Future Directions in Biology
Lessons from Nature

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" Experiments are the Only Means of Knowledge at Our Disposal
The Rest is Poetry and Imagination" - Max Planck

New Adage in Science : You must be a Jack of All Trades and Master of One

1. Health Care

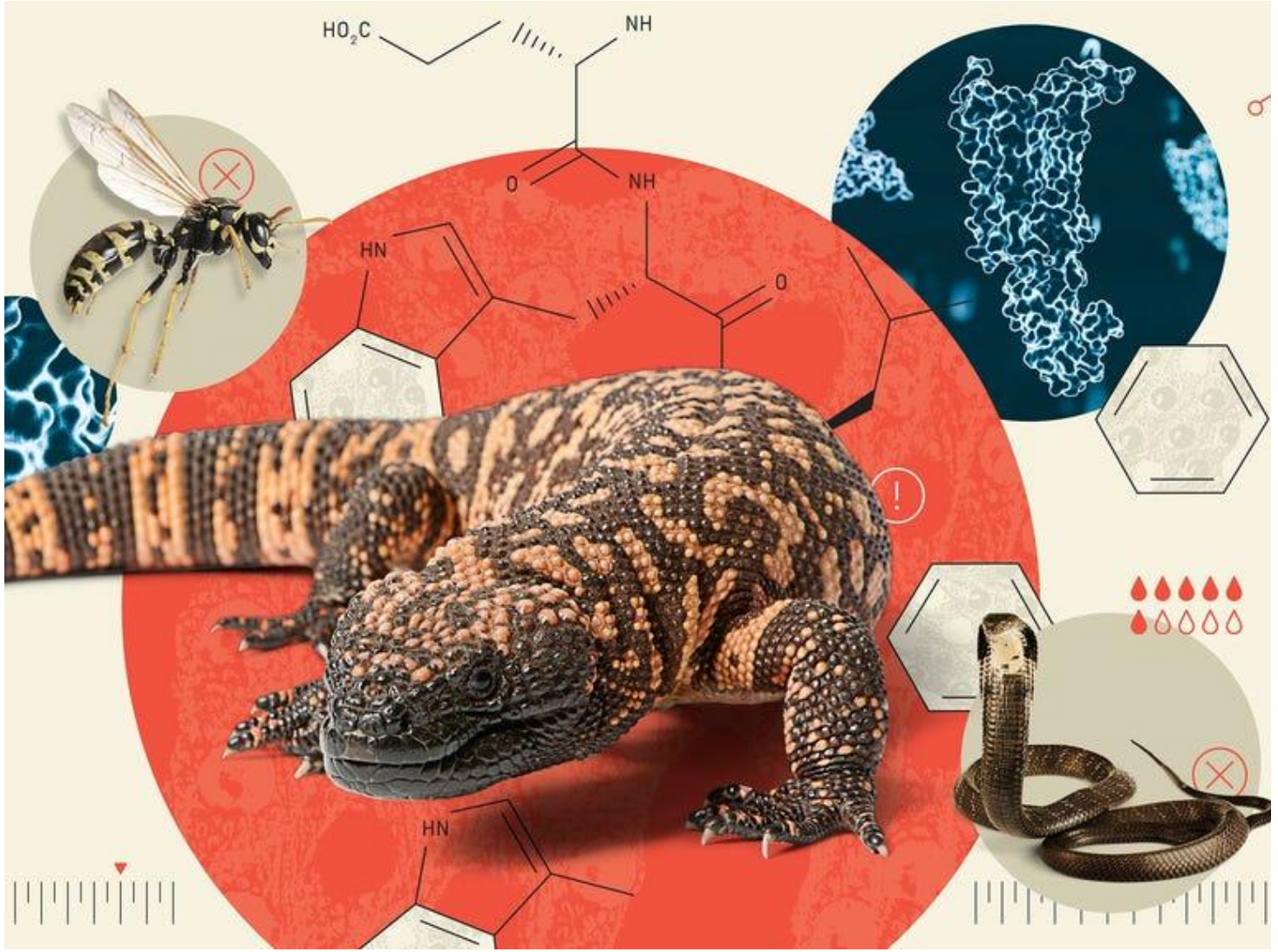
2. Agriculture & Sustainability

3. Materials

4. Computation

5. Home Garden

Health Care

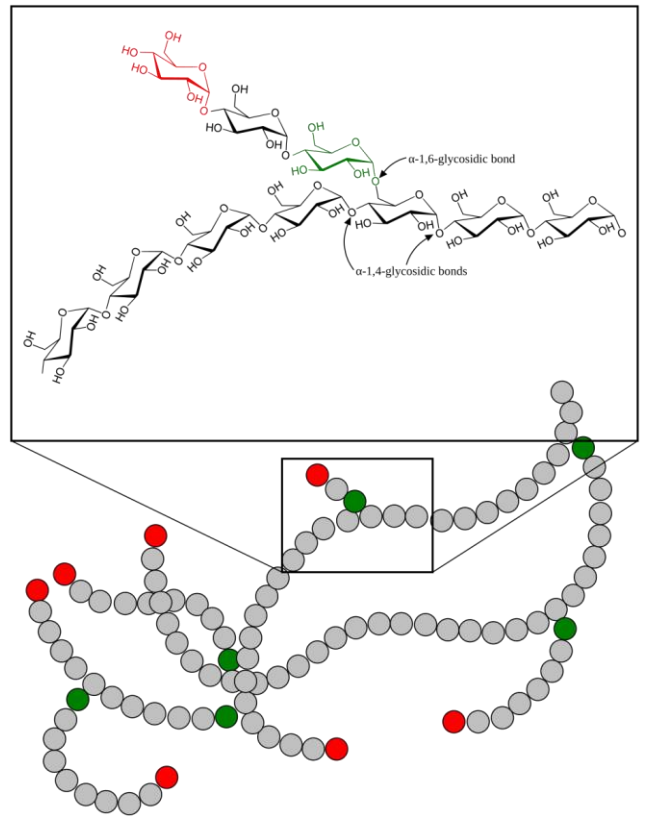


Some Definitions

- Glucagon is a 29-amino acid polypeptide. Its primary structure in humans is: NH_2-His-Ser-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-Leu-Asp-Ser-Arg-Arg-Ala-Gln-Asp-Phe-Val-Gln-Trp-Leu-Met-Asn-Thr-COOH (HSQGTFTSDYSKYLDSRRAQDFVQWLMNT).
- Binds to the Receptor & Releases Glycogen , which is then converted to Glucose.
- GLP : Glucagon Like Peptide.
- GIP : **Gastric inhibitory polypeptide** (**GIP**), also known as **glucose-dependent insulinotropic polypeptide** is to stimulate insulin secretion
- Agonist : An **agonist** is a chemical that activates a receptor to produce a biological response.

Essays Biochem, 2020 Sep 25;64(4):649–680. doi: 10.1042/EBC20190042

Glucagon Binding to its Receptor



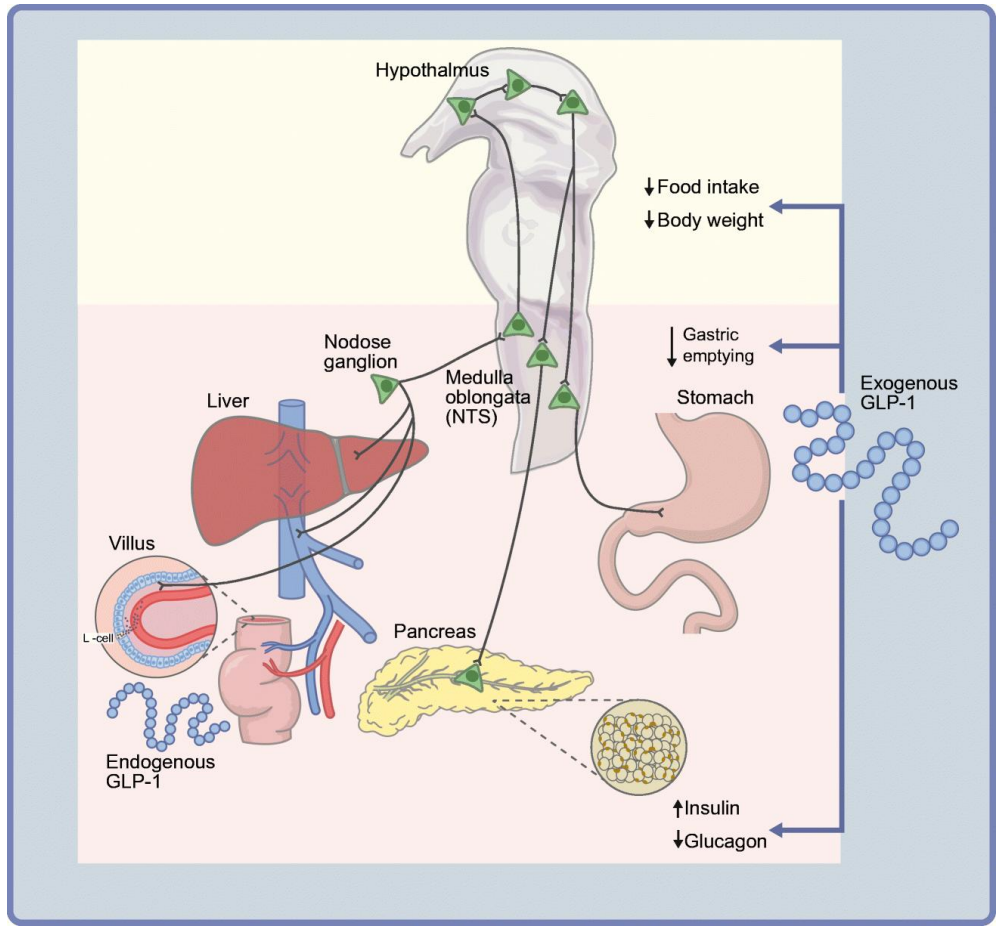
Structure of Glycogen

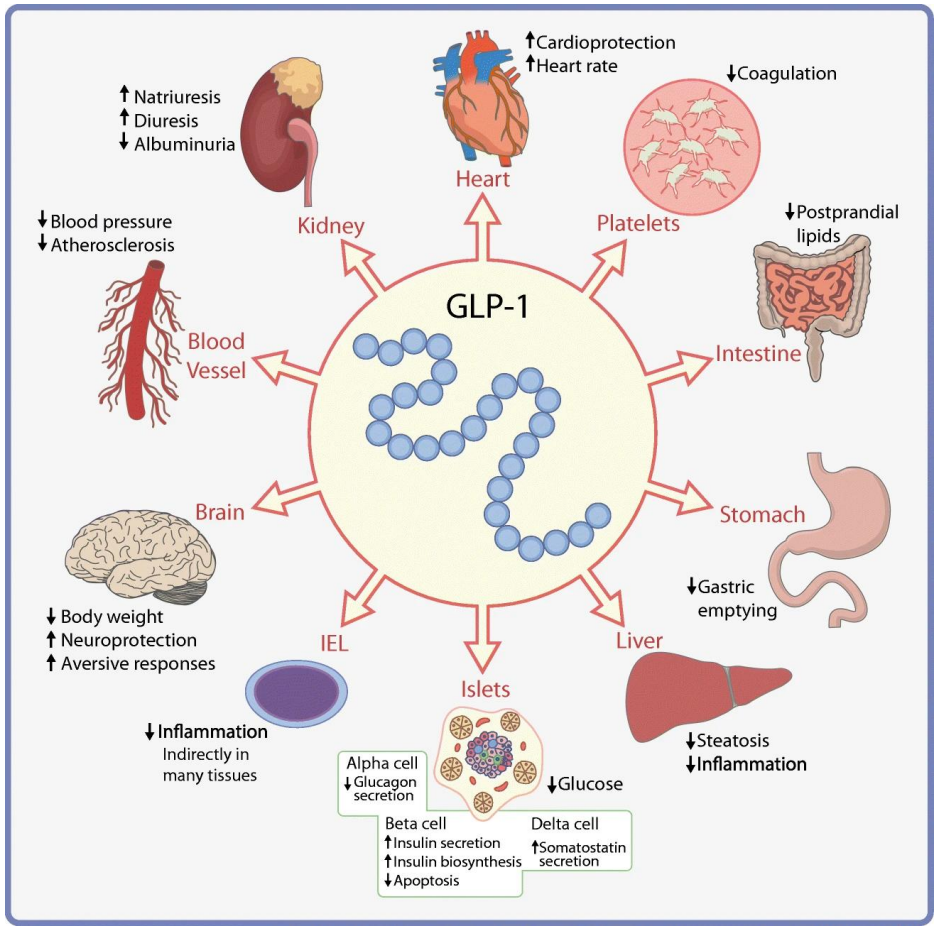
Mechanism of Action of Glucagon Like Peptide -1 (GLP-1)

- Glucagon-like peptide-1 (GLP-1) released from gut enteroendocrine cells controls meal-related glycemic concentrations through augmentation of insulin and inhibition of glucagon secretion. GLP-1 also inhibits gastric emptying and food intake, actions maximizing nutrient absorption while limiting weight gain
- GLP-1-based therapies for the treatment of diabetes and obesity has stimulated development of orally bioavailable agonists, allosteric modulators, and unimolecular multi-agonists, all targeting the GLP-1R.
- Challenges for development and optimization of GLP-1R agonists in the treatment of metabolic disease.
- Ref: Cell Metabolism , Volume 27, Issue 4 p740-756 April 03, 2018 Open Archive

Mechanisms of Action and Therapeutic Application of Glucagon-like Peptide-1

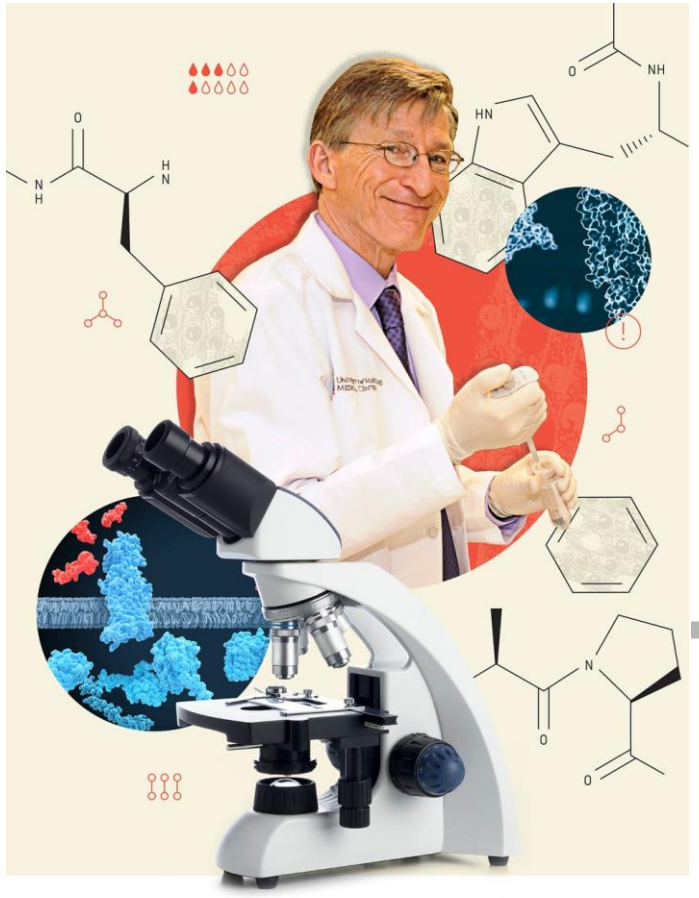
Daniel J. Drucker





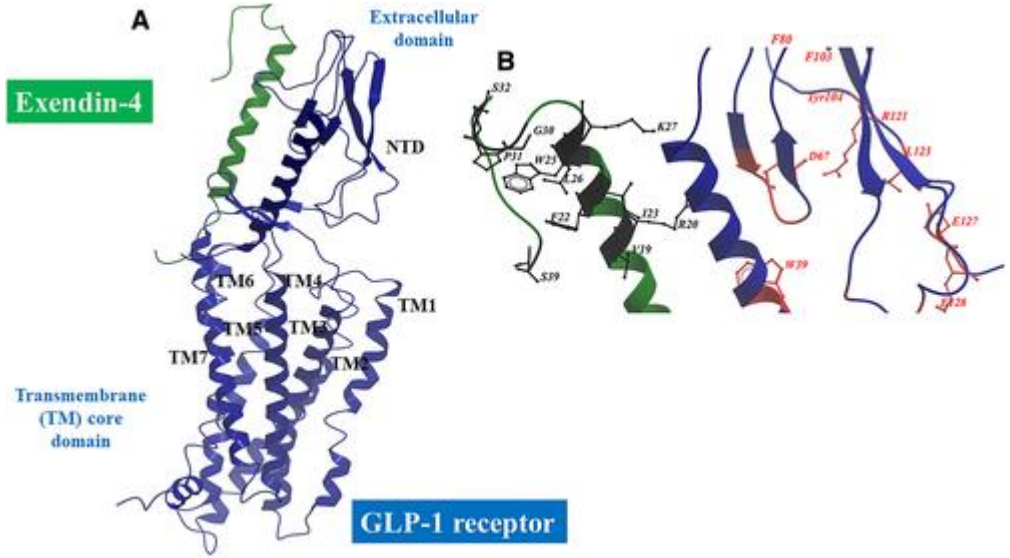
The expanding incretin universe: from basic biology to clinical translation, Drucker et.al., Diabetetologia, 66, 1765–1779, 2023.

