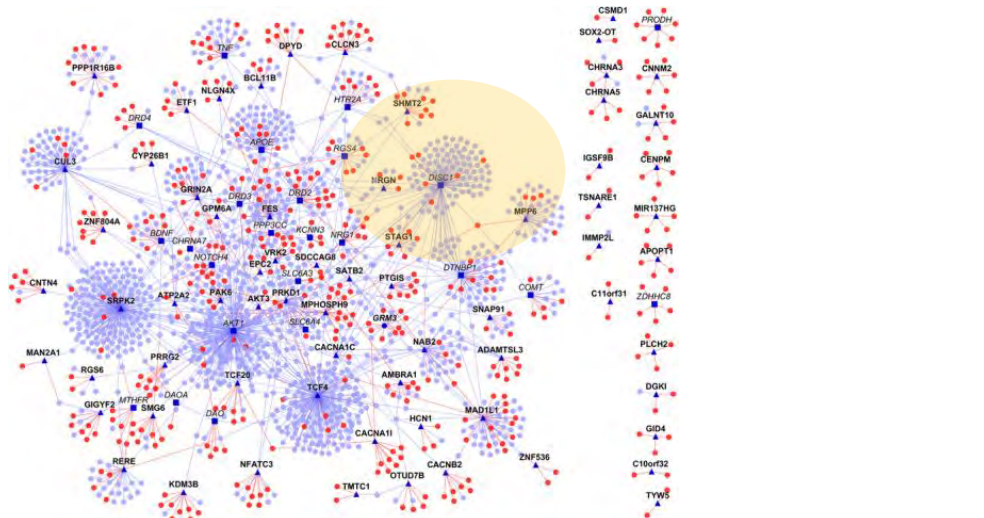
# Setting the Stage

## Interactoms .....Zooming “Out” .....

Ganapathiraju, MK et al (2016)

NPJ Schizophr 2:16012

“Schizophrenia Protein:Protein Interactome”



**pale orange shade: DISC1**

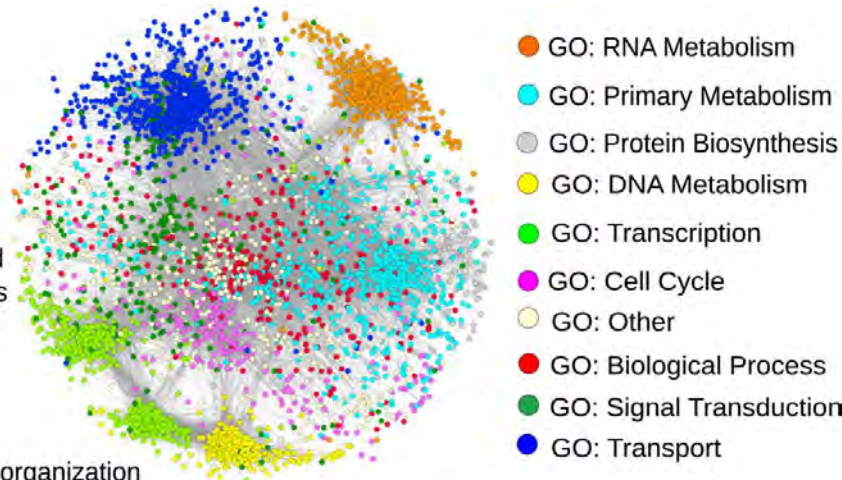
➔ this is what we looked at in the previous slides!

Look at the bigger context .... still the same principle but now involving hundreds of network components!

© 2016 Schizophrenia International Research Society/Nature Publishing Group

## And the same organizing principles are at work here

© Pancaldi V et al (2012),  
Genes, Genomes, Genetics 2(4):453-67



- GO: RNA Metabolism
- GO: Primary Metabolism
- GO: Protein Biosynthesis
- GO: DNA Metabolism
- GO: Transcription
- GO: Cell Cycle
- GO: Other
- GO: Biological Process
- GO: Signal Transduction
- GO: Transport

GO means: Gene Ontology (a bioinformatics initiative to annotate genes and functions of gene products in a consistent way and with a uniform vocabulary)

