

Physics in 100 Years

Queries

Unifications

The Grand Tradition

Why seek unification?

Answer 1: Success stories!

space and number; geometry and algebra (Descartes)

celestial and terrestrial law (Galileo, Newton)

mechanics and ray optics (Hamilton)

electricity, magnetism, and wave optics (Maxwell)

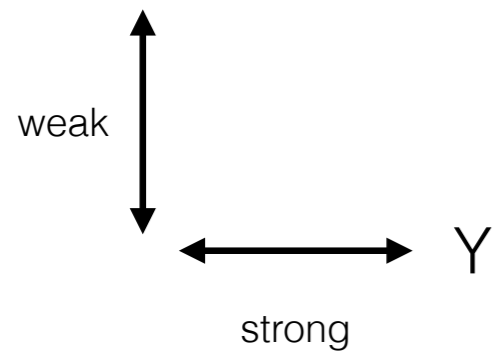
space and time (Einstein, Minkowski)

wave and particle (Einstein, de Broglie)

reasoning and calculation (Boole, Turing)

Answer 2: Isn't it pretty to think so?

Unification I: Forces and Substances (Separately)

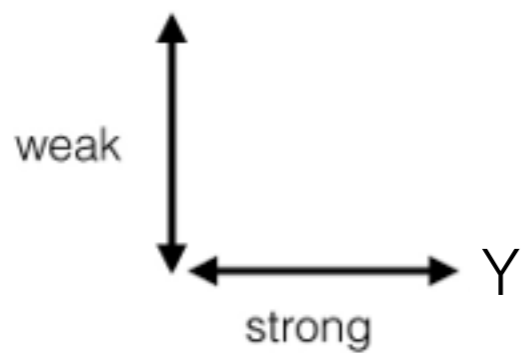


three
fundamental
forces
(plus gravity)

$$\begin{pmatrix} \text{yellow} \\ \text{purple} \end{pmatrix}_{-1/2} \quad \begin{pmatrix} H^0 \\ H^+ \end{pmatrix}$$

Higgs fluid

$\begin{pmatrix} \text{red} & \text{yellow} \\ \text{red} & \text{purple} \end{pmatrix}_{1/6}^L$	$\begin{pmatrix} \text{green} & \text{yellow} \\ \text{green} & \text{purple} \end{pmatrix}_{1/6}^L$	$\begin{pmatrix} \text{blue} & \text{yellow} \\ \text{blue} & \text{purple} \end{pmatrix}_{1/6}^L$	A	$\begin{pmatrix} u \\ d \end{pmatrix}^L$
$(\text{red})_{2/3}^R$	$(\text{green})_{2/3}^R$	$(\text{blue})_{2/3}^R$	B	$(u)^R$
$(\text{red})_{-1/6}^R$	$(\text{green})_{-1/6}^R$	$(\text{blue})_{-1/6}^R$	C	$(d)^R$
$\begin{pmatrix} \text{yellow} \\ \text{purple} \end{pmatrix}_{-1/2}^L$	<p>six fundamental "entities" (plus two repeats)</p>		D	$\begin{pmatrix} \nu \\ e \end{pmatrix}^L$
$(\text{red})_{-1}^R$			E	$(e)^R$
$(\text{red})_0^R$			F	$(\nu)^R$



three
fundamental
forces

$$\begin{pmatrix} \text{red} & \text{yellow} & \text{green} & \text{yellow} & \text{blue} & \text{yellow} \\ \text{red} & \text{purple} & \text{green} & \text{purple} & \text{blue} & \text{purple} \end{pmatrix}^L_{1/6}$$

A

$$\begin{pmatrix} u \\ d \end{pmatrix}^L$$

$$\begin{pmatrix} \text{red} \\ \text{green} \\ \text{blue} \end{pmatrix}^R_{2/3}$$

B

$$(u)^R$$

$$\begin{pmatrix} \text{red} \\ \text{green} \\ \text{blue} \end{pmatrix}^R_{-1/6}$$