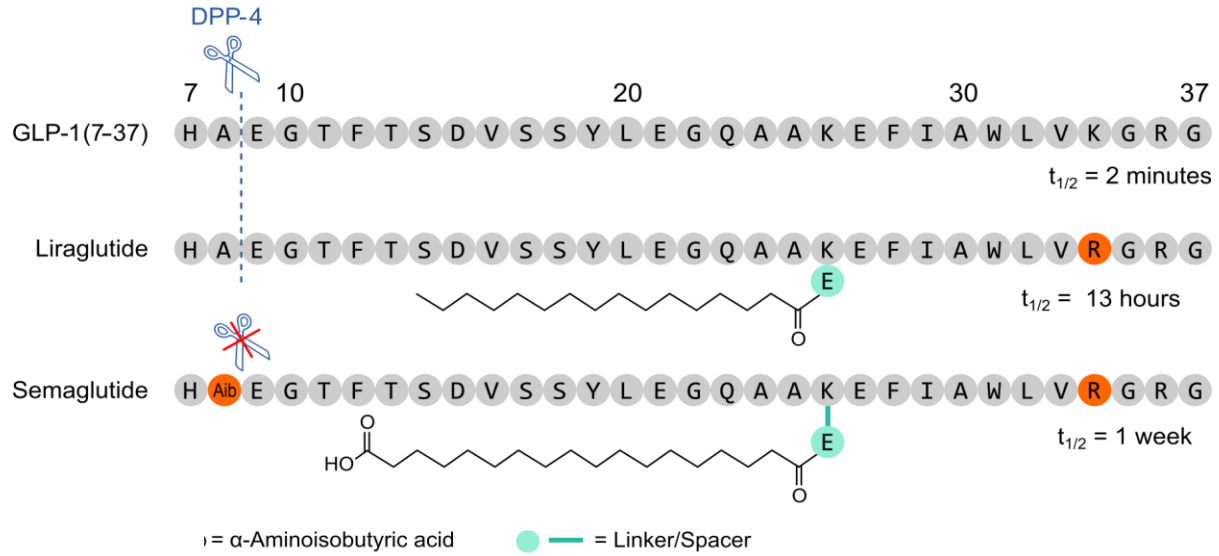
GLP – The Story of Ozempic



John Raufman , who as a young student , studied venomous creatures, especially Gila Monster

Exendin-4 from Heloderma suspectum venom: From discovery to its latest application as type II diabetes combatant



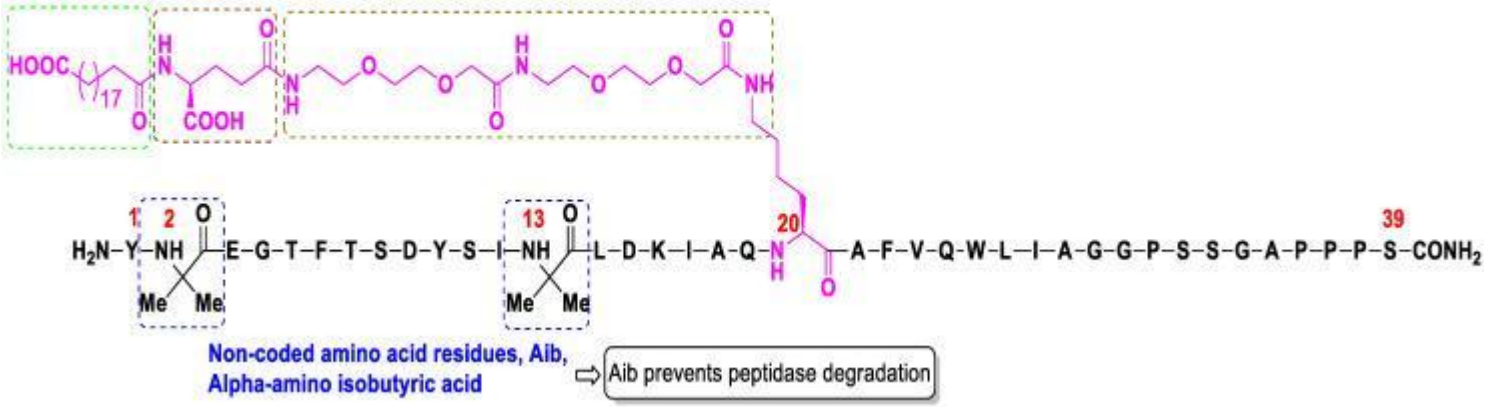


Linker responsible for peptide flexibility, optimized binding to receptor and long half-life

C20 fatty diacid, eicosanedioic acid

Gamma glutamate

bis-aminoethoxyacetyl



Non-coded amino acid residues, Aib, Alpha-amino isobutyric acid

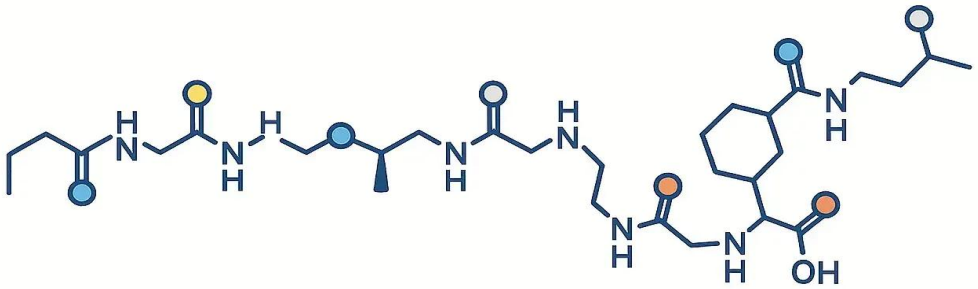
Aib prevents peptidase degradation

Targets – a Single Hormone Receptor that Regulates Hunger

Basic Clin Pharma Tox, Volume: 124, Issue: 5, Pages: 513-527, First published: 12 November 2018, DOI: (10.1111/bcpt.13169)

Eli Lily's New Drug Candidate

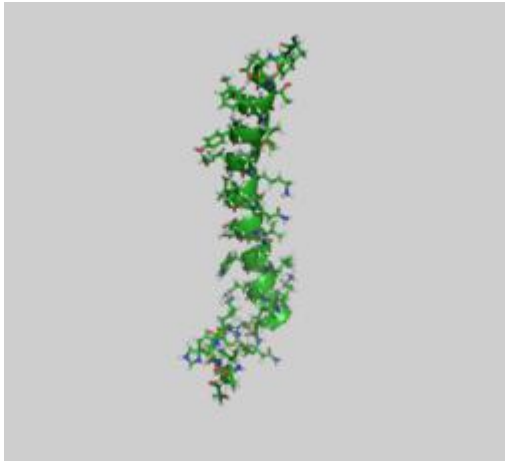
RETATRUTIDE



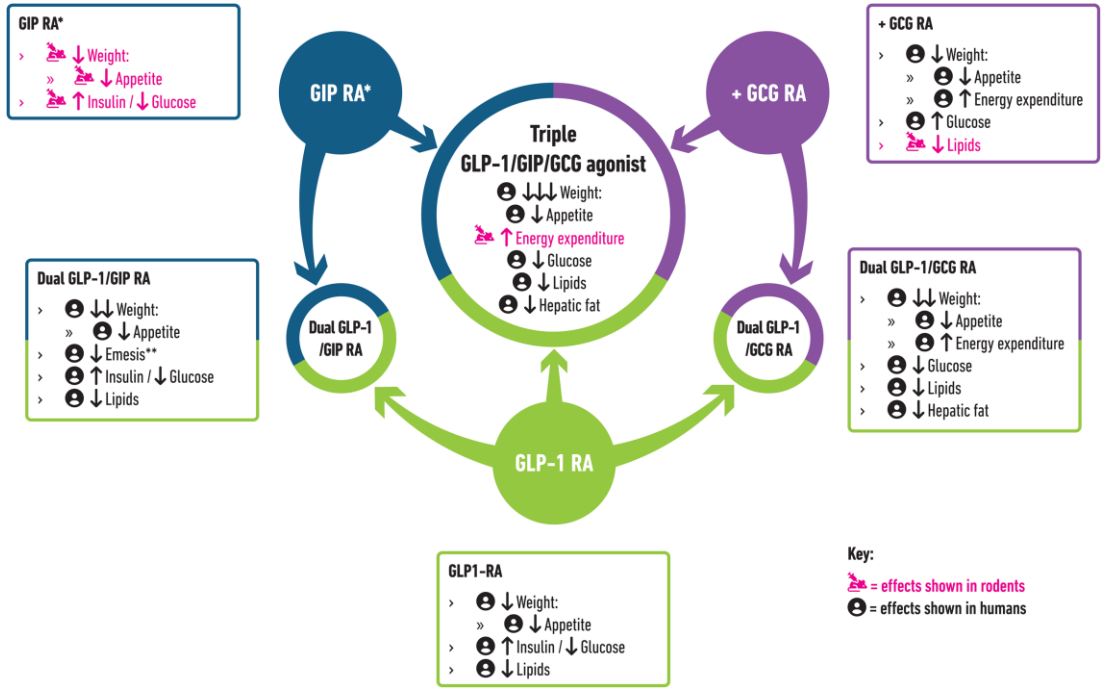
UNIQUE TRIPLE-AGONIST MECHANISM TARGETS

GLP-1 | GIP | GLUCAGON

Retatrutide is the first triple agonist (acting on GLP-1/GIP/glucagon receptors) with published phase 2 data in people with obesity as well as in people with T2D. Retatrutide achieved up to 24.2% mean weight loss after 48 weeks in individuals with obesity and 16.9% in those with T2D after 36 weeks. In the T2D study, HbA1c improved by 2.2%, with 82% of participants reaching HbA1c ≤ 6.5%. Retatrutide also improved multiple cardiometabolic parameters, including blood pressure, lipids, waist circumference, and liver fat (82% reduction in hepatic steatosis)

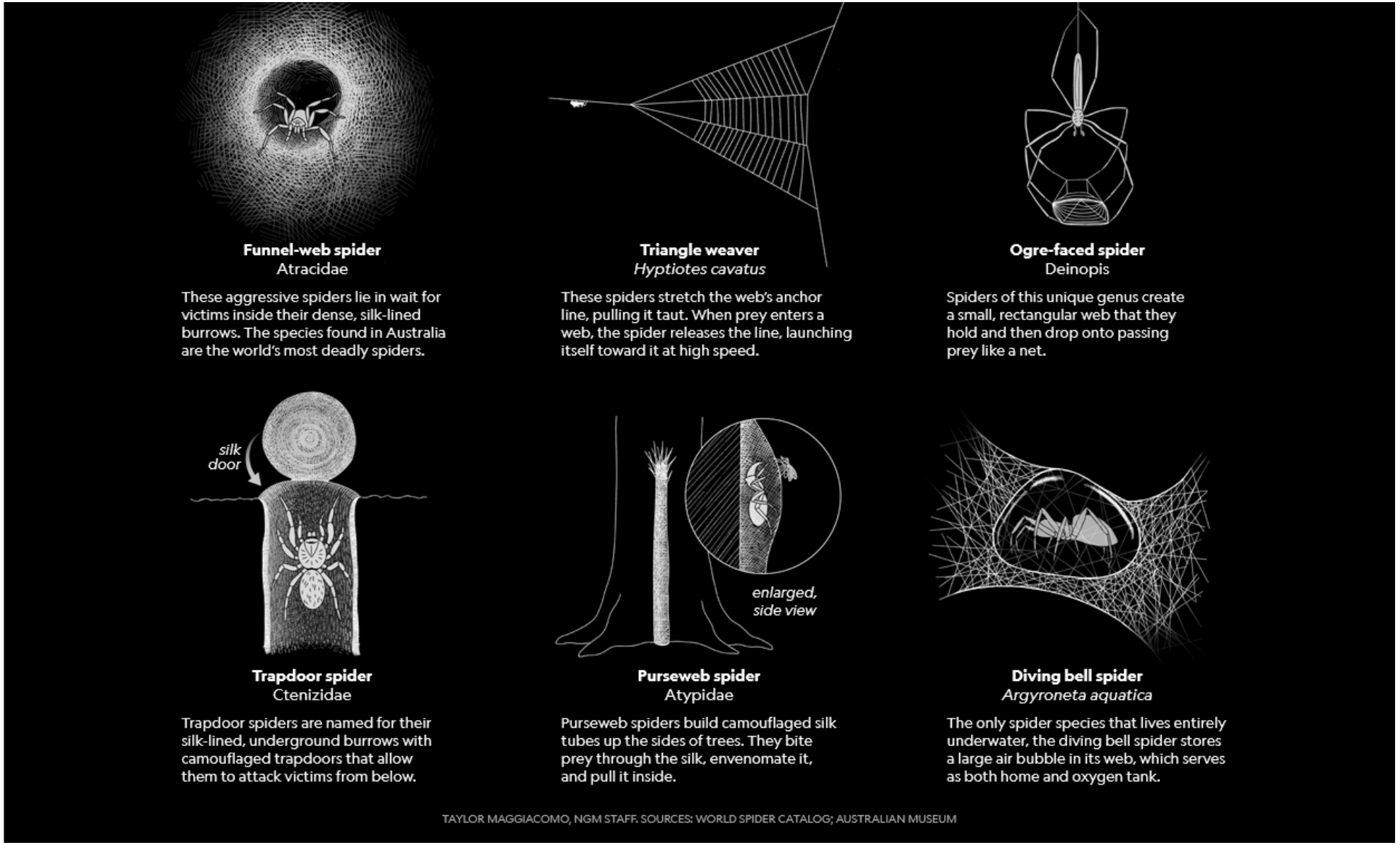


Gastric Inhibitory Peptide :