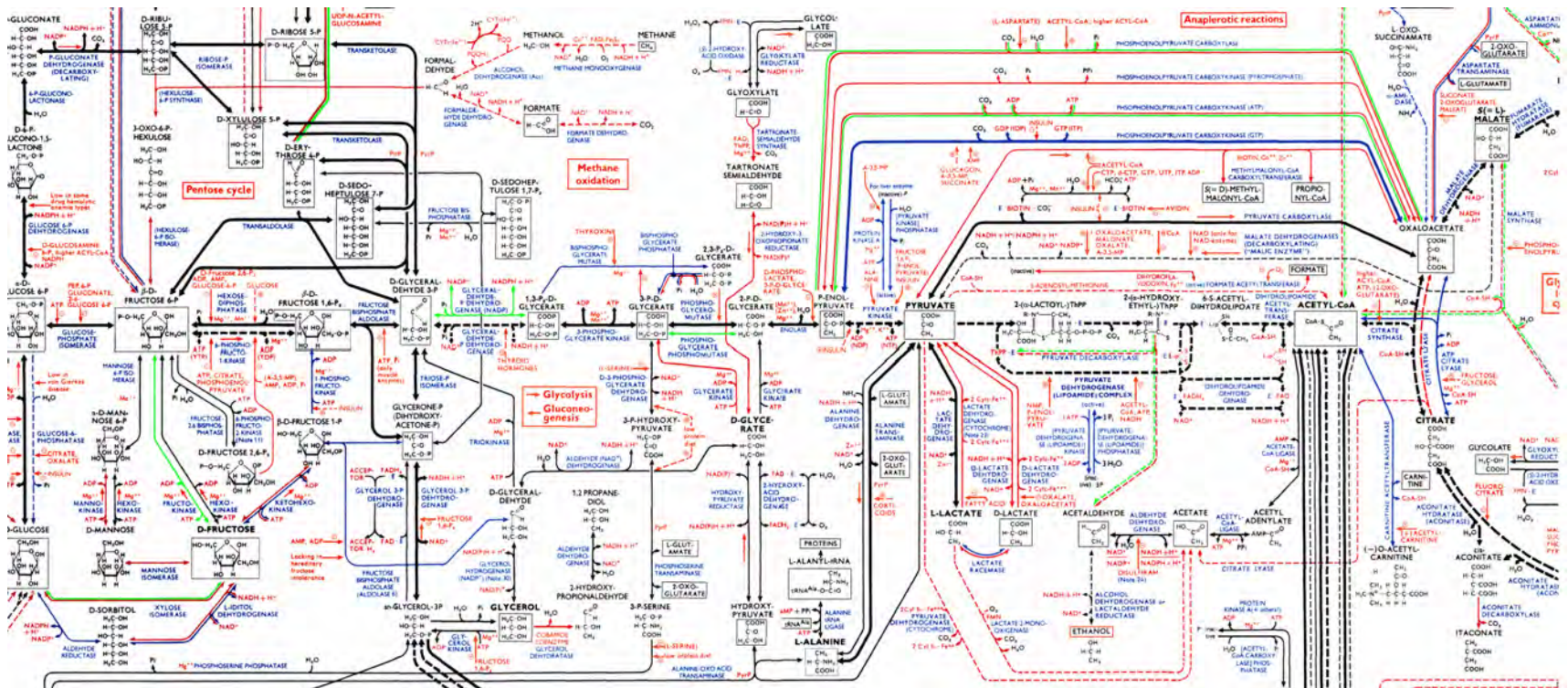
Transcription and RNA biosynthesis

Chromatin organization and modification

# Setting the Stage

AND HERE ....

....the chemical engine inside biology is highly integrated and interconnected because many of the individual chemicals act as regulators in loops that control the activity of the biological catalysts (= the “interactome and metabolome” are extensively interconnected)

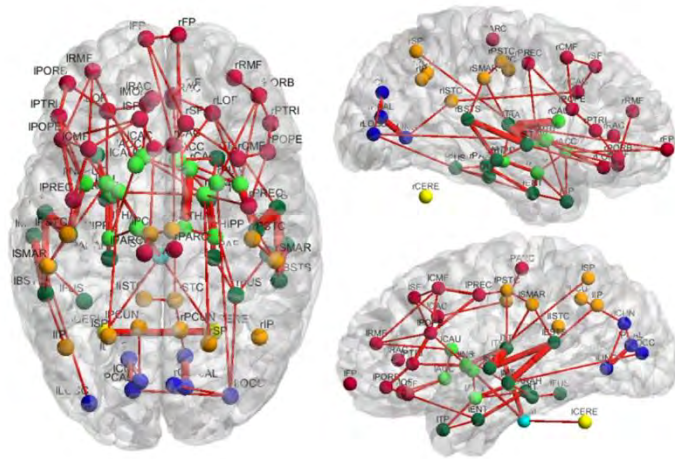


Partial View from Boehringer's Metabolism Chart (no longer available from Boehringer)

[https://github.com/usnish/biochemical-pathways-poster/blob/master/prebuilt\\_hires.png](https://github.com/usnish/biochemical-pathways-poster/blob/master/prebuilt_hires.png)