C

$$(d)^R$$

$$\begin{pmatrix} \text{yellow} \\ \text{purple} \end{pmatrix}^L_{-1/2}$$

D

$$\begin{pmatrix} \nu \\ e \end{pmatrix}^L$$

$$\text{O}^R_{-1}$$

E

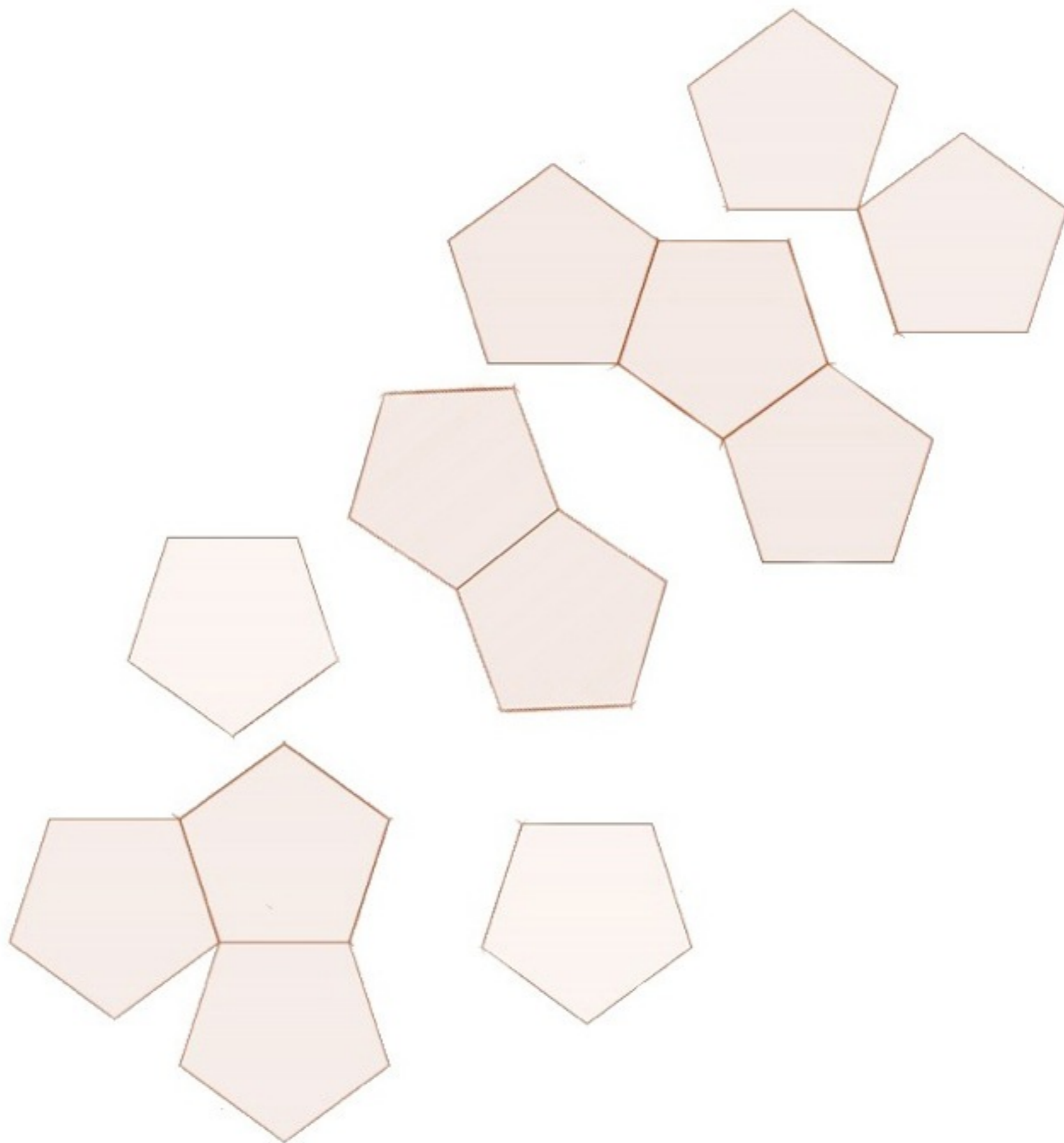
$$(e)^R$$

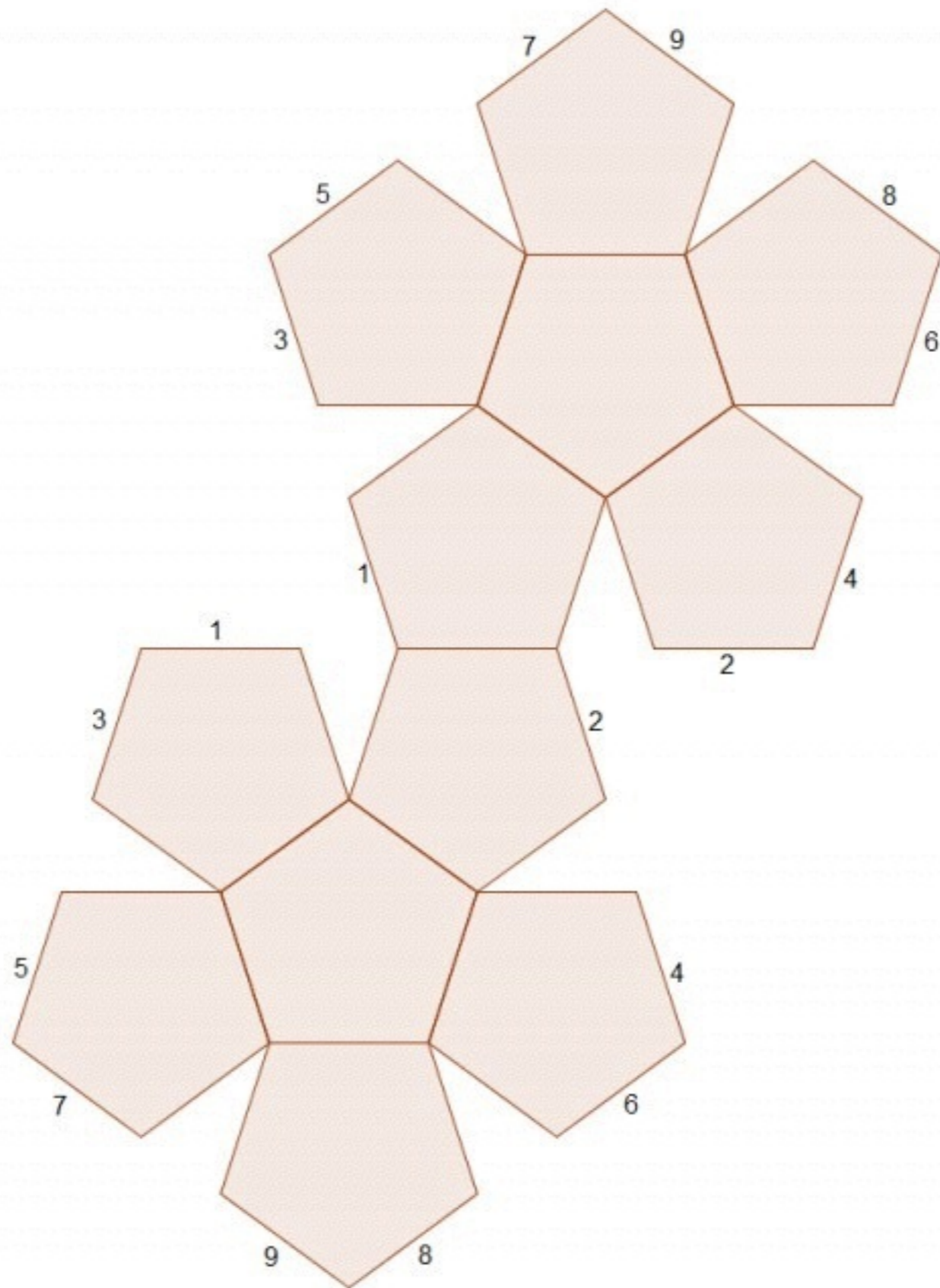
$$\text{O}^R_0$$

F

$$(\nu)^R$$

six
fundamental
"entities"