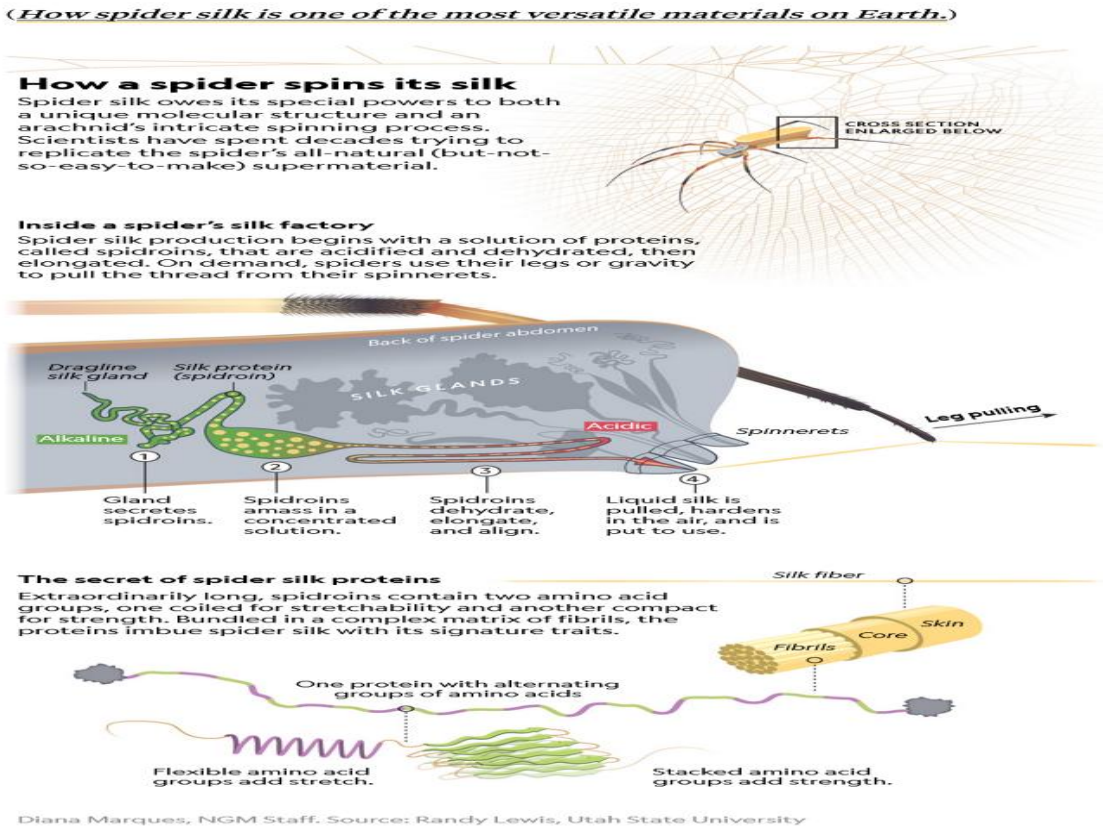
Dimitris Papamargaritis *et.al.* Current Cardiovascular Risk Reports , Volume 19, article number 18, (2025)

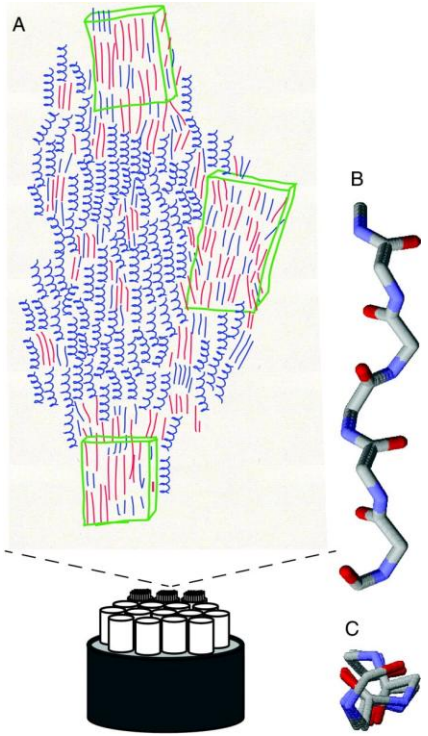
Materials: The Story of Web Spider Web



National Geographic , Jason Bittel, September 12, 2019

Mechanism of Spider Web Spinning Process, Strength & Structure

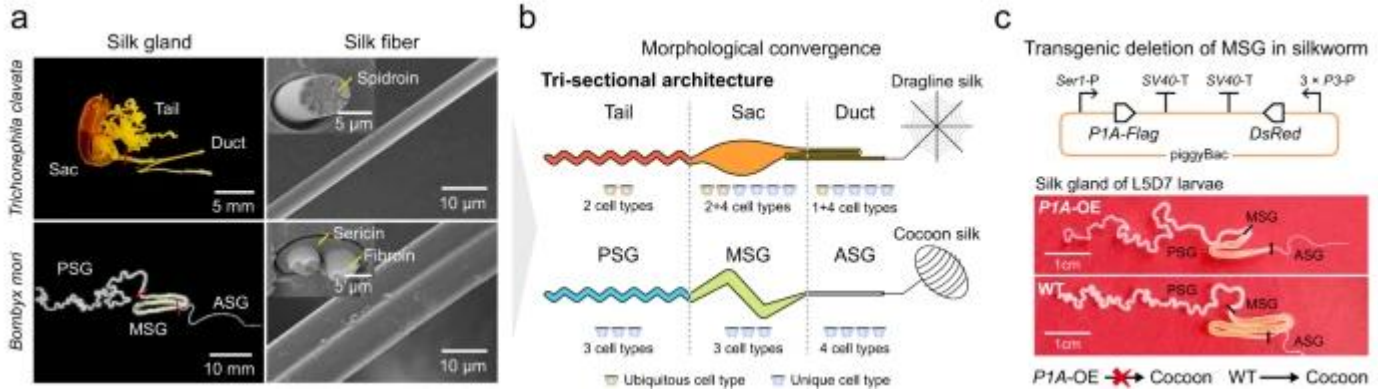




(*A*) Proposed model for spider dragline silk: a skin-core organization, with a multitude of fibrillar substructures and covered by a hard skin, forms the fiber . The molecular structure consists of β sheet regions, containing alanine (red lines) and glycine (blue lines), interleaved with predominantly 3_1-helical parts (blue curls), which do not contain alanine. All chains tend to be parallel. The crystallites are irregular and strongly depend on processing [e.g., drawing speed]. Depending on the method, larger or smaller ordered domains can be identified as crystalline (green boxes) (*B* and *C*) Side and top projections of a repetitive model peptide with dihedral angles (−60, 135) to show the approximate 3-fold symmetry.

The molecular structure of spider dragline silk: Folding and orientation of the protein backbone.
Meier et.al. July 29, 2002
99 (16) 10266-10271,
https://doi.org/10.1073/pnas.152162299

Convergent evolution of the tri-sectional silk gland between *T. clavata* and *B. mori*.

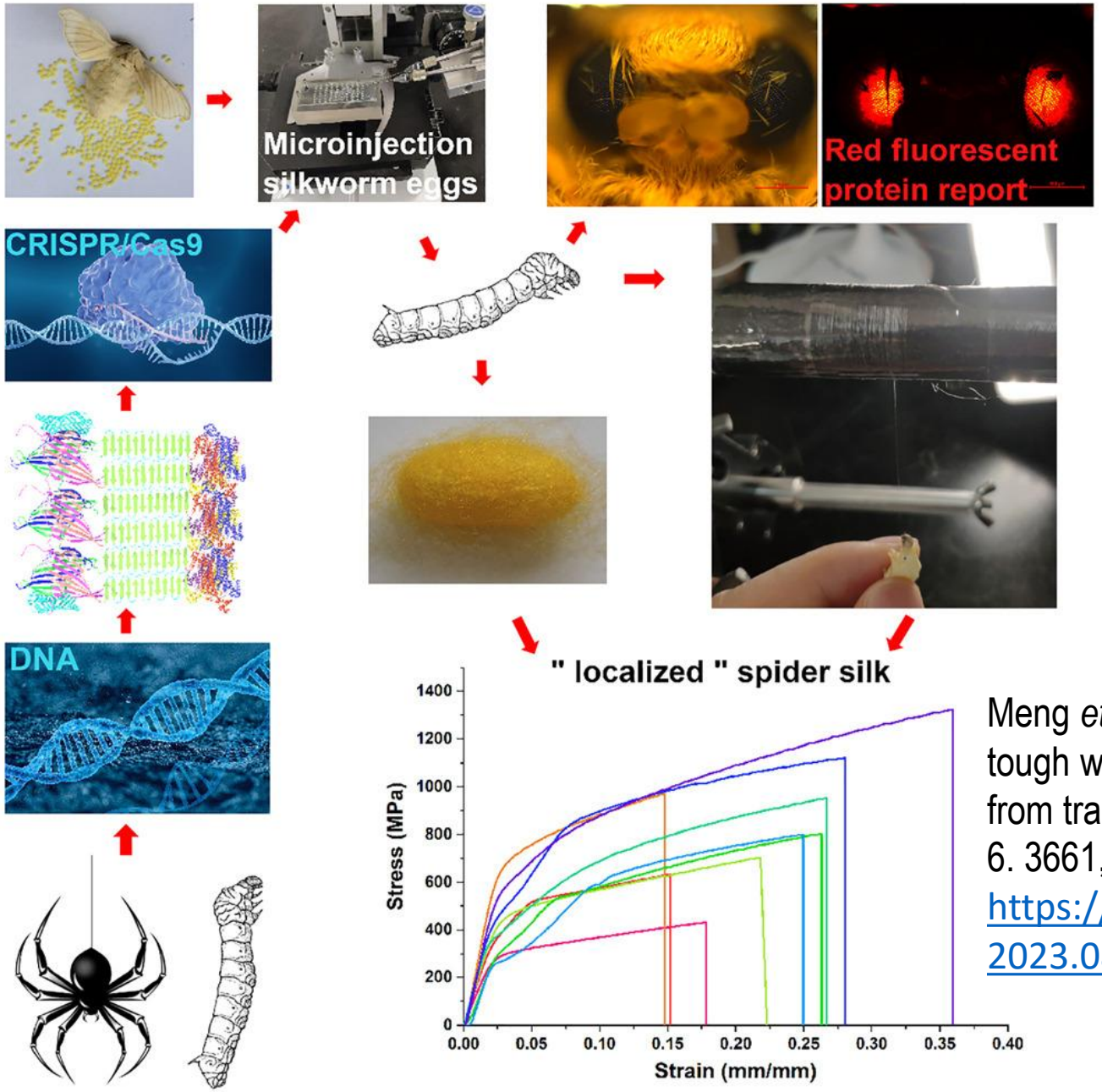


A molecular atlas reveals the tri-sectional spinning mechanism of spider dragline silk.
Yi Wang et.al. *Nature Communications* **volume 14**, Article number: 837 (2023)

The Joro Spider which Weaves Large Webs of Exceptional Strength

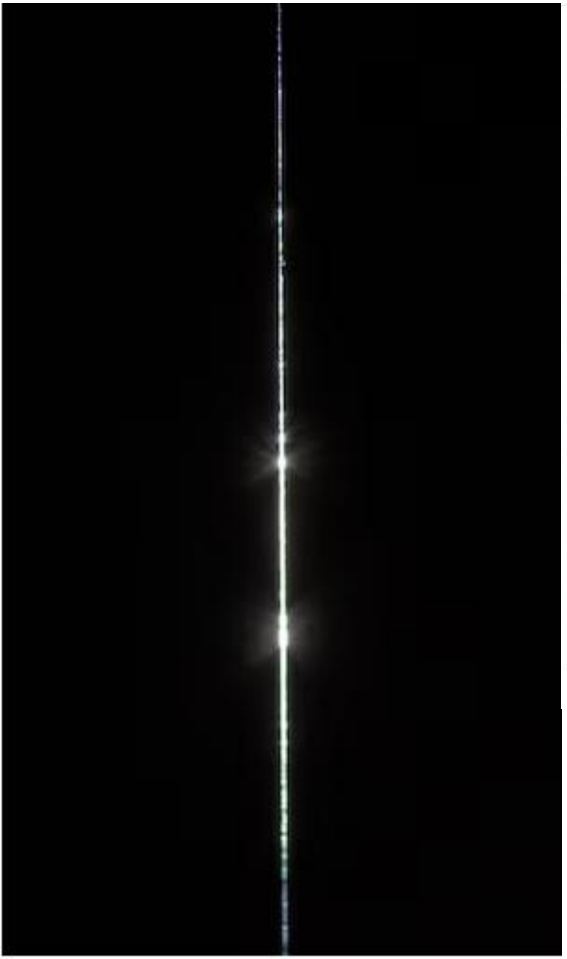
Joro spiders are known to weave exceptional large webs. In this case, a joro spider web was strong enough to support a perching cardinal.

Extracting a strand of silk from a live pinned-down Joro spider requires precision, as Hu demonstrates in a lab at Southwest University.



Meng *et. al.* High-strength and ultra-tough whole spider silk fibers spun from transgenic silkworms, Matter , 6. 3661, 2023. https://doi.org/10.1016/j.matt.2023.08.013.

Properties of Engineered Silk



At Soochow University, in eastern China, a single fiber of supersilk produced by a transgenic silkworm is stress tested to see how it compares with true spider silk.

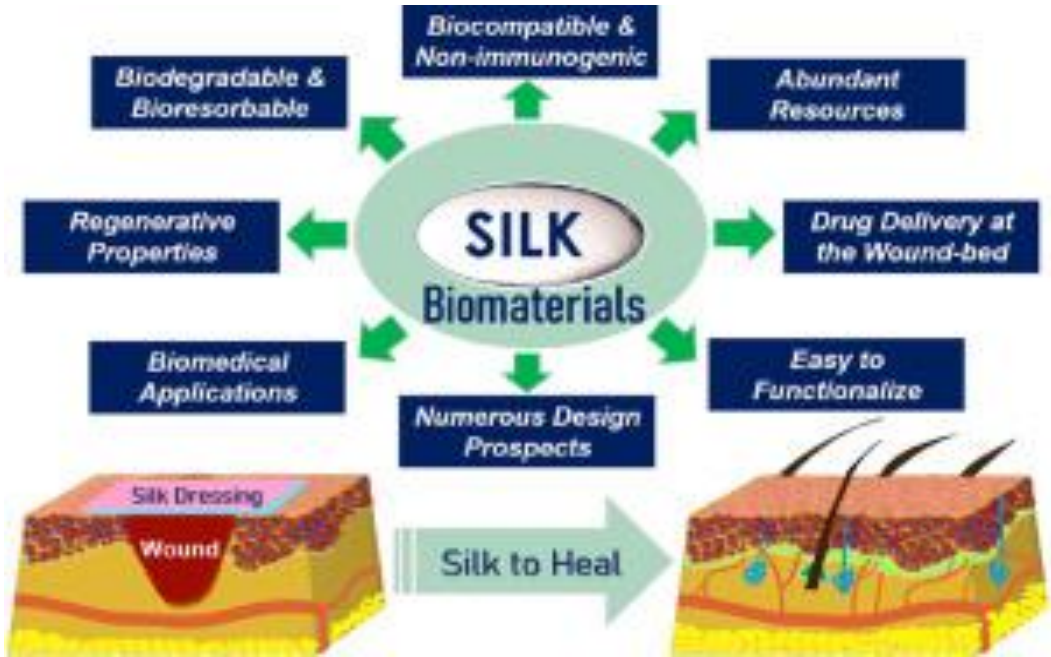
Kraig Biocraft CEO Kim Thompson is hopeful that his company's silk will impress the luxury fashion brands beginning to line up for sample shipments in 2026.