# Setting the Stage

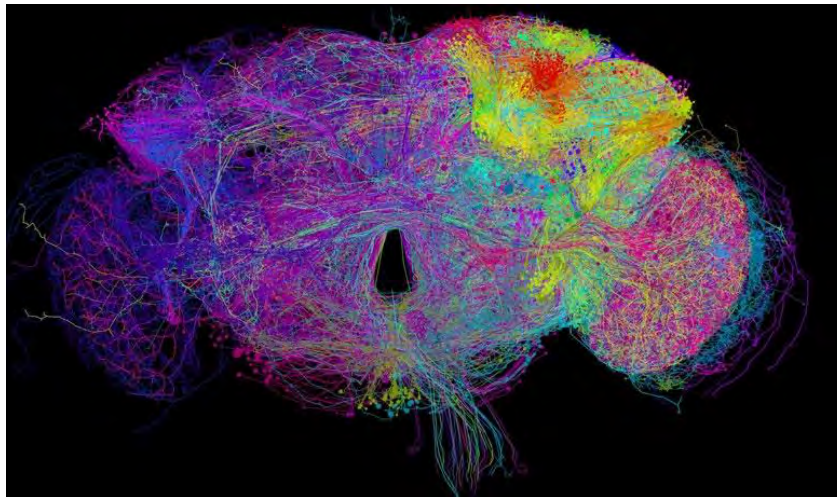
....**AND HERE** .... making our way back towards the “Universe” by zooming out.....



## Structural-Functional-Connectivity Map for Language Processing in Human Brain

Showing Top 20 connectivities observed in test subjects; line thickness represents consistency between different subjects

© Chu SH, Parhi KK, Lenglet C.  
Sci Rep. 2018 Mar 16;8(1):4741



## Circuit Map of Whole *Drosophila melanogaster* (fruitfly) brain

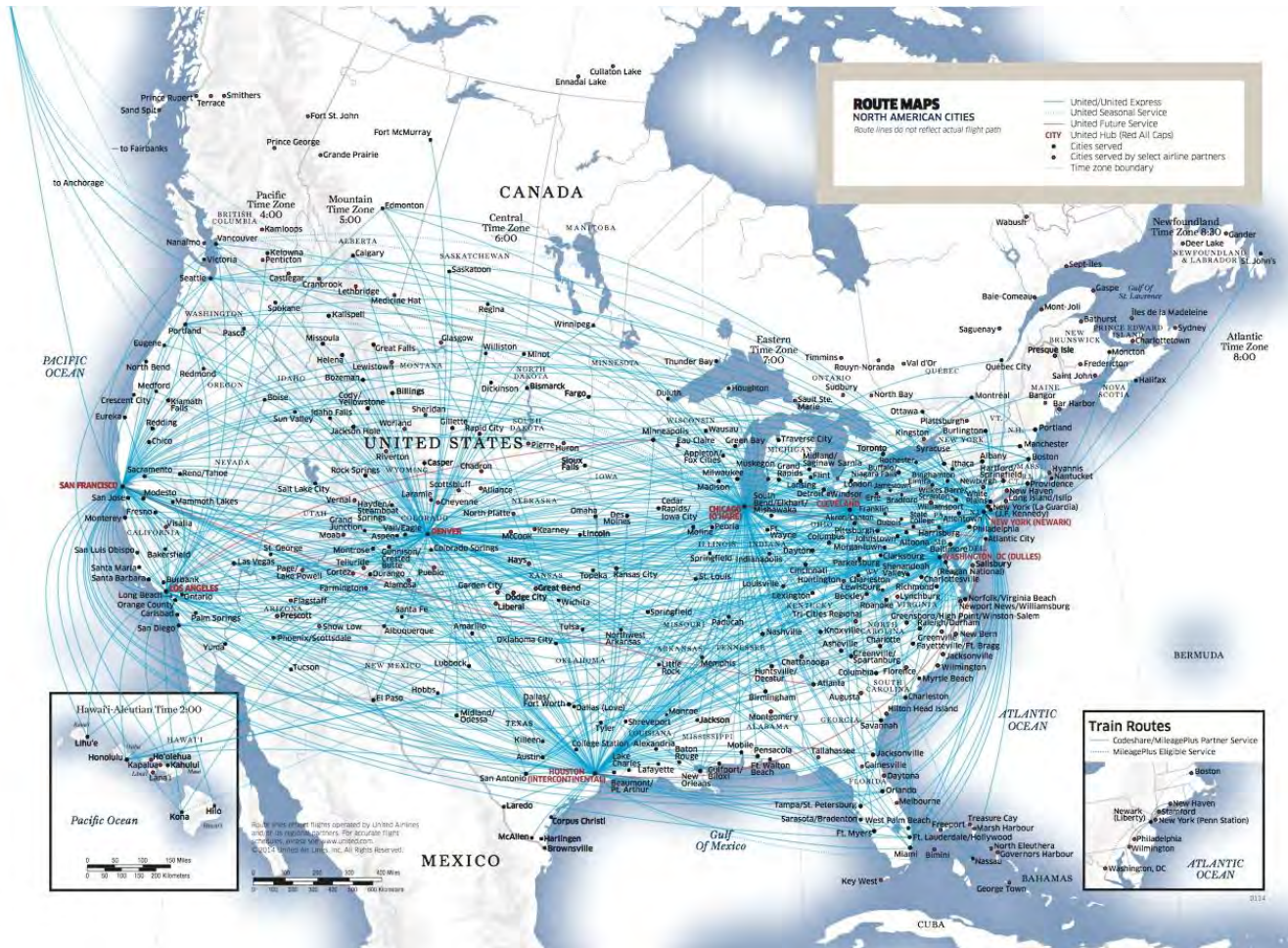
Colorized to distinguish neural paths originating in different brain regions