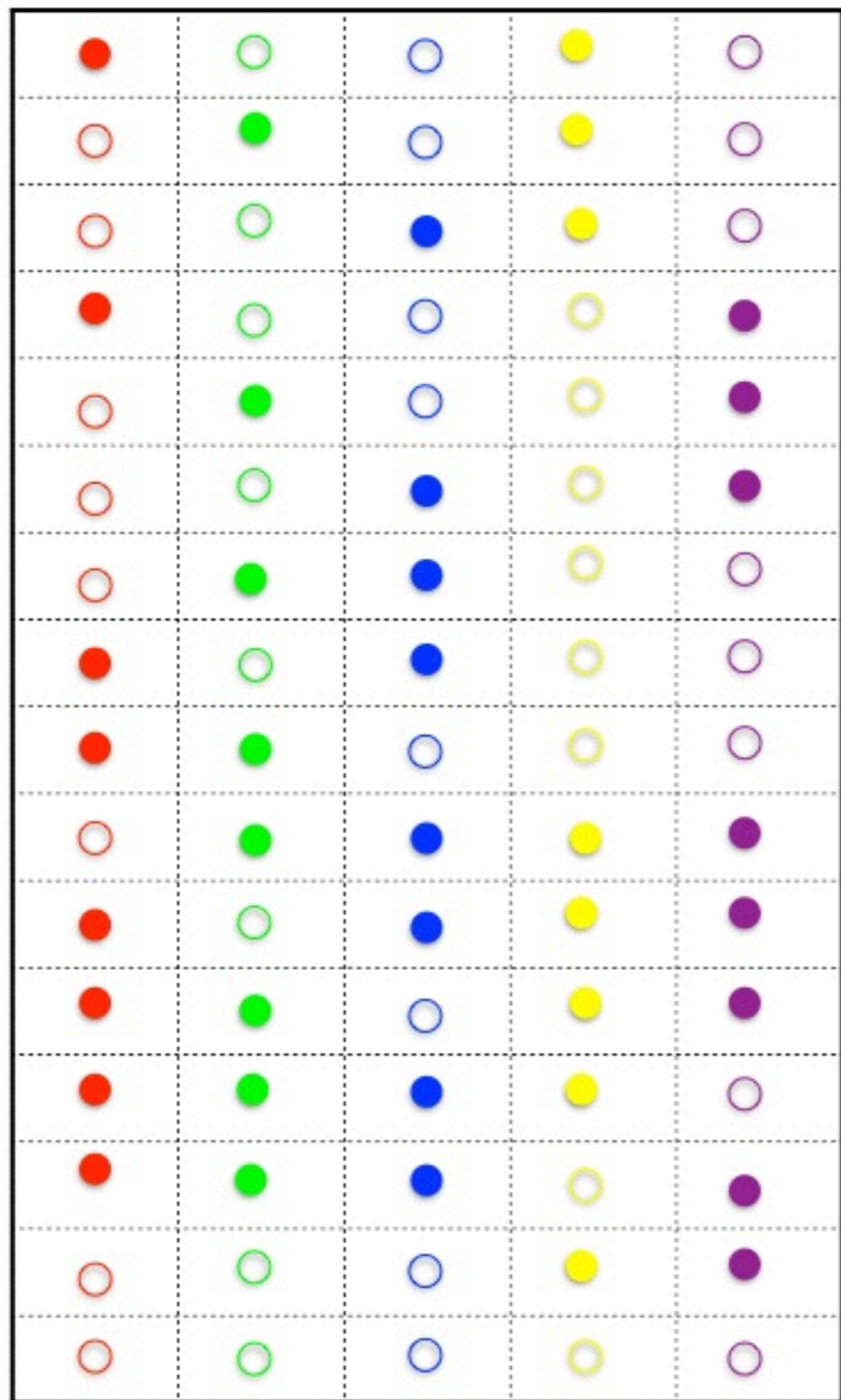


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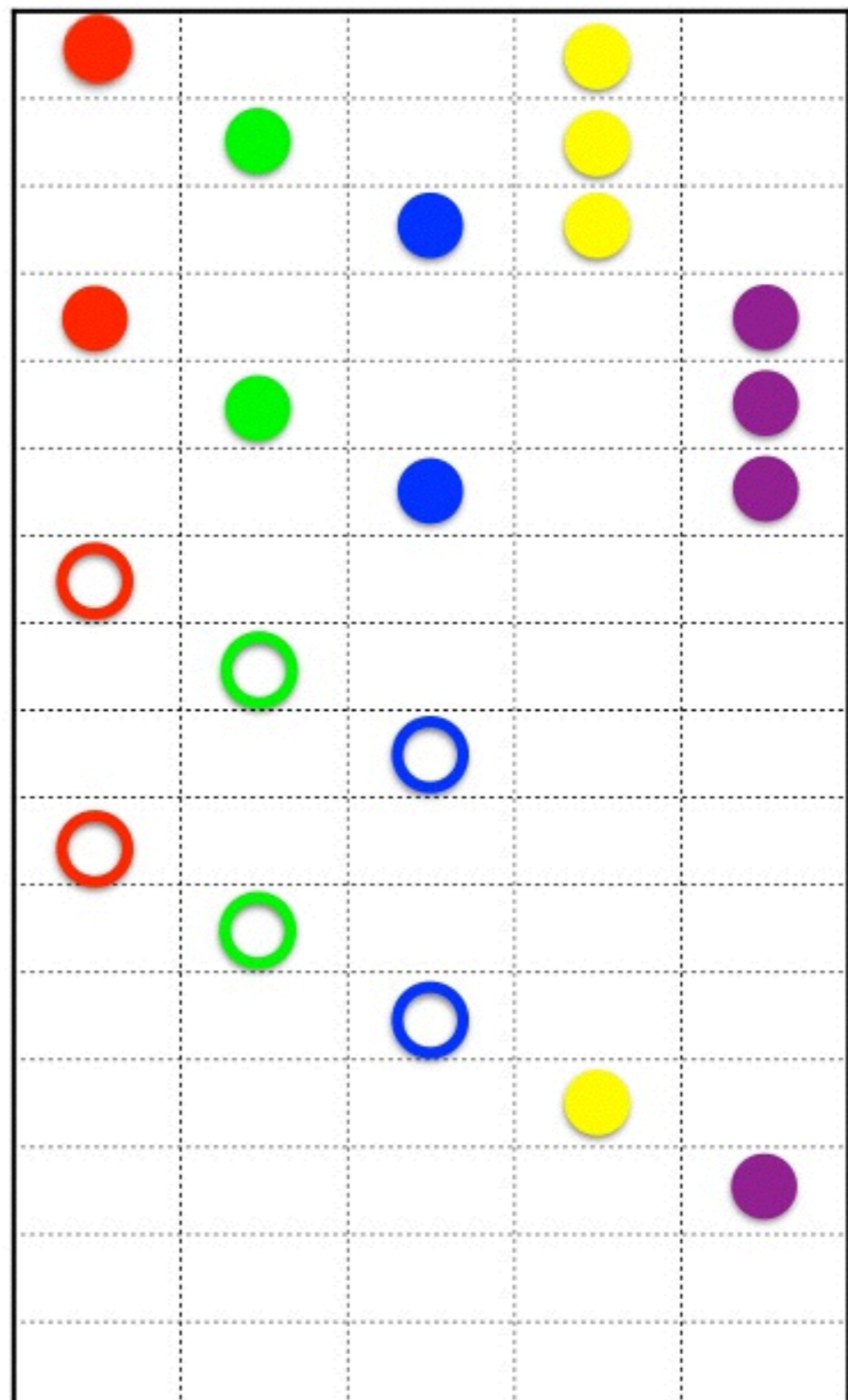
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$$Y = -\frac{1}{3}(\text{Red} + \text{Green} + \text{Blue}) + \frac{1}{2}(\text{Yellow} + \text{Purple})$$



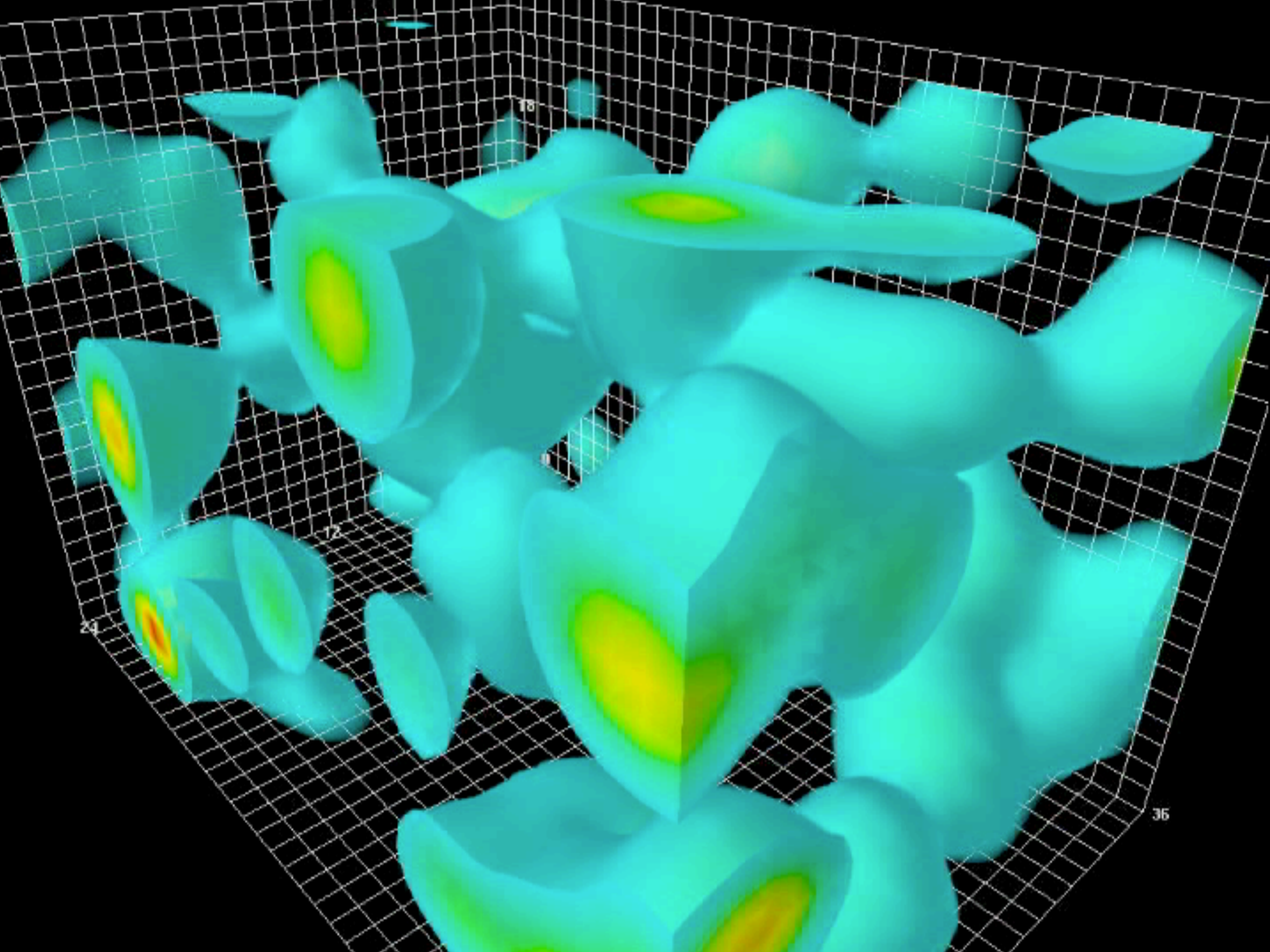
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One Entity, One Force (?)