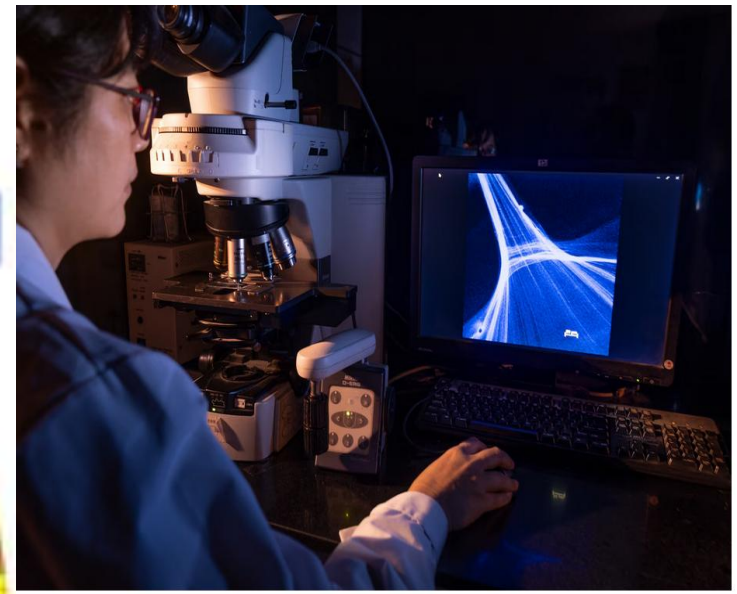
Supersilk's almost miraculous ability to stretch without breaking gets put to the test in National Geographic's photo studio by photo engineer Eric Flynn, who rigged a 170-pound tractor tire to hang from a 0.35-ounce loop of Kraig Biocraft's silk.

The Weight of this Spider Silk is ~ 6gms!
It holds a 80 kg Tractor Tire !

Kraig projects it could produce up to 10 metric tons of spider silk annually at its new facility in Vietnam.

Biomedical Applications



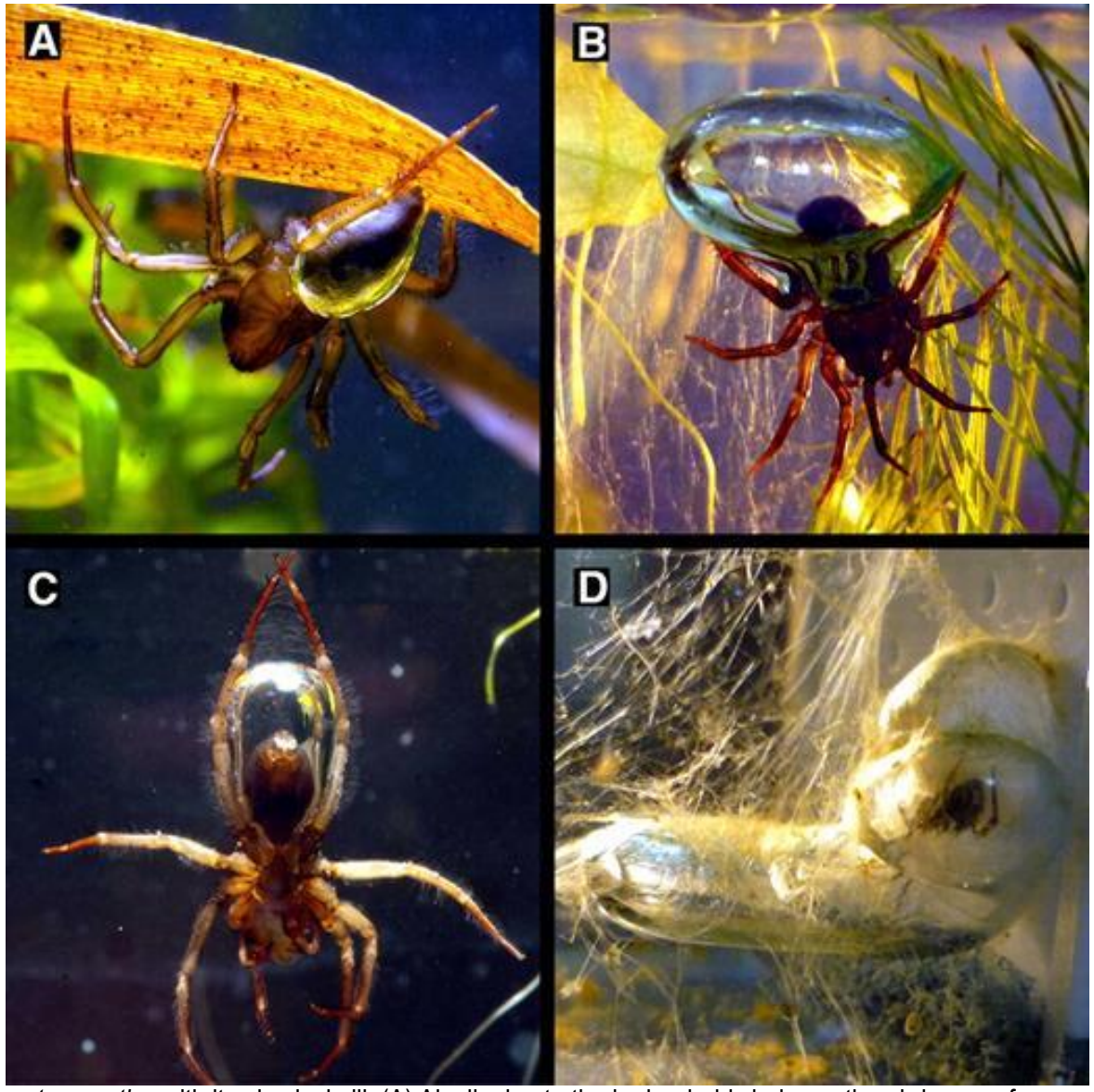


Silkworms are not the only way to produce spider silk proteins. Some companies and researchers, like Soochow University biologist Xingmei Qi, modify fermented bacteria.

Scientists at Beijing's Tsinghua University use silk protein–based sensors to detect brain wave patterns—one of the myriad applications the proteins could have in the medical world.

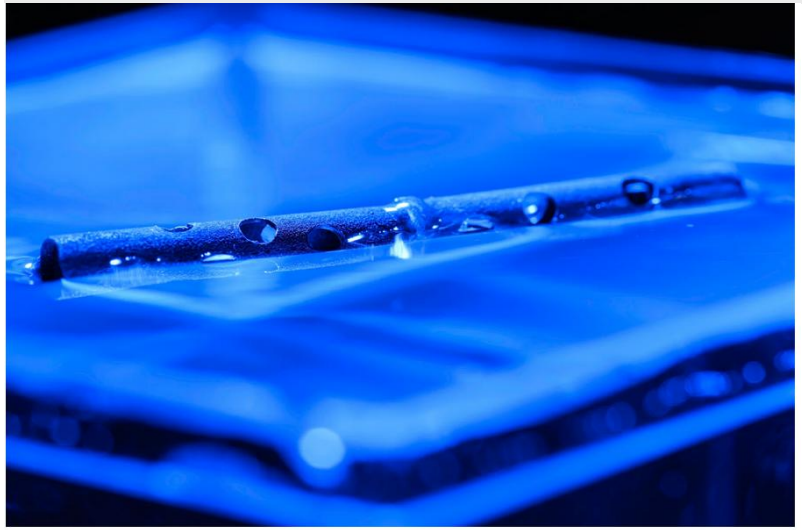
https://pmc.ncbi.nlm.nih.gov/articles/PMC10967872/

Diving Bell Spider & the Quest for Unsinkable Metal



Argyroneta aquatica with its physical gill. (A) Air clinging to the hydrophobic hairs on the abdomen of a spider away from the diving bell. (B) A small diving bell, supported by invisible web, large enough to admit the abdomen only. (C) A large bubble, captured at the surface and held on the abdomen and rear legs, is carried down to the diving bell. (D) A female in her diving bell, below the cocoon.

An "unsinkable" metal tube floats in distilled water in the lab of University of Rochester professor Chunlei Guo on January 9, 2026. J. Adam Fenster/University of Rochester

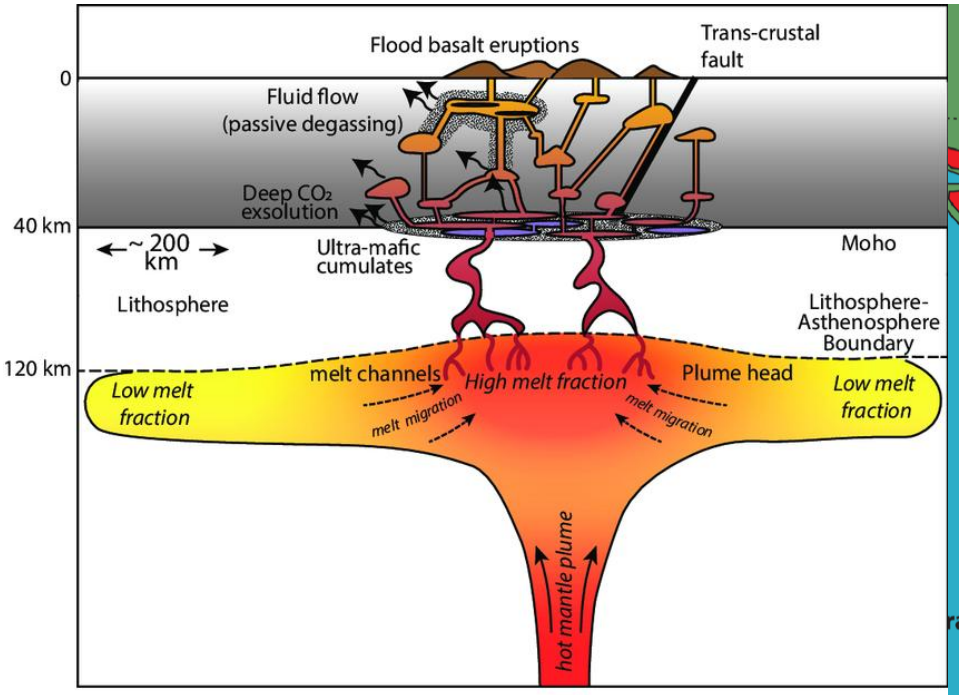


An "unsinkable" metal tube damaged with holes floats in distilled water in the lab of University of Rochester professor Chunlei Guo on January 9, 2026. J. Adam Fenster / University of Rochester

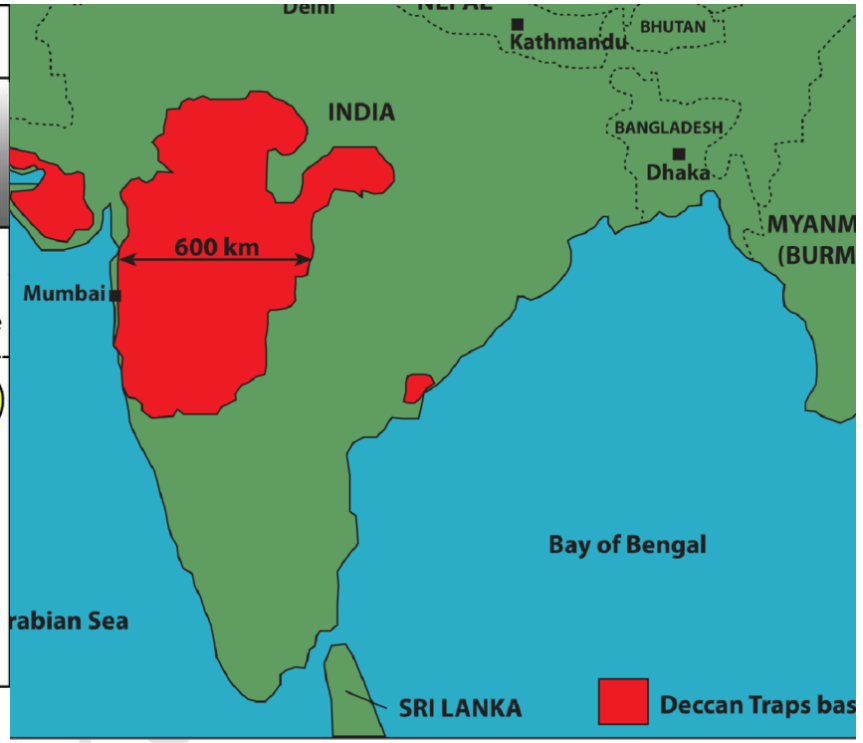
1. Seymour , R.S. & Hetz, K.S. The diving bell and the spider: the physical gill of *Argyroneta aquatica* . J. Exp. Biol. 214, 2175, **2013.** https://doi.org/10.1242/jeb.056093

2. Guo *et.al.* Geometry-Enabled Recoverable Floating Superhydrophobic Metallic Tubes, Advanced Functional Materials https://doi.org/10.1002/adfm.202526033

Agriculture & Sustainability



Formation of Basalt During the Volcano Eruption in India ~66-67 Million Years Ago



The Event was the Eruption of a super volcano. The lava flow was 1500 kms long.

View of the Deccan Traps near Pune. Trap is derived from the Swedish word **Trappsteg** for Steps

Minerals in Deccan Traps

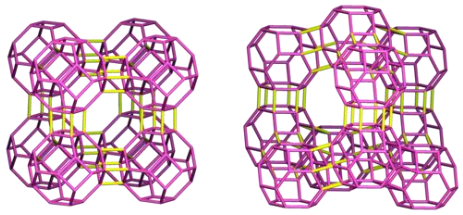
Table 1. Average composition of Deccan basalts and other differentiated rocks (wt. percent oxide).

Oxide	Lower Deccan basalt (Qz-tholeiite)		Upper Deccan basalt (Qz-tholeiite)	Average Deccan basalt++		Olivine tholeiite	Olivine basalt	Alkali olivine basalt	Nephelinite	Saturated intermediate differentiates	Undersaturated intermediate differentiate	Acid rock
	1	S	2	3	S	4	5	6	7	8	9	10
SiO_2	49.65	0.86	48.37	48.97	2.08	46.03	44.76	45.73	44.55	51.03	51.84	68.69
TiO_2	2.66	0.48	2.18	2.49	0.89	2.02	1.47	1.81	0.84	1.30	0.83	0.58
Al_2O_3	12.71	1.05	15.10	13.66	1.68	13.76	10.44	14.37	16.50	17.54	18.88	13.52
Fe_2O_3	3.70	1.20	5.14	4.15	1.49	3.99	2.25	4.82	6.54	4.74	3.92	2.66
FeO	9.93	2.10	7.37	9.02	1.68	8.12	9.69	8.47	2.06	4.24	2.88	2.48
MnO	0.21	0.03	0.20	0.20	0.08	0.19	0.15	0.13	0.43	0.20	0.14	0.14
MgO	5.31	0.46	5.28	5.90	1.69	8.97	15.57	7.95	1.76	3.96	1.63	0.69
CaO	10.19	0.69	9.65	9.88	1.44	10.79	10.32	8.52	10.40	6.80	4.07	1.84
Na_2O	2.35	0.29	2.91	2.50	0.67	2.17	1.53	4.18	5.82	3.29	7.20	3.70
K_2O	0.64	0.28	0.94	0.72	0.40	0.76	0.65	1.14	1.43	3.12	5.67	4.10
H_2O^+	1.93	0.69	1.75	1.47	0.71	1.20	2.60	2.00	4.43	1.85	1.82	1.13
H_2O^-	0.57	0.32	0.75	0.98	0.79	1.22	0.97					0.45
P_2O_5	0.31	0.08	0.37	0.29	0.13	0.26	0.17	0.33	0.57	0.32	0.25	0.15
CO_2								0.62	4.28	2.14	0.41	
Total	100.16		100.01	100.23		99.48	100.57	100.07	99.61*	100.53	99.54	100.13
No. of analyses	44		65	99		10	3	15	8	9	20	38

++ Superior analyses of basalts containing silica percentage between 44 to 54.
S=Standard deviation. * Also contains SO_3=0.24.
N.B. Detailed sources of analyses are available from the author.
Rocks included for average composition are:
col. 6 – mugearite, limburgite, oceanite and other ne-normative basalts.
col. 8 – trachyte, quartz micro-syenite and micro-lusitanite.
col. 9 – phonolite, tinguite, nepheline micro-syenite, alkali syenite and pulaskite.
col. 10 – rhyolite, rhyodacite, granophyre, pitchstone, felsite, acid porphyry, micro-granite, micro-monzo-granite and dacite.