© <https://www.sciencenews.org/article/most-complete-look-yet-fruit-fly-brain-cells>

Univ Cambridge/UK

# Setting the Stage

EVEN HERE ....zooming out some more....and leaving the realm of biology



© United Airlines Domestic Route Map (not current)



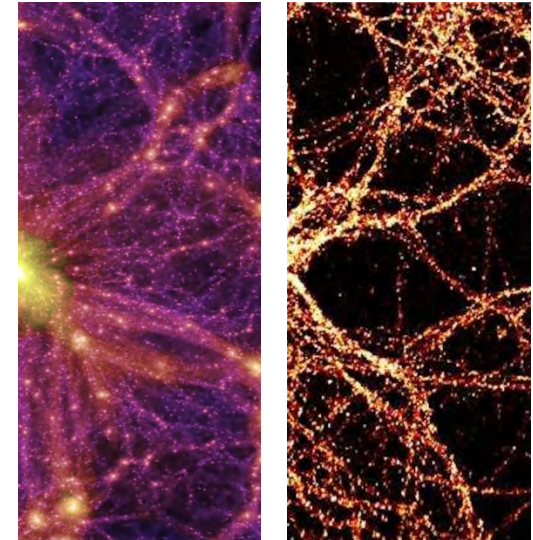


## Setting the Stage

.....and look where we got.....starting by googling “cell images” we ended up in a very different place. That place teaches us what very well may be **the most important things** to take away from this entire Chapter....

**Insight 1:** Life, the Universe and “Cell Biology” are idiosyncratic, emergent properties of matter that is capable of non-random atomic/molecular interactions. The non-random interactions drive self assembly processes that create remarkably similar patterns and ensemble dynamics, independent of scale.

**Insight 2:** “emergent property” implies many, equally valid trajectories and solutions. That is: **the observable status quo of the entire ensemble is a local minimum that reflects boundary conditions past and present**



Meaning for Life: despite its mindboggling complexity, **Life is NOT overdesigned.**

While one can simplify processes in isolation, any significant (mechanistic) change causes ripples within the entire system that, overall, reduce fitness of the lifeform because the observed complexity of the status quo is Nature's strongest safeguard to allow survival and adaptation.

→ **bottomline:** as of today, synthetic biologists can build minimal bacterial cells, but even their biology contains unresolved mysteries  
(more on that topic can be found in the "Molecular and Cell Biology – GENOMES" chapter)

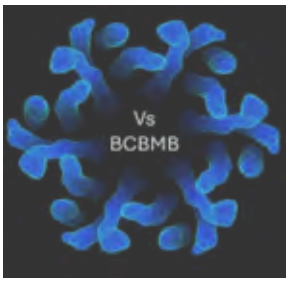


## Setting the Stage

Realizing that the macroscopic structure of the Universe is eerily similar to seemingly different things like biological structures or airline route maps clarifies why the result from a Google Search on “Cell Images” is ...frankly....puzzelsome and scary .....