Unification 2: Force and Substance



coupling strength
↓

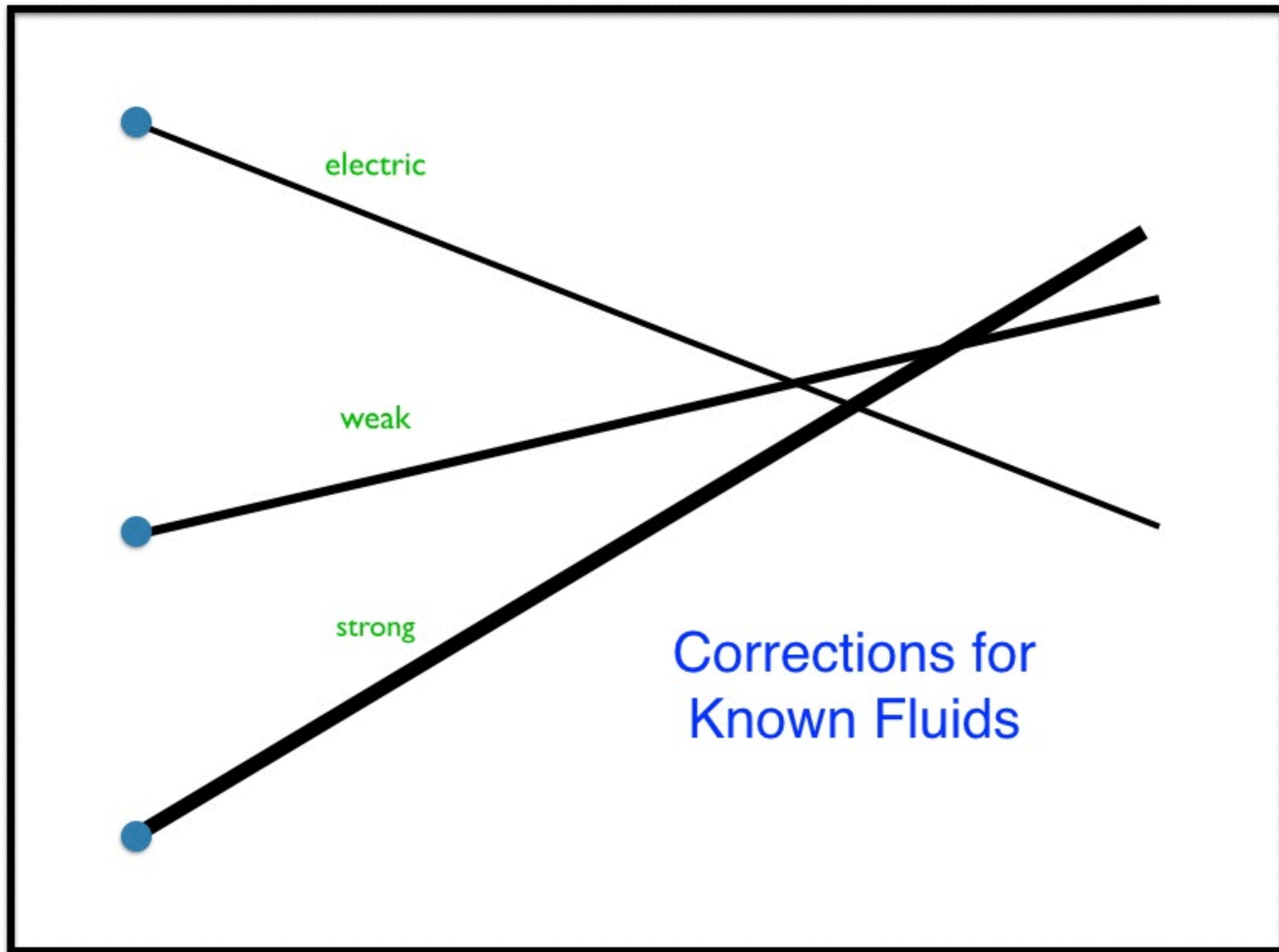
electric

weak

strong

Corrections for
Known Fluids

large energy, short distance →