Name of the minerals	Apophyllite	Stilbite	Mordenite
Chemical Composition	(K, Na) $Ca_4Si_8O_{20}(F,OH)\ 8H_2O$ (Hatch, 1912)	(Ca, Na_2, K_2) $(Al_2Si_7O_{18})\ 7H_2O$ (Hatch, 1912)	(Ca, Na_2, K_2) (Al_2Si_7) $O_{18}\ H_2O$ (Hatch, 1912)
Crystal System	Tetragonal	Monoclinic	Orthorhombic
Form	Crystalline	Acicular	Radiating
Color	Colorless, Pale Green	Brownish	White, Colorless
Luster	Vitreous	Vitreous to Pearly	Vitreous Silky
Streak	White	White	Colourless
Fracture	Uneven	Uneven	Uneven
Cleavage	Perfect on {001}, imperfect on {110}	{010} Perfect	{010} Perfect
Hardness	4.5 to 5.0	2.1 to 2.2	5
Specific Gravity	2.33 to 2.37	3.5 to 4.0	2.12

Zeolites are a group of several microporous crystalline aluminosilicate minerals commonly used as commercial adsorbents and catalysts.They mainly consist of silicon, aluminium, and oxygen, and have the general Formula $M^{n+}_{1/n}(AlO_2)^-(SiO_2)_x \cdot yH_2O$ where $M^{n+}_{1/n}$ is either a metal ion or H^+.



Apophyllite

a mineral occurring typically as white glassy prisms, usually as a secondary mineral in volcanic rocks. It is a hydrated silicate and fluoride of calcium and potassium.

Stilbite

a mineral in the series of tectosilicate minerals of the zeolite group. with the mineral species being named:

- Stilbite-Ca
- Stilbite-Na, sometimes also called *stilbite*

Mordenite

a mineral in the zeolite group it is one of the six most abundant zeolites and is used commercially

Reactions of Basalt

Chemical & CO_2 Sequestration Reactions

Stilbite: Used in water purification. Its natural properties make it effective in removing impurities and contaminants from water. Stilbitecan absorb heavy metals, an essential feature in treating industrial wastewater and protecting environmental quality. It is a class A zeolite used in many Catalytical Process.

Modenite : Mordenite-bearing zeolitic tuff is dried and crushed to produce a variety of products including adsorbents for soaking up oil/chemical spills and animal wastes, animal feed supplements, water treatment, and sports turf and slow release fertiliz n mordenite-rich tuffs have been operating in Japan since the end of the

CO_2 Sequestration by Basaltic Rocks

$CaAl_2Si_2O_8 + 2CO_2 + 3H_2O \rightarrow Al_2Si_2O_5(OH)_4 + Ca^{2+} + 2HCO^-_3$

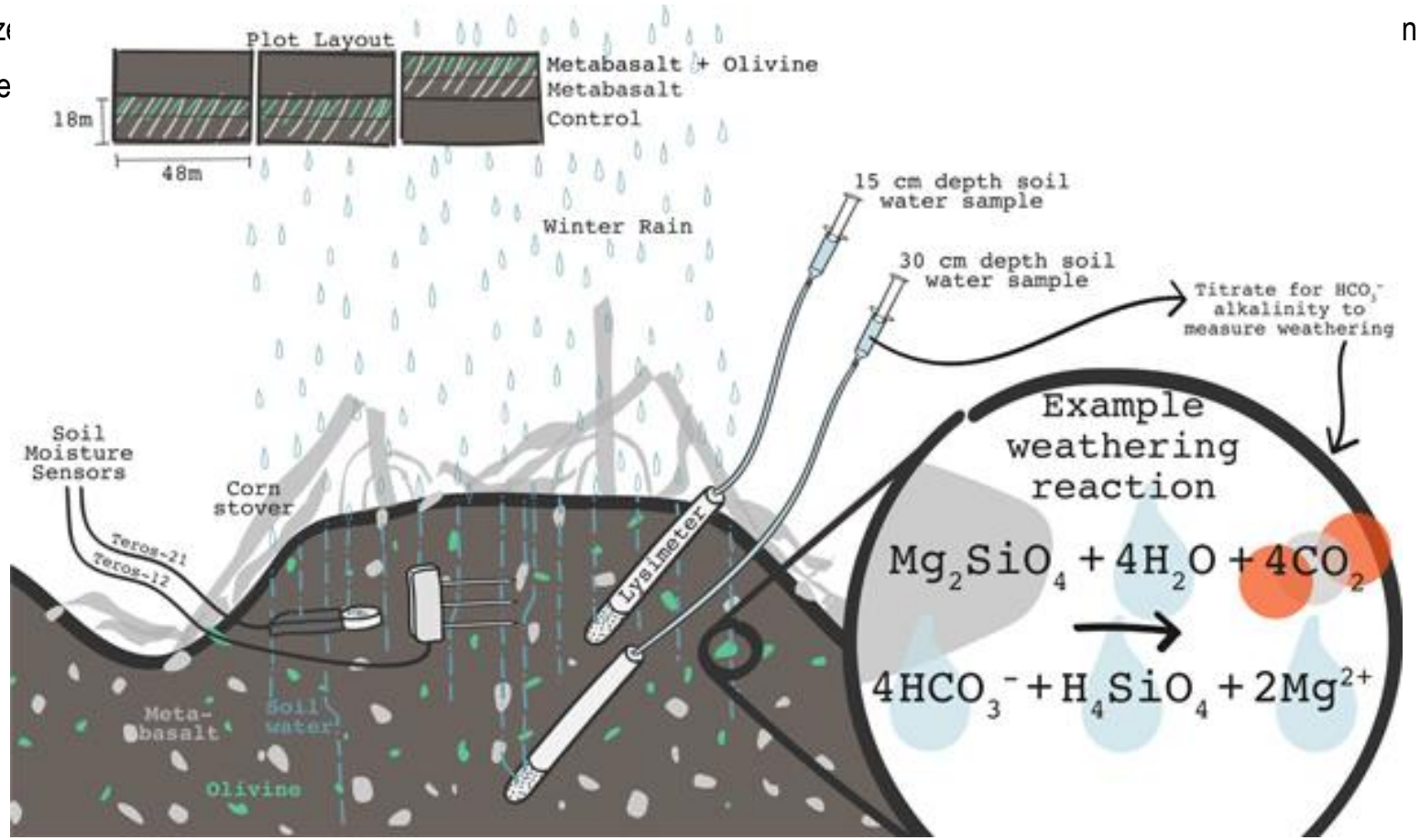
$MgAl_2Si_2O_8 + 2CO_2 + 3H_2O \rightarrow Al_2Si_2O_5(OH)_4 + Mg^{2+} + 2HCO^-_3$

whereas the congruent reaction is given by:

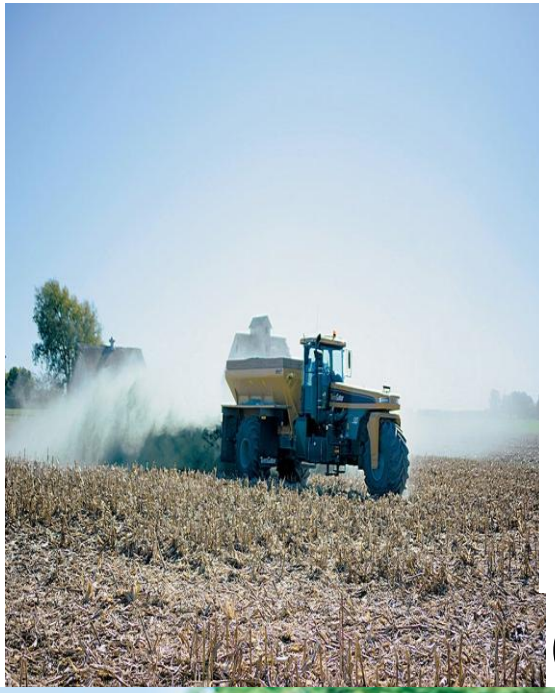
$CaAl_2Si_2O_8 + 8CO_2 + 8H_2O \rightarrow Ca^{2+} + 2Al^{3+} + 2H_4SiO_4 + 8HCO^-_3$

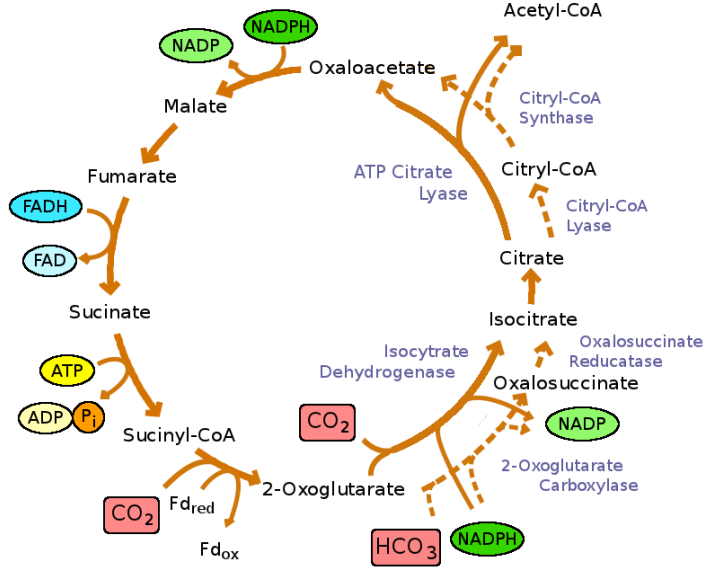
$MgAl_2Si_2O_8 + 8CO_2 + 8H_2O \rightarrow Mg^{2+} + 2Al^{3+} + 2H_4SiO_4 + 8HCO^-_3$

By sequestering CO_2 and subsequent hydrolysis Ca^{2+} , SiO_2 , Mg^{2+} residual Fe^{3+} and other metal ions which are beneficial for overall Plant growth are released in the soil.



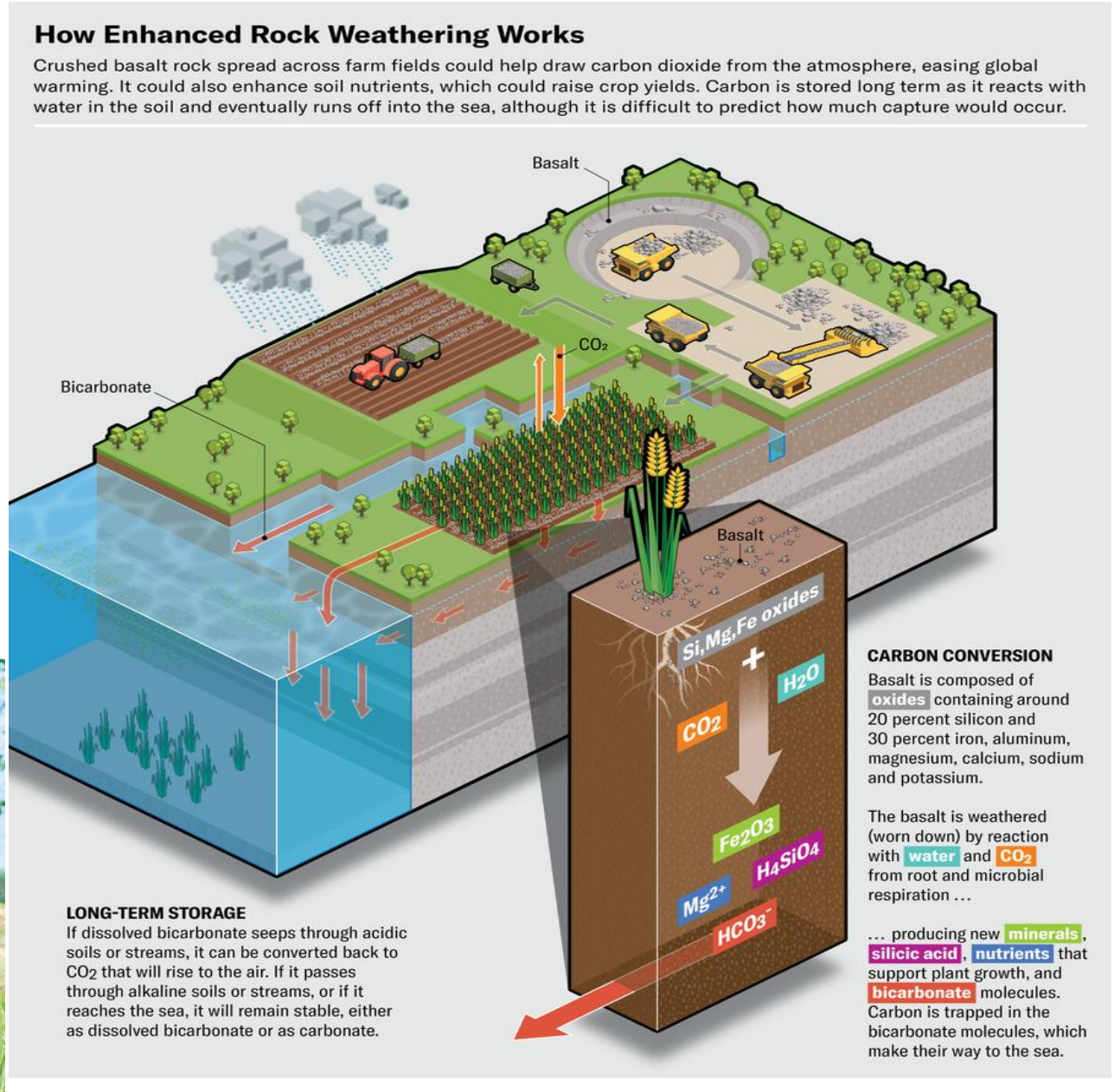
Direct evidence for atmospheric carbon dioxide removal via enhanced weathering in cropland soil ,Iris O Holzer, Mallika A Nocco & Benjamin Z Houlton, Environmental Research Communications, 5, 101004 (2023). Environ. Res. Commun. 5 101004 DOI 10.1088/2515-7620/acfd89





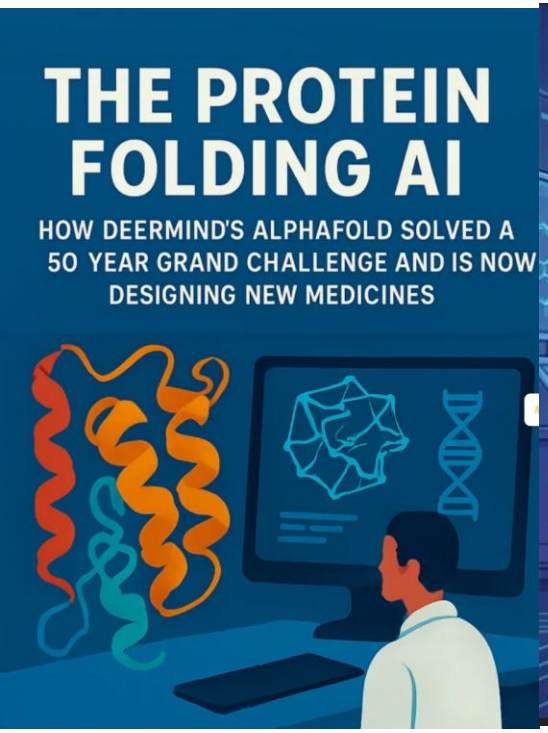
r- Krebs Cycle $CO_2 + H_2O$ -> C compounds

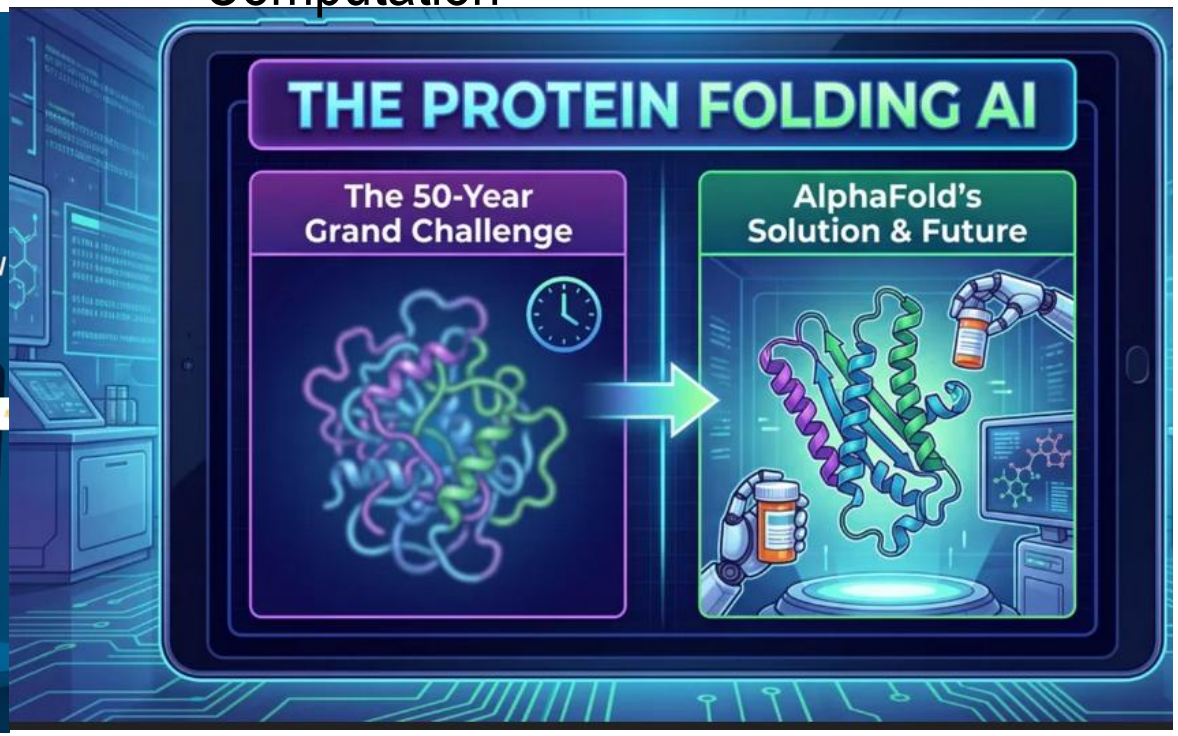
Can one think of this ?