**How so?**

**Answer:.... *what do you think??***



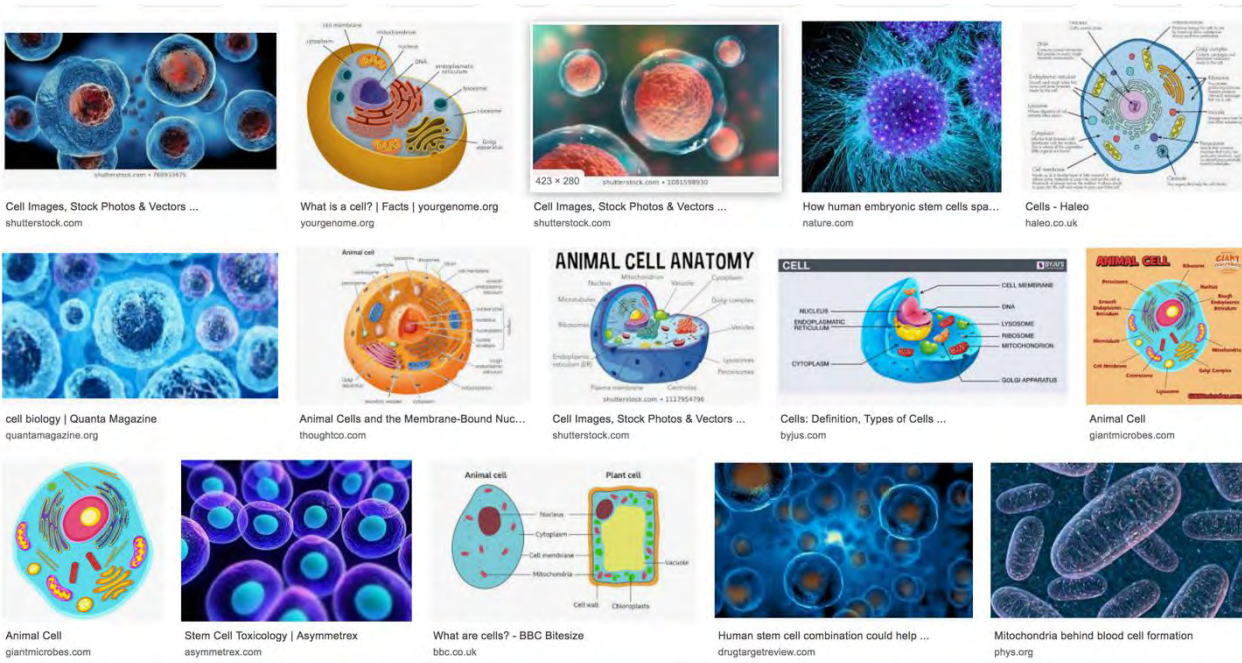


# Setting the Stage

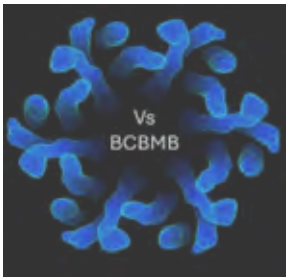
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How so?

Answer:.... asked “what is a cell?” is, Google **ONLY** shows you .....



- ➔ exceptionally biased and narrow, with seemingly just one answer!
- ➔ Scary!! And untrue..... – open your mind and ask....**what contexts other than biology use the term “cell”?** .....thank you!



## Setting the Stage

.....solar, fuel, atmospheric/storm, religious, terror, prison,  
hospital, dormroom, tiny house/studio apartment,  
spreadsheet/table,.....looking at all of them at once,  
**what is their common denominator?**



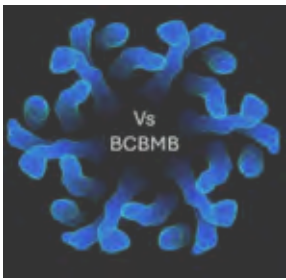
**Answer:** ....*your bid* .....



## Setting the Stage

.....solar, fuel, atmospheric/storm, religious, terror, prison,  
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**Answer: "Cell" simply means: "small space/unit" ...and just from that generic fact we  
learn another hugely important thing about Life/Cell Biology/Universe...  
and what is that?**





## Setting the Stage

.....solar, fuel, atmospheric/storm, religious, terror, prison, hospital, dormroom, tiny house/studio apartment, spreadsheet/table,.....looking at all of them at once, **what is their common denominator?**

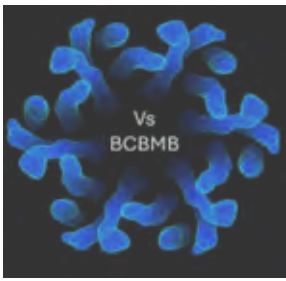
**Answer: "Cell" simply means: "small space/unit"** ...and just from that generic fact we learn another hugely important thing about Life/Cell Biology/Universe... **and what is that?**

**Answer: "small space/unit" implies partitioning across boundaries/barriers** that enable a fundamental **asymmetry** in the distribution of matter. The correlated **compartmentalization** (regardless of its physical nature [eg object, phase boundary; scaffold induced spatial segregation, ideology ... ] is what allows emergent properties to manifest themselves.