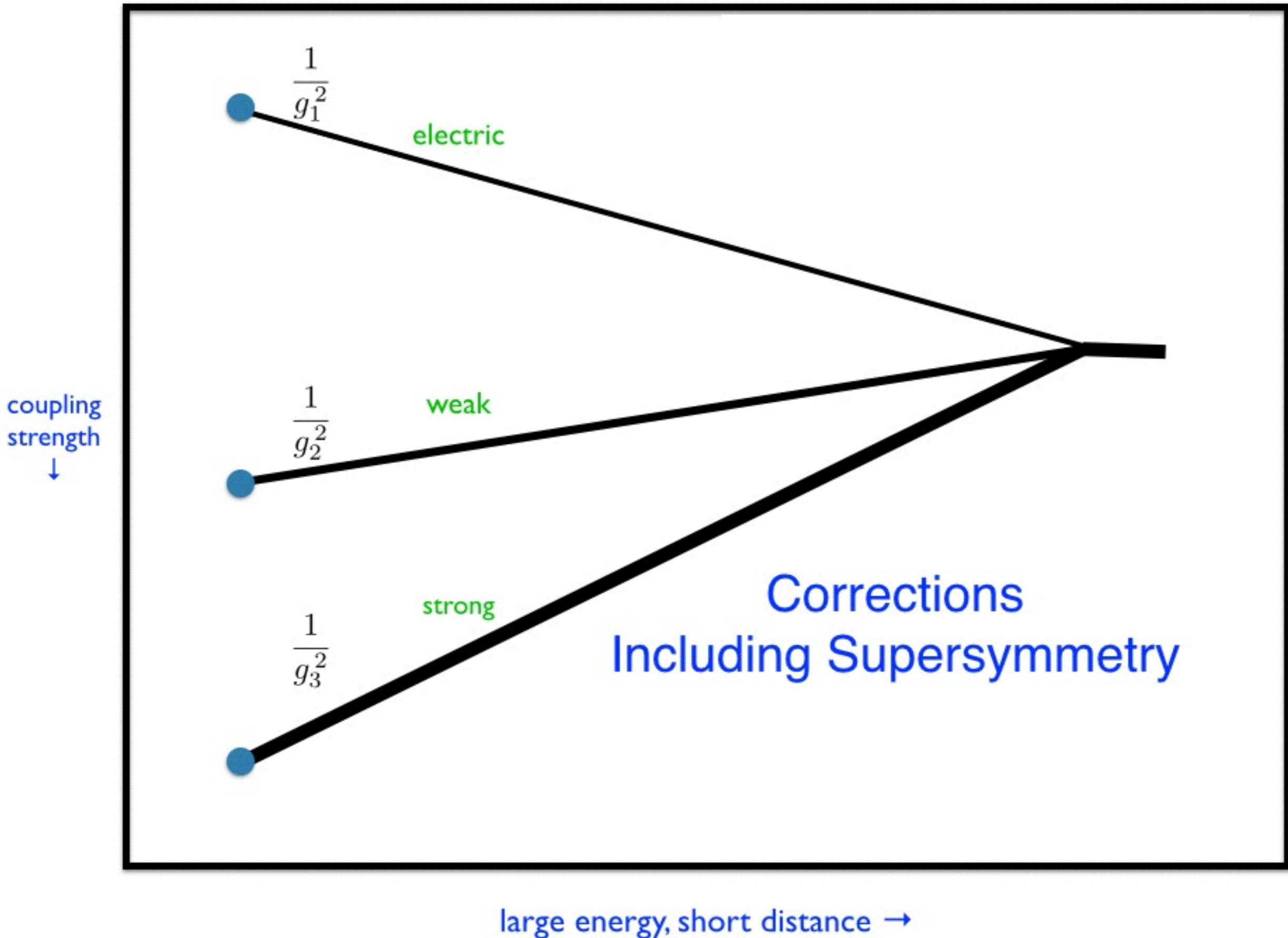
太極淺魚乃中華

文化之精髓今以之為考

寫照 甲午冬初何北

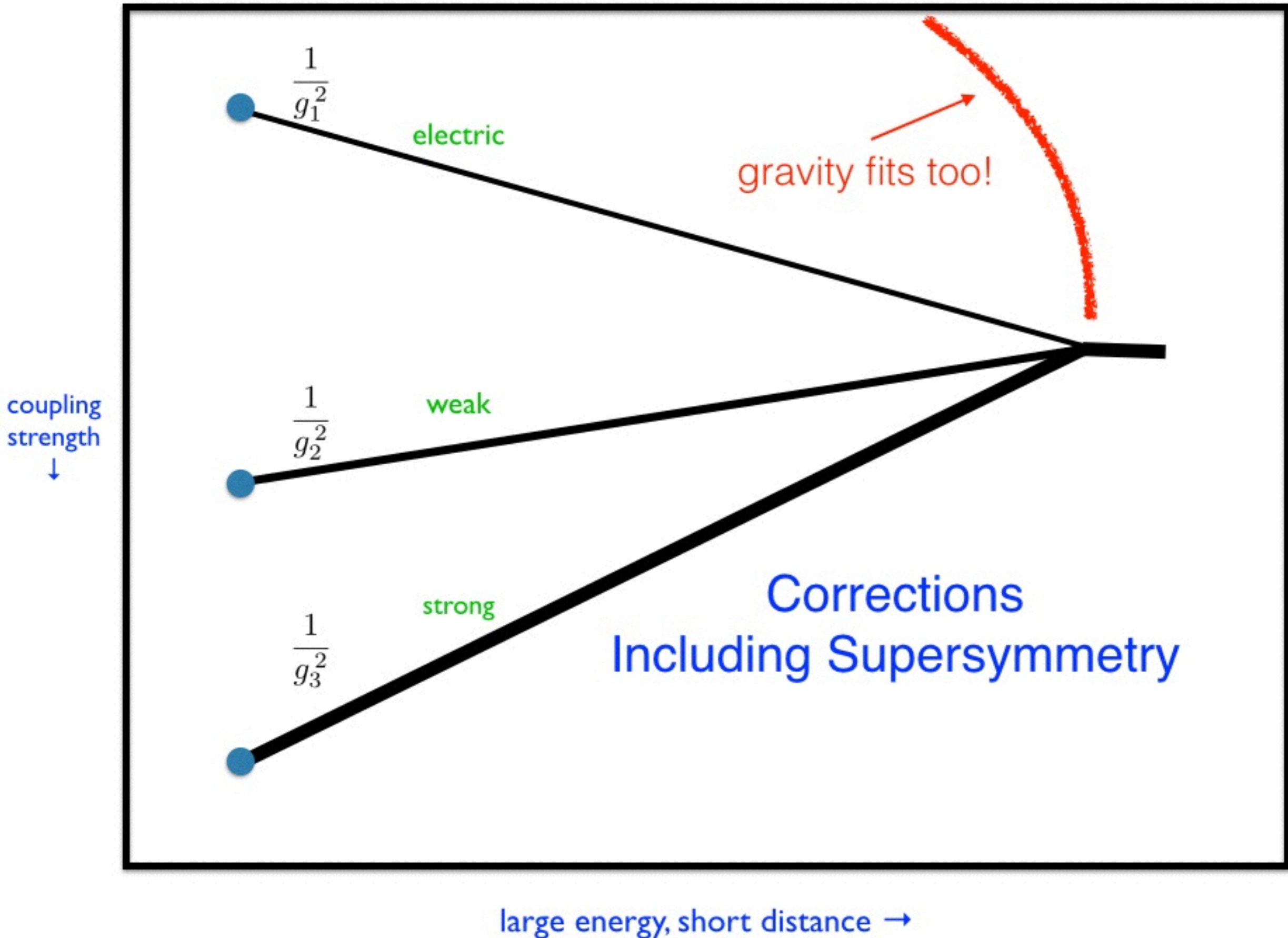


Why I ♥ SUSY



Unification 3: Space- Time and Matter

Why I ♥ SUSY