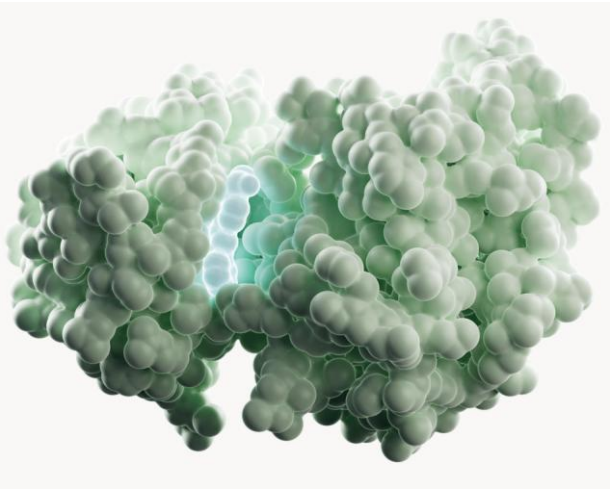
For a superb Discussion on the reverse Krebs Cycle
Transformer: The Deep Chemistry of Life and Death, Nick Lane, (2023) . Available at www.amazon.in for Rs. 640.

Computation





https://thedailyexplainer.com/alphafold-protein-folding-ai-deepmind-guide/



Karl Freed, Professor of Chemistry, University of Chicago.
Prof. M. Bawendi, MIT, Nobel Prize Chemistry, 2023. Ph.D advisor, K. Freed & T. Oka.
Dr. J. Jumper, Google Deep Mind, Nobel Prize Chemistry , 2024. Ph.D advisor, K. Freed & T. R. Sosnik.

Reality: It solved a specific, critical *prediction* problem. Biology is about dynamics, interactions, regulation, and function in living systems. AlphaFold provides a static snapshot of one player—a vital piece, but far from the whole puzzle.

"It replaces experimental structural biology."

Reality: It transforms it. Experimentalists are freed from the slowest, most tedious steps and can now focus on the most interesting, complex targets: flexible proteins, large complexes, and structures with bound drugs. Cryo-EM and crystallography are more important than ever for validating AI predictions and solving what AI cannot. **T**

The predictions are perfect and always correct."

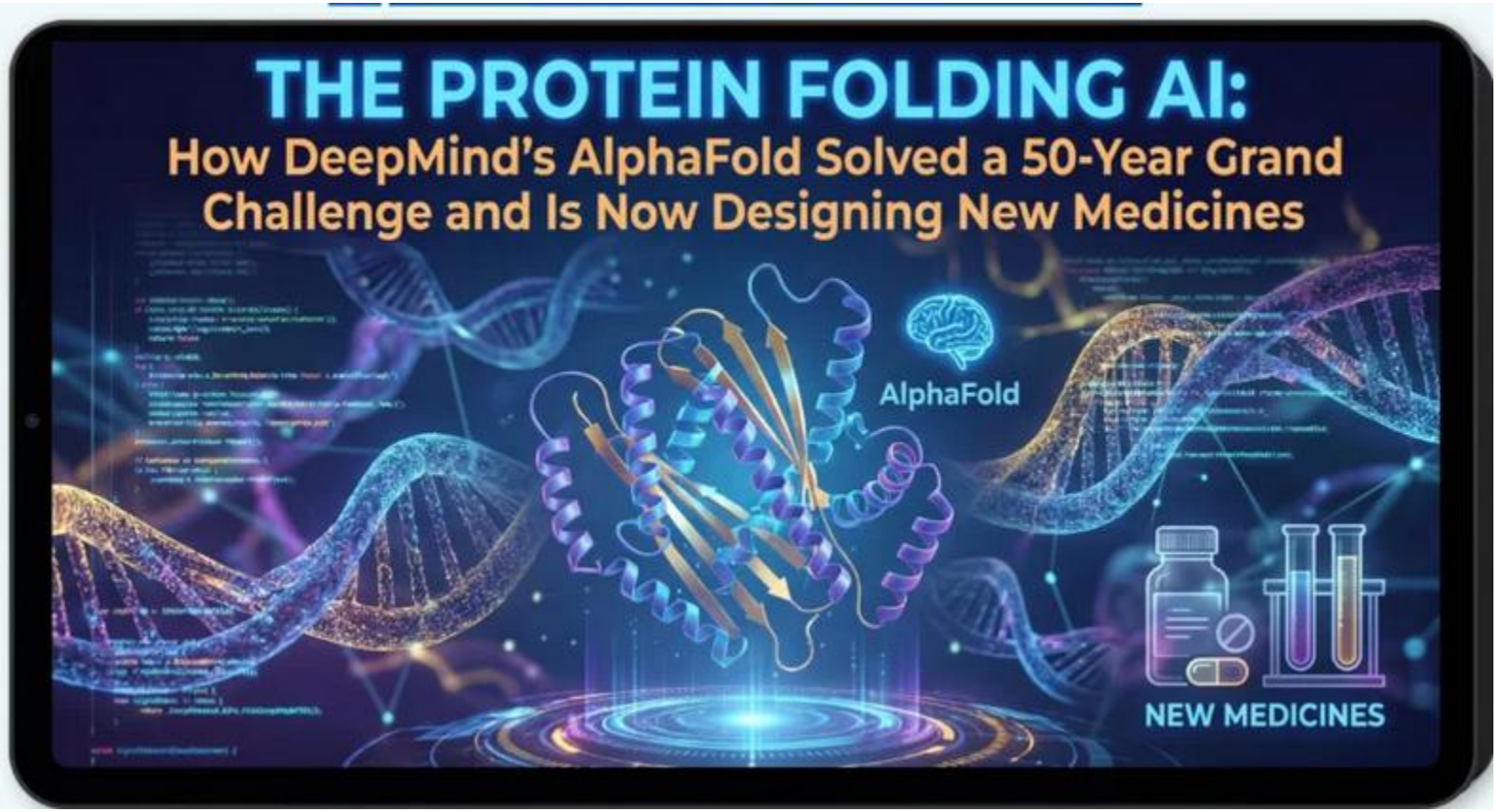
•**Reality:** They are astonishingly accurate for many proteins, but the **pLDDT confidence score is essential**. Low-confidence regions (often flexible loops or disordered segments) may be incorrect. The model can also hallucinate plausible-looking but wrong structures for proteins with very few evolutionary relatives.

• **"It can predict how any protein will interact with any drug."**

•**Reality:** Predicting protein-drug binding (**molecular docking**) is a separate, though related, challenge. While AlphaFold structures improve docking, accurately predicting binding affinity and the induced fit of the protein around the drug molecule requires additional, specialized AI tools and simulations.

https://www.biorxiv.org/content/10.1101/2024.11.19.624167v1.full, boltz.bio

Success Stories



The Search for a "Plastic-Eating" Enzyme Variant

•**Challenge:** While the enzyme PETase can break down PET plastic, it is not stable or efficient enough for industrial use.

•**Solution:** A global team used AlphaFold to model thousands of hypothetical mutant versions of PETase, predicting which mutations would improve stability at high temperatures without disrupting the active site.

•**Outcome:** They identified a set of five mutations that, when combined, created a **"FAST-PETase"** variant. Experimentally confirmed, this AI-guided enzyme depolymerizes 51 different PET products within a week and works at 50°C, making it a viable candidate for large-scale biological recycling.

Unlocking the "Malaria Parasite's Secret Weapon"

•**Challenge:** The *Plasmodium* parasite, which causes malaria, has a mysterious protein called **PfCyRPA** that is essential for invading human red blood cells. Its structure was unknown, hindering vaccine design.

•Researchers used AlphaFold to predict the structure of PfCyRPA with high confidence. The model revealed it had a well-defined, stable shape with a surface likely targeted by antibodies.

•This prediction directly guided the engineering of a stable, immunogenic protein fragment for a new malaria vaccine candidate, now in preclinical development. What might have taken years of trial-and-error crystallography was achieved in days.

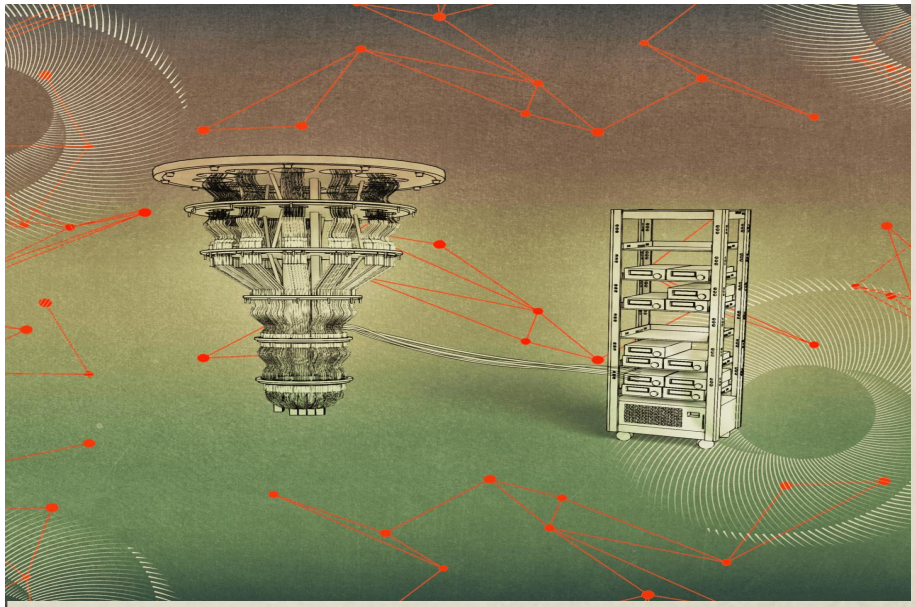
Designing a Hyperstable Vaccine for RSV

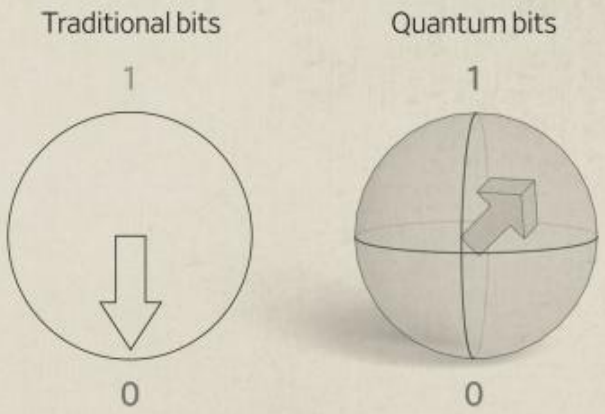
•**Challenge:** The respiratory syncytial virus (RSV) F protein is a key vaccine target but is unstable and shape-shifts, making it hard to design an effective immunogen.

•**Solution:** Scientists at the University of Washington used **Rosetta design software combined with AlphaFold checks** to computationally design over 100,000 new versions of the F protein with mutations aimed at locking it into its most vulnerable shape.

•**Outcome:** They produced a novel protein, **DS-Cav1**, which was far more stable and elicited powerfully protective antibodies in animal models. This computationally designed antigen is a core component of several leading RSV vaccine candidates now on the market or in late-stage trials.

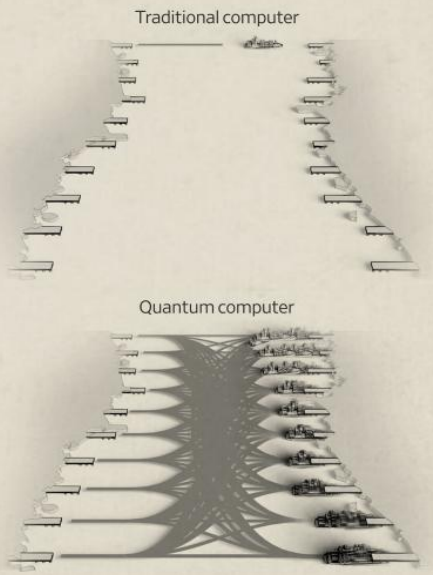
Quantum Computation - Introduction





Quantum computers, instead, use quantum bits, or "qubits." Most qubits are subatomic particles, like electrons, that are put in "superposition," or many states at once: a 1, a 0, and all values between the two.