*throughout chapters, words highlighted in pink are overarching themes = true concepts that help unifying and explaining why things happen in certain ways.*

*If you are interested in exploring how concepts help you to organize and to understand your knowledge, consider registering for my 50min workshop on "Conceptual Frameworks". You can find more detail and registration access here:*

*<https://vsbcbmbstudy.com/online-workshops-details>*





## Setting the Stage

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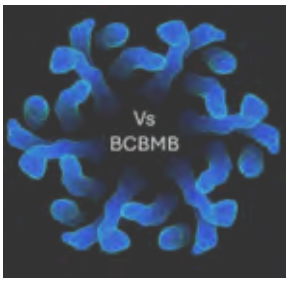
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What sets biology/life apart from other emergent systems is that it learned how to deliberately manipulate and to control the properties of space over time. This brings us to a third important insight we want to add:

**Insight 3: Emergent properties are more than the sum of the components, they are non-linear, and they are exceptionally damped (resilient). These characteristics allow for an enormous amount of diversification and adaptation....**

...lets take a look.....





# Setting the Stage

But the record holders are.....

## Tardigrades (Water Bears)



Typically water dwelling but **can survive**:

### Temperature

A few minutes at 151 °C (304 F);

30 years at -20 °C (-4 F);

A few days at -200 °C (-328 F; 73 K);

A few minutes at -272 °C (-458 F; 1 K)

Pressure – they can withstand vacuum and also very high pressures up to 6,000 atmospheres, which is nearly six times the pressure of water in the deepest ocean trench

Dehydration – the longest that living tardigrades have been shown to survive in a dry state is nearly 10 years

Radiation – tardigrades can withstand 1,000 times more radiation than other animals, median lethal doses of 5,000 Gy (gamma rays) and 6,200 Gy (heavy ions) in hydrated animals, compared to 5-10 Gy that are fatal to a human.

**Source:** Wikipedia.com

©Taylor Turner/The Washington Post

[https://www.washingtonpost.com/video/national/health-science/meet-the-tardigrade-the-animal-that-will-outlive-us-all/2017/07/14/4b921e54-68ae-11e7-94ab-5b1f0ff459df\\_video.html?noredirect=on](https://www.washingtonpost.com/video/national/health-science/meet-the-tardigrade-the-animal-that-will-outlive-us-all/2017/07/14/4b921e54-68ae-11e7-94ab-5b1f0ff459df_video.html?noredirect=on)

# Setting the Stage

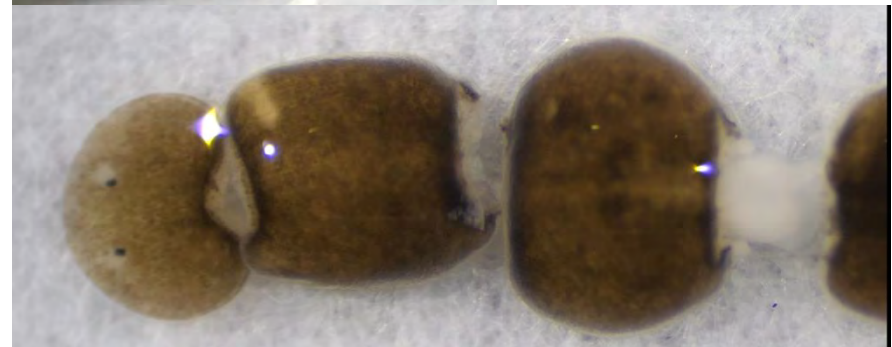
.....and.....

## Planarian Flatworms



©  
<https://aeon.co/videos/the-blob-with-a-superpower-cut-a-flatworm-in-four-pieces-and-watch-it-regenerate-four-fold>

...you can cut them into pieces....and they regenerate complete new animals!  
(...if humans had that ability, the French revolution would have had different consequences...among other things)



# Setting the Stage ...Cell Biology at Last

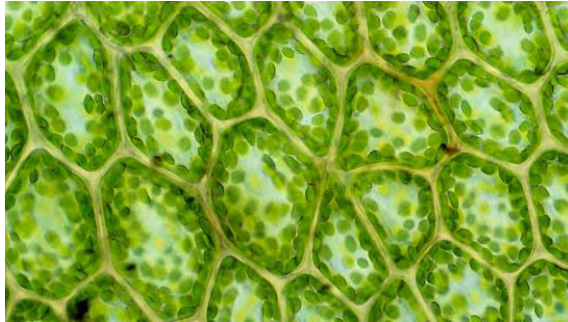
The amazing adaptability of biological organisms is a macroscopic reflection of the underlying pliability of the basic units that make up these organisms

Salmonella bacteria



Image source:  
<https://www.fda.gov/food/foodborne-pathogens/salmonella-salmonellosis>