quantum gravity - more material, please!

gravity waves: a new window

or several

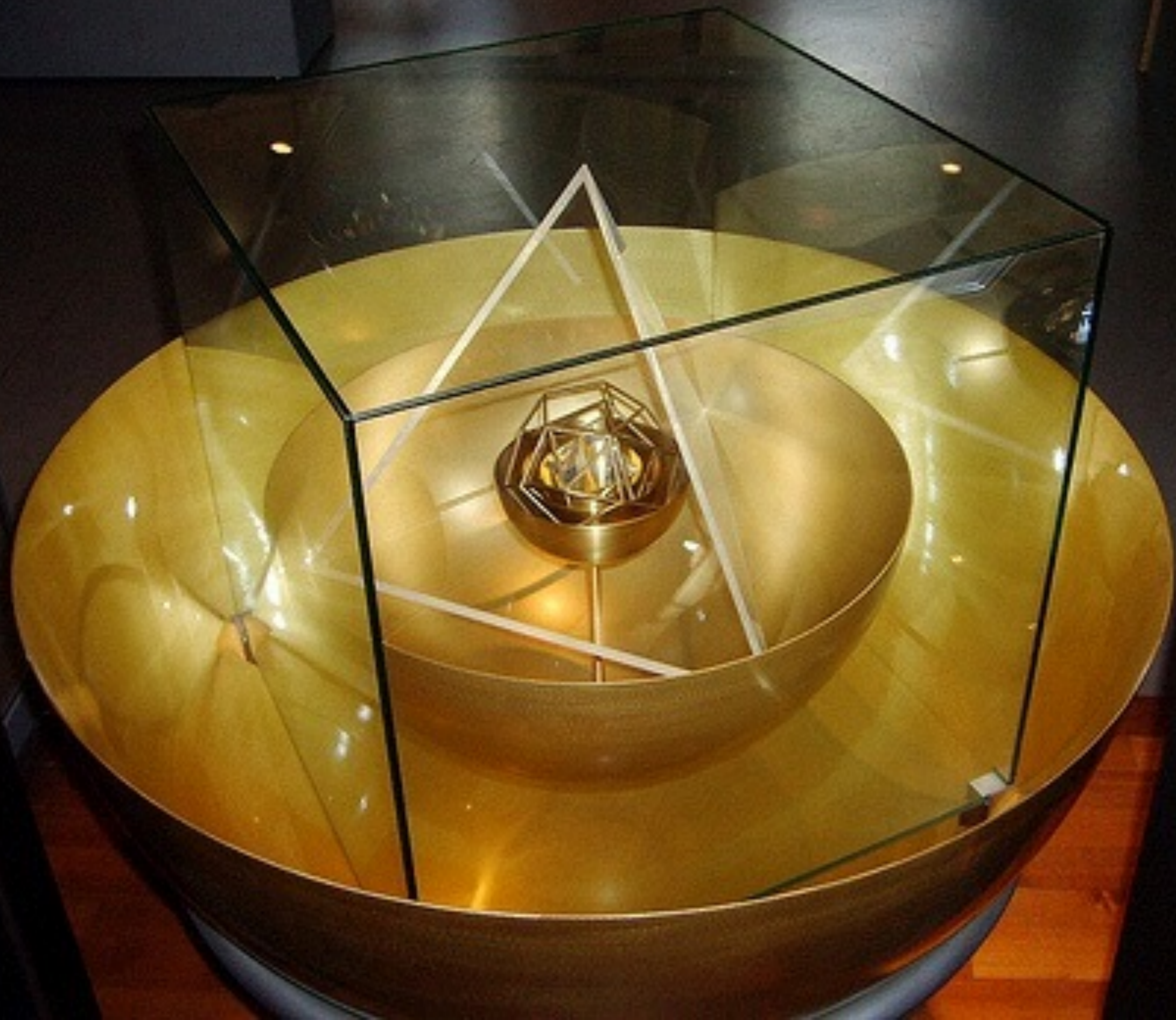
beyond real numbers

Grassmann numbers

infinitesimals?