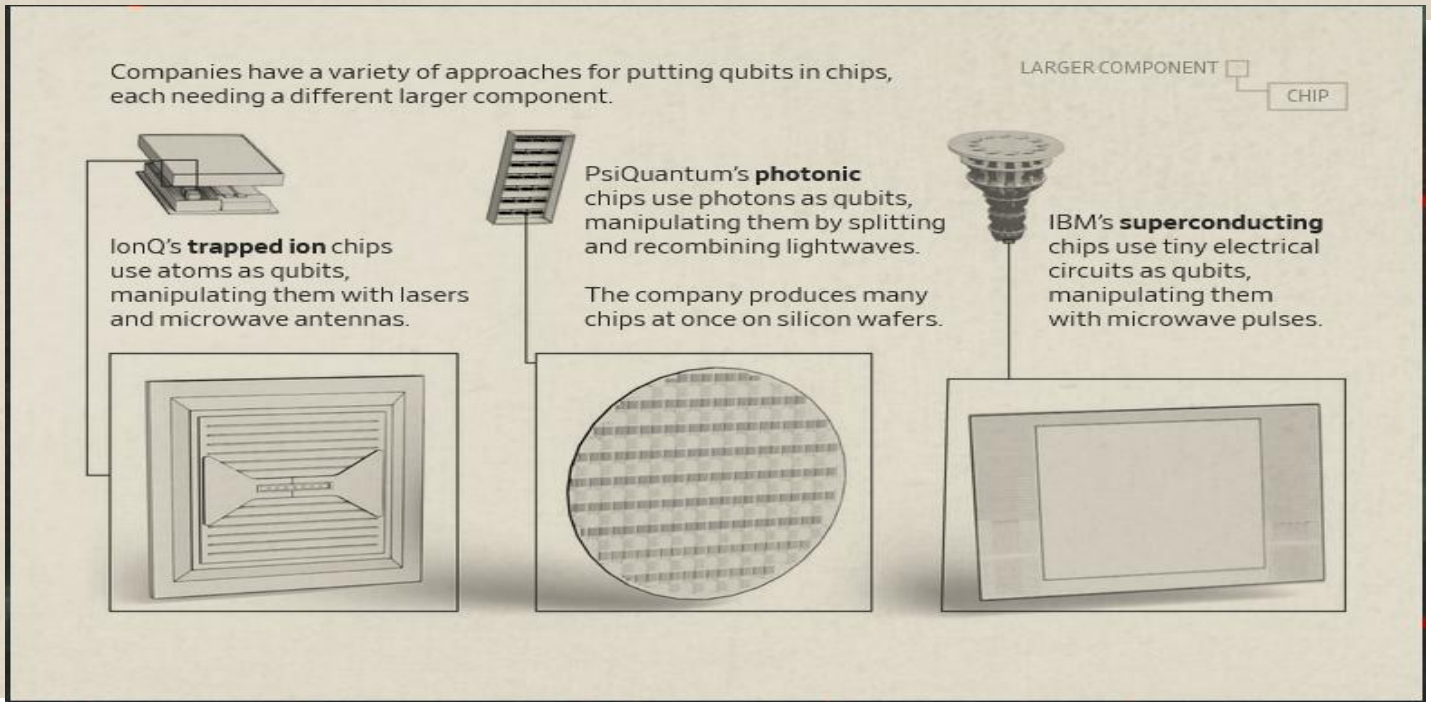
When the qubit is taken out of superposition, its value between 1 and 0—representing a probability—is captured.



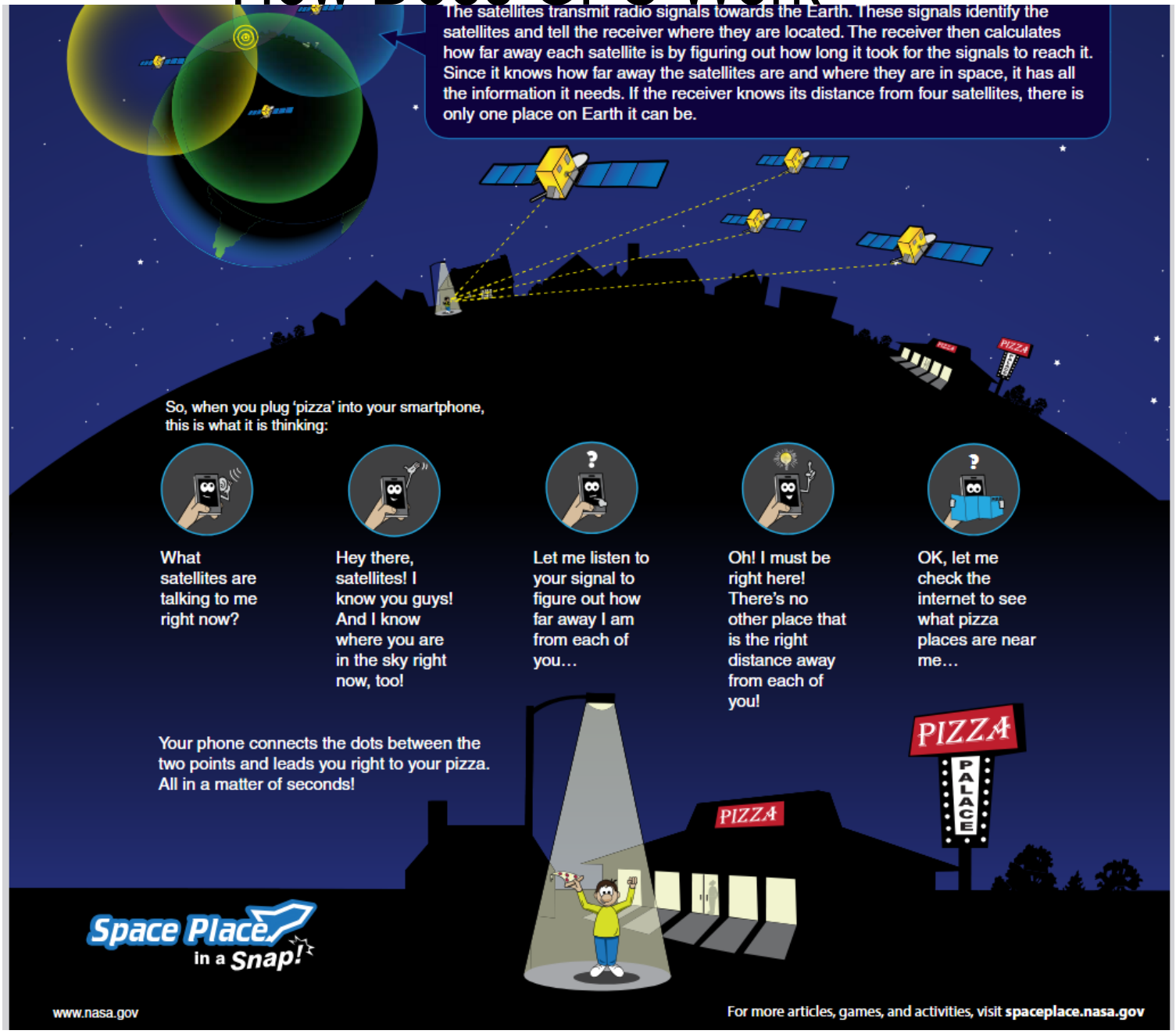
Now imagine it scaled up.

If there were 10 origins and 10 destinations, there would be 100 unique options.

A traditional computer still needs to try each combination sequentially, while a powerful-enough quantum computer can evaluate all options at once.

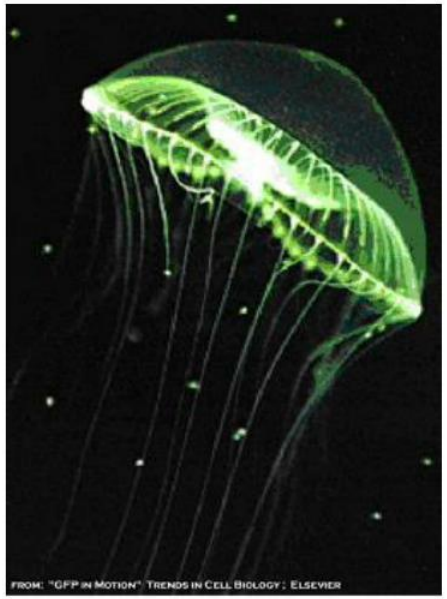


How Does GPS Work

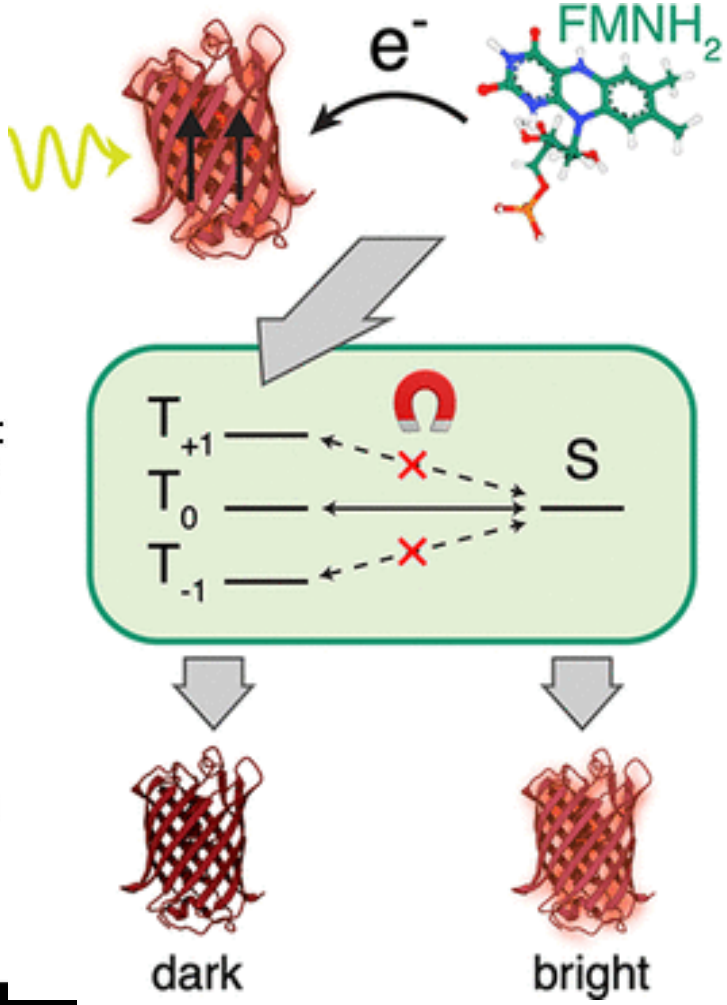


Quantum Sensing

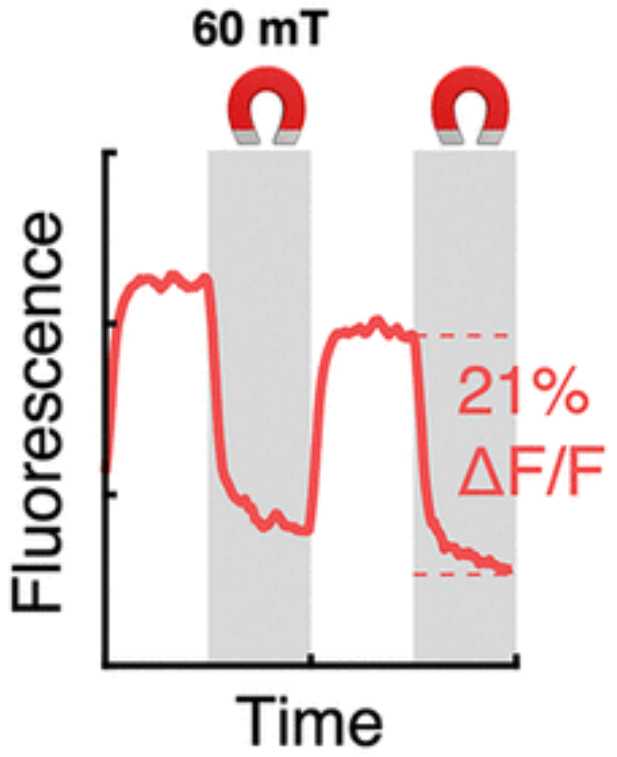
Jellyfish GFP gene



- Bioluminescent jelly fish *Aquorea victoria*: natural host of green fluorescent protein (**GFP**)
- **GFP** is produced in special photogenic cells in the base of the jellyfish umbrella



$FMNH_2$: Reduced Flavin Mononucleotide



doi:10.5281/ZENODO.8137174

Science, Sustainability & You : Measure, Measure and Record it in a Notebook

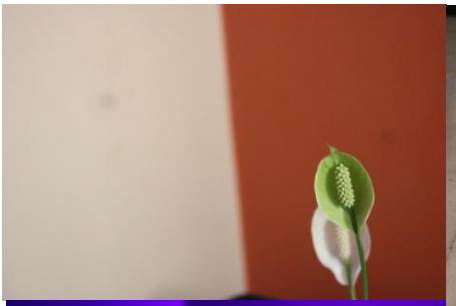
Residual Water

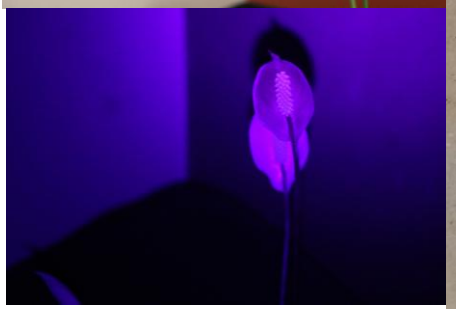
Vegetable Peels

Mascerated in a Blender

Vermi/Milli compost bin

Steaming Vegetables





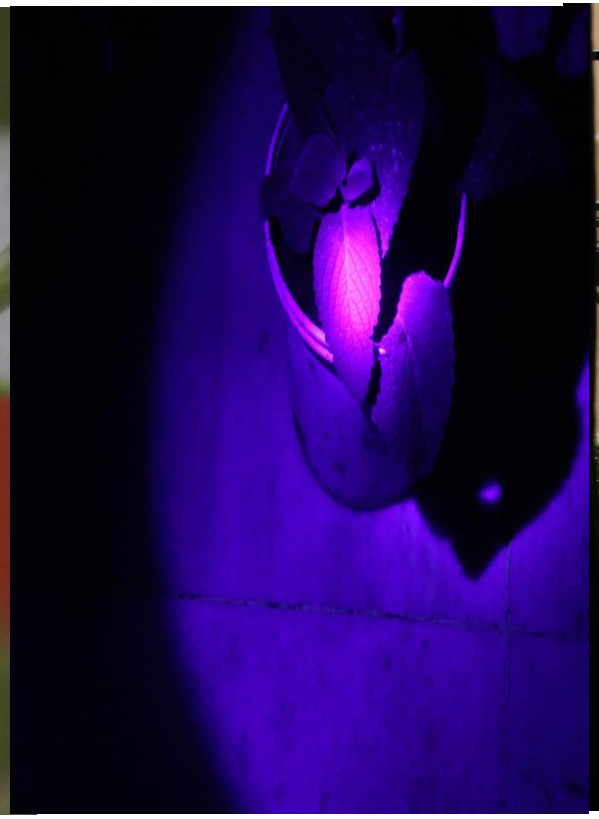
Peace Lily Flower
1. Normal Light
2. UV Light (390-400 nm).

1. Laboratory Notebook, Fountain Pen.
2. Screw Gauge, Vernier Calipers, Tape Measure, Weighing Scale, UV Flashlight (390-400 nm) . Total Cost ~ Rs.2500.

Fix a Speedometer to the Bicycle. Calculate Average Speed Daily.