Plant cells



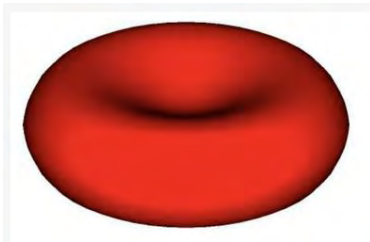
©  
<https://www.bbc.co.uk/bitesize/topics/znycdm/article/s/z2vrr2p>

Neuron



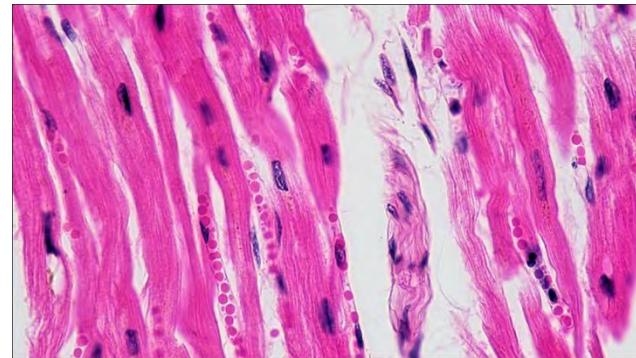
© Image by vecstock, AI generated

Red Blood Cell



©  
<https://doi.org/10.3390/cells11243987>

Muscle Tissue



Attribution: Berkshire Community College Bioscience Image Library, CC0, via Wikimedia Commons

Note: different cell types (e.g. red blood cells, muscle cells and neurons) in a multicellular organism ALL have the same fundamental programming, but the interpretation of that programming is **redundant** (= tweak of a given/identical template → genome of one species in this case)



## Setting the Stage ...Cell Biology at Last

Curiously... **redundancy** motivates much of modern cell biology because it **triggers a vast expansion beyond the founding question that cell biologists study, which is.....**

**What is a biological cell?** → answering that question doesn't get you far because of the question's interrogative pronoun "what?" = will return a simple fact like "basic unit of life", or "an irregularly shaped soft object formed from various organic macromolecules and inorganic ions, capable of maintaining life".

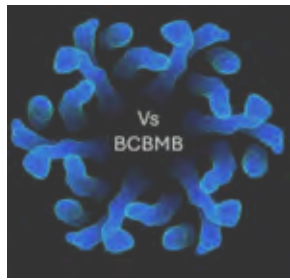
More interesting is to ask: "**How does a cell work?**". The answer to this question aims at understanding mechanism = "what molecules?"+"where?"+"when"+ "what do they do?"

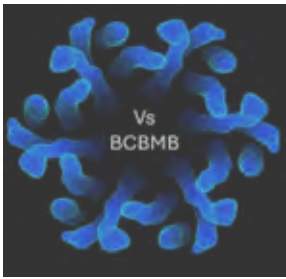
→ **This "playbook" teaches you about:** How do cells/cellular components form? How do they exchange matter? How do they build (their own) components? How do they power the chemical engine? How do they store information? How do they replicate? How do they communicate with the environment? How do they move if they are motile? .....

**Redundancy** comes in as driver in defining questions when you start to look at: how do cells specialize? → How do they form tissues? How do they form multicellular organisms?

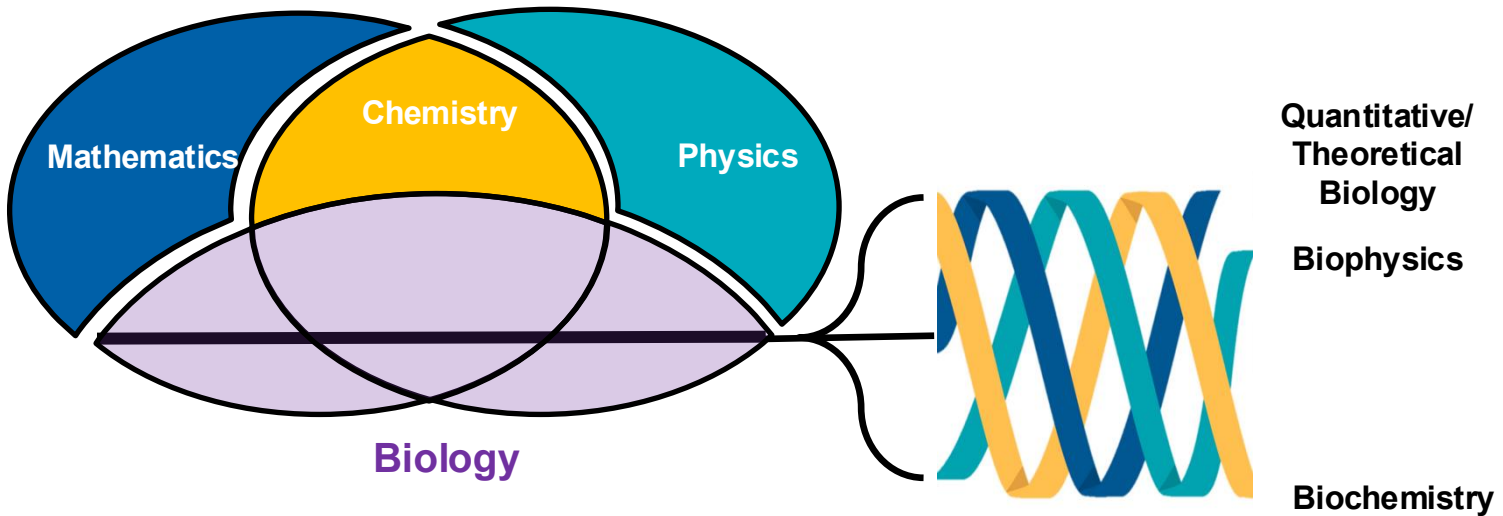
**Taken together: Cell Biology is the Science that Studies the Structure and Functional Behavior of Life's Basic Units**

**Curiously:** a question that is rarely asked, answered, or taught (in biology and many other sciences) is: "why does something work the way it does?" Looking at "why?" is rare because it requires to see the bigger picture, and –ultimately/ideally- follow the trace all the way back to first principles ...





# Talking about First Principles ... in the Realm of STEM: **Biology is the MOST Complex Science Because it Integrates ALL Other Basic Sciences**

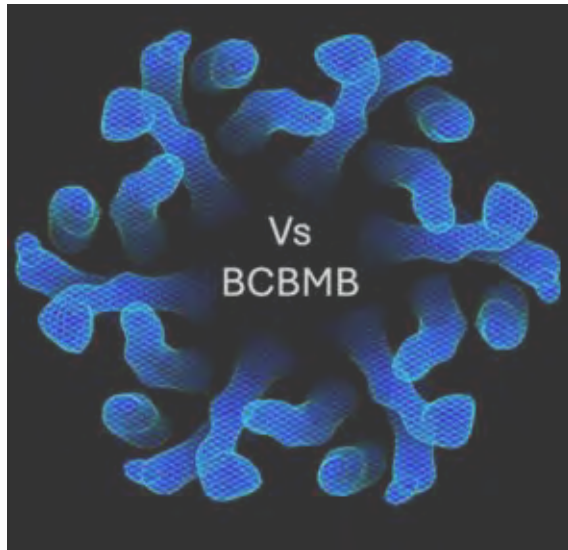


➔ The high degree of integration and the fact that much of biology is still stuck at a descriptive "fact finding stage" are key reasons why studying biology can feel frustrating ... there just doesn't seem to be system in all the madness.

...until you ask: "why something works the way it does?"

... we will try to do that whenever possible ... and while it will fall far short of going all the way to first principles, you hopefully will discover that life is amazingly organized and "logical" once you care to look closely enough.



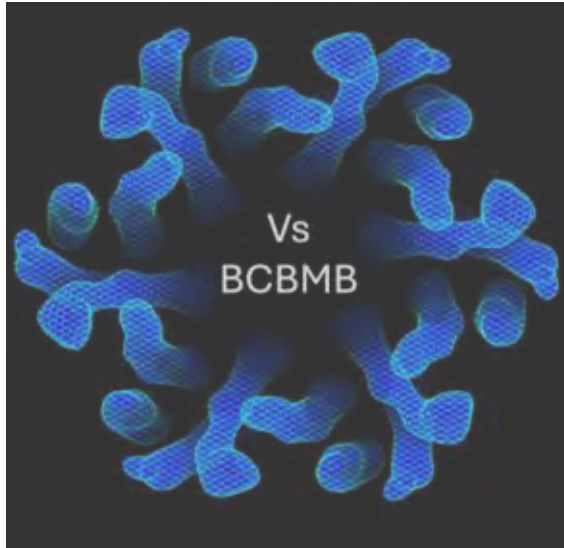


If you found this non-canonical approach to introducing cells helpful – recommend it to friends and consider downloading other chapters.

As mentioned at the very beginning: the chapters are formatted as "silent lectures", which you can work through at your own pace by engaging with the question that are posed along the way.

...best if you make it a complete immersion by playing some of your favorite music in the background, or light some aromatherapy candles to set the mood, (even better ... if you do it as a group and play the music : ) ).

...seriously! ... not kidding!! ....this will give you the best outcomes ... brain physiology and the biochemistry of learning say so ....



Slides are freely available at  
[vsbcbmbstudy.com](http://vsbcbmbstudy.com)