Science, Sustainability & You (Observe, Observe , Observe and Carry Out Experiments)

Plectranthus amboinicus (Karpuravalli)



Fluorescence of the leaves *(*390 nm *)*

Home made Drip Irrigation

Ocimum tenuiflorum (Tulsi)

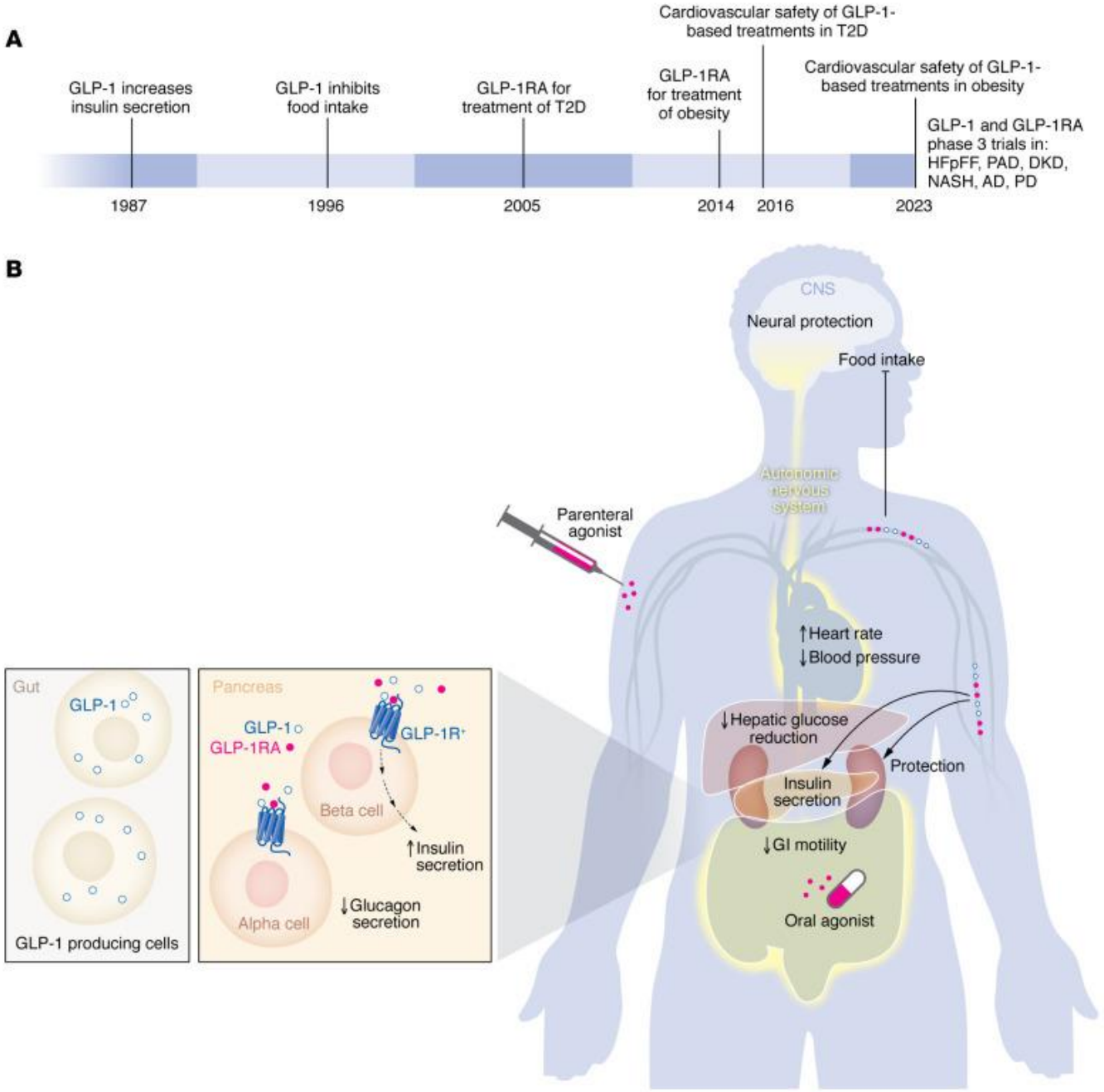
1. Can one develop a cellphone App to quantify chlorophyll ?
2. Will Red Light increase the Production of Volatile Products ?
3. Can the Volatiles be Collected and their Analysis Done ?
4. Techniques to be used Gas Chromatography & Mass Spectrometry ?
5. Can the Fine Hairs on the Stem & Leaves of the Plants be collected and Microsopy studies carried out to find their Microstructure ?

Acknowledgments

1. My wife Mrs. Rama Gautam for putting up With my Idiosyncrasies. Sometimes she wishes that I had not retired and go to work everyday.

2. Dr. Ketika Garg for patiently going through various iterations of the talk and offering many helpful suggestions and comments.

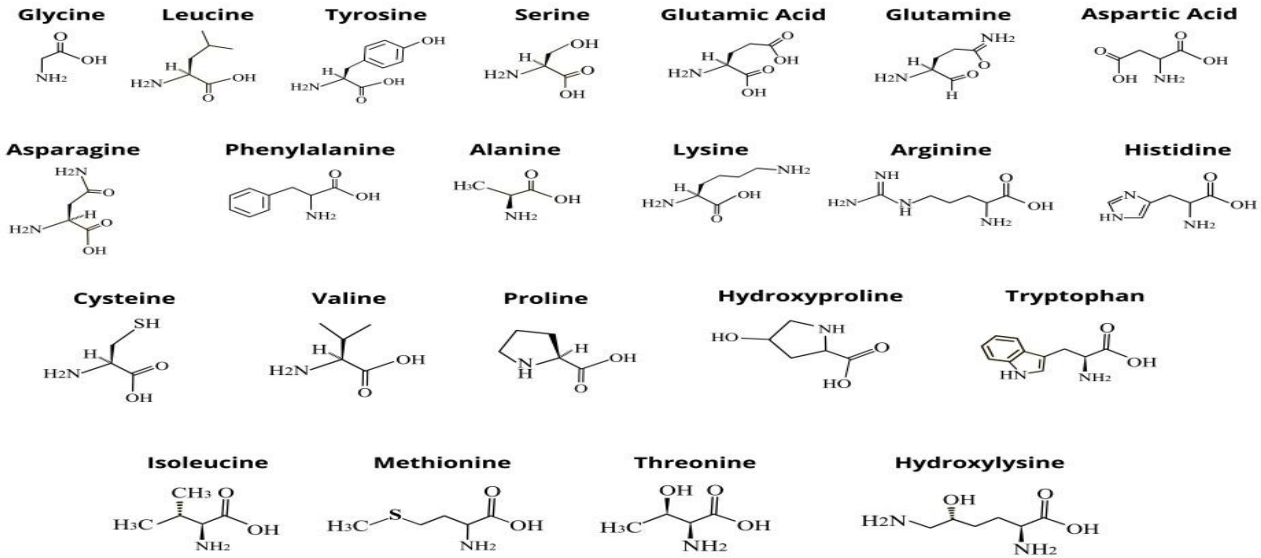
3. Dr. Anuj Pennathur for his usual pithy comments.

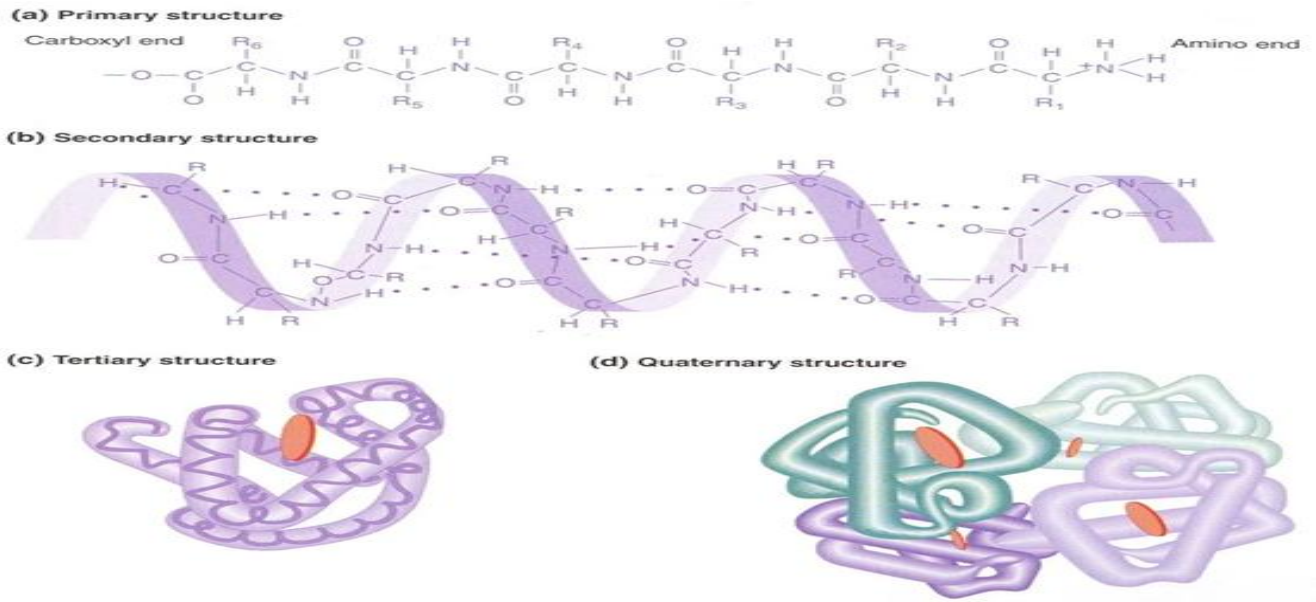


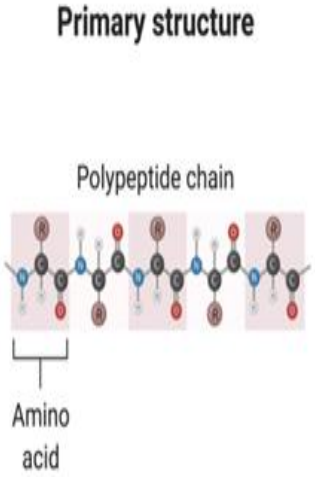
A) Data revealing GLP-1–stimulated insulin secretion supported the approval of the first GLP-1RA for the treatment of T2D in 2005. Nine years later, the link between GLP-1 and reduced food intake resulted the development and approval of the first GLP-1RA for obesity. The cardiovascular safety of GLP-1–based medicines was first demonstrated in T2D in 2016, and in people with obesity in 2023. GLP-1RA are currently being studied in phase 3 trials for the treatment of HFpEF, peripheral artery disease (PAD), diabetic kidney disease (DKD), metabolic liver disorders such as nonalcoholic steatohepatitis (NASH), and neurodegenerative disorders. (**B**) GLP-1 and GLP-1RAs act through the GLP-1R, which is a G protein coupled receptor. GLP-1 potentiates glucose-dependent insulin secretion in β-cells. The GLP-1R is also widely expressed in multiple tissues including several regions of the brain. Notably, activation of GLP-1R$^+$ neurons in the hypothalamus and brainstem reduces food intake and promotes weight loss. GLP-1R$^+$ neurons in the hindbrain also suppress hepatic glucose production. Further, GLP-1R influences BP and HR via the autonomic nervous system.

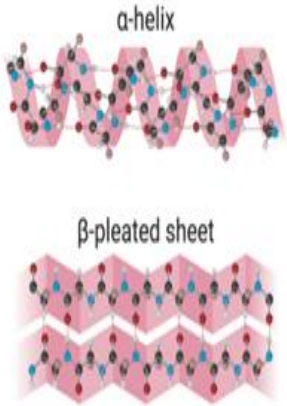
Ref: **The GLP-1 journey: from discovery science to therapeutic impact** Daniel J Drucker, Journal of Clinical Investigations 16;134(2):, 2024, e175634. doi: 10.1172/JCI175634

Amino Acids

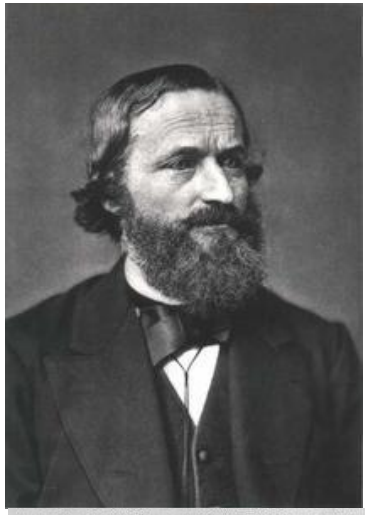




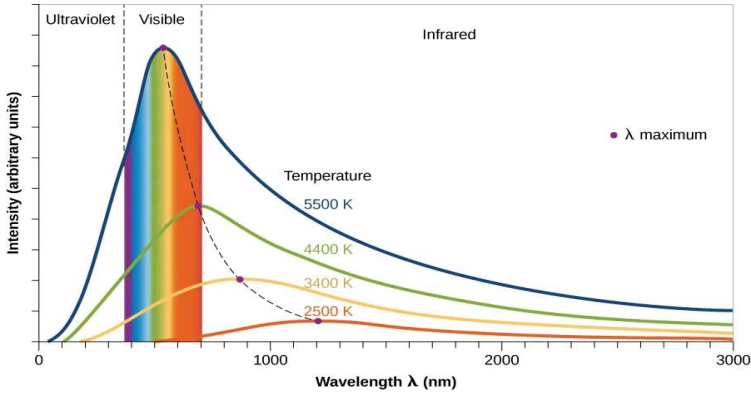


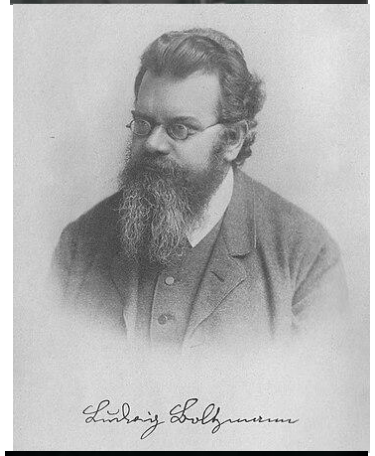


Amino acid	Three letter code	One letter code
alanine	ala	A
arginine	arg	R
asparagine	asn	N
aspartic acid	asp	D
asparagine or aspartic acid	asx	B
cysteine	cys	C
glutamic acid	glu	E
glutamine	gln	Q
glutamine or glutamic acid	glx	Z
glycine	gly	G
histidine	his	H
isoleucine	ile	I
leucine	leu	L
lysine	lys	K
methionine	met	M
phenylalanine	phe	F
proline	pro	P
serine	ser	S
threonine	thr	T
tryptophan	trp	W
tyrosine	tyr	Y
valine	val	V

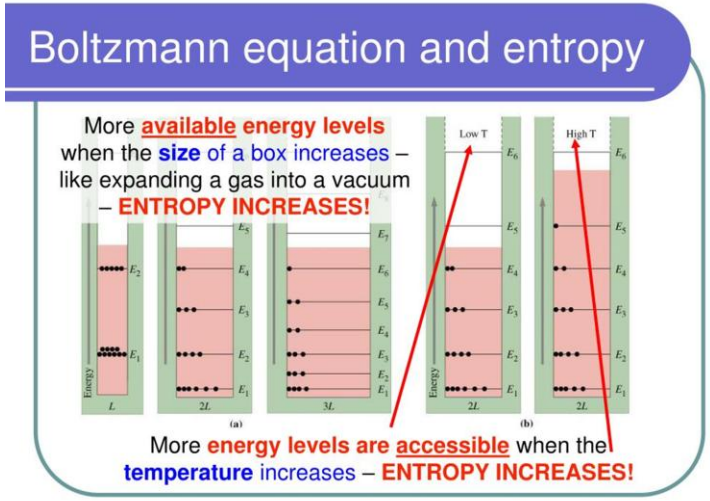


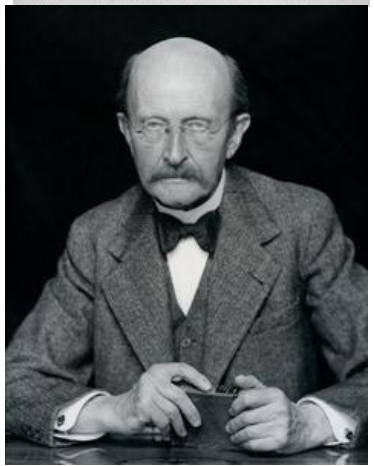
Gustav Kirchoff was a superb experimentalist and the leading scientist in thermodynamics and was Professor of Physics at the University of Berlin. Planck was appointed Professor on Kirchoff's Death. Accurately measured wavelengths emitted by a blackbody by designing his own spectroscope .





Introduced the statistical interpretation of the Entropy. Defined States and discrete energy levels. His most famous quote "Bring forward what is true. Write it so that it is clear. Defend it to your last breath."
"The life contest is not a struggle for raw materials, nor for energy which exists in plenty, but a struggle for entropy."





" to interpret U_N ['the vibrational energy of N oscillators'] not as a continuous, infinitely divisible quantity, but as a discrete quantity composed of an integral number of finite equal parts" . Planck was able to calculate the value of **h** from experimental data on black-body radiation: his result, 6.55×10^{-34} J·s, is within 1.2% of the currently defined value. He also made the first determination of the Boltzmann constant k_B from the same data and theory.
E = hf (Einstein – Planck Relation) (h = , Hilfsgrosse, Auxiliary Energy,(the unit for action), later the Planck's constant)