Unification 4: Evolution and Origin

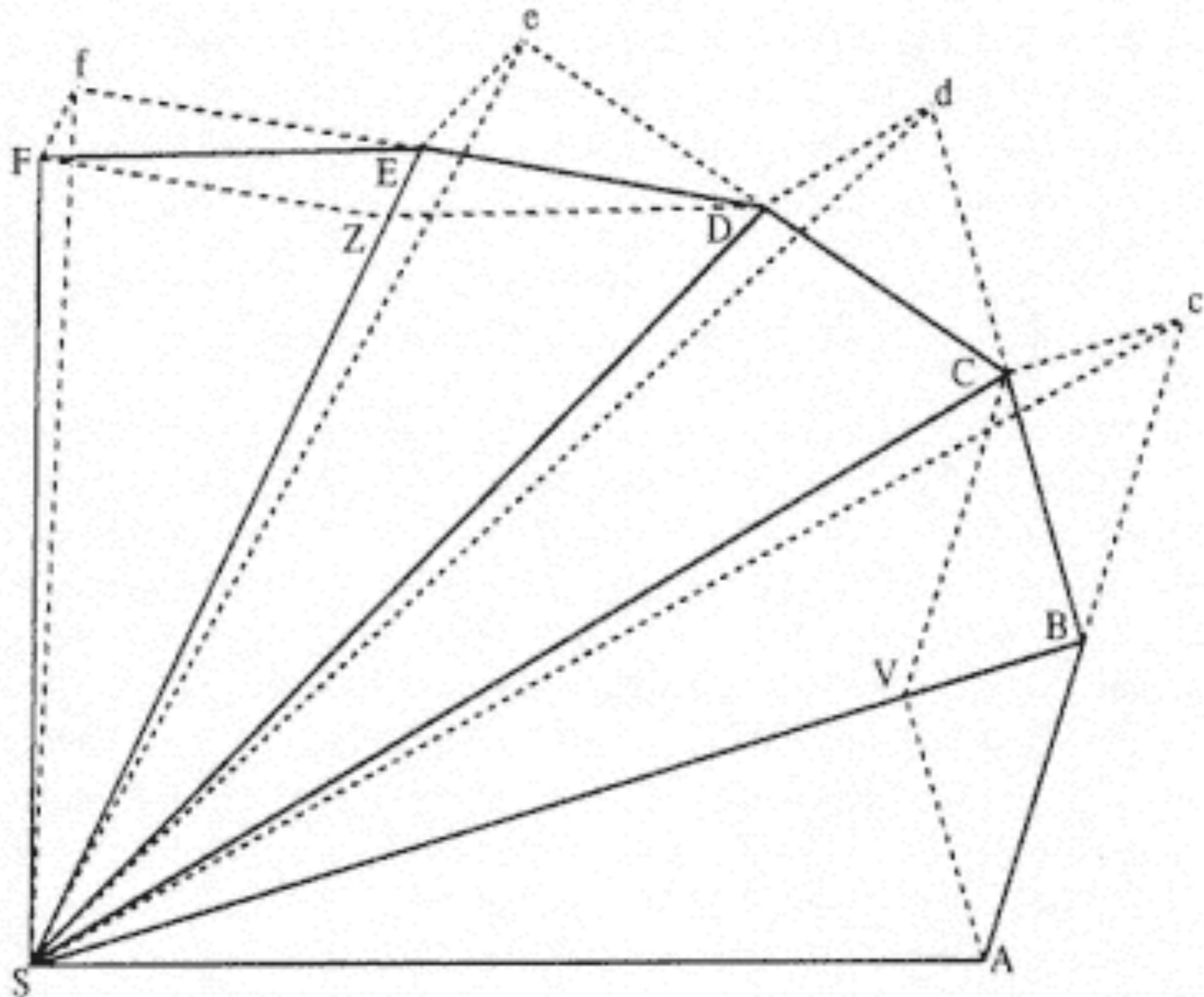
Kepler (Parmenides) versus Newton (Heraclitus)



Kepler's Darstellung des Kepler's Description of the

Kepler's heliocentric model of the solar system, which was first published in 1609 in his work *De Revolutionibus Astronomiacum*. The model shows the Sun at the center, with the planets orbiting in elliptical paths. The orbits are shown as white lines on a golden background. The Sun is represented by a golden sphere with a faceted top. The planets are represented by smaller golden spheres. The model is a physical representation of Kepler's laws of planetary motion.

According to the model, the planets were determined by the Sun's force, the distance between the Sun and the planets, and the planets' own force. The model was a significant contribution to the development of modern astronomy.



The strategy of separating our description of the world into two components, dynamical equations and initial conditions, has dominated physics since Newton's time, and worked extremely well.

But in relativity, we merge space + time →
space-time, and the separation seems
unnatural.

The world simply is.

In my consciousness

Tethered to my brain and body

Fleeting images come to life -

Of the world, samples only.

The world simply is,

It does not happen.

Unification 5: Quantum and Symmetry

$$[x_j, p_k] = i\hbar \delta_{jk}$$

$$[T^a, T^b] = if_c^{ab} T^c$$

Unification 6: Information and Action

In the current formulation of physics, the foundational concept is *action*.

Action is what appears in path integrals, as the measure.

Action is what is *invariant* under fundamental symmetry transformations.

Action is implicit in Hamiltonian mechanics, which quantum theory relies on.

(Physics progresses by integration ...)

Given Planck's constant as a unit, action becomes a purely numerical (dimensionless) quantity. The world-action is therefore a specific *numerical* quantity that governs the basic operation of the physical world.

One would like for such a basic quantity to have profound independent meaning.

Information is another dimensionless quantity that plays a large and increasing role in our description of the world.

Can one unify action with information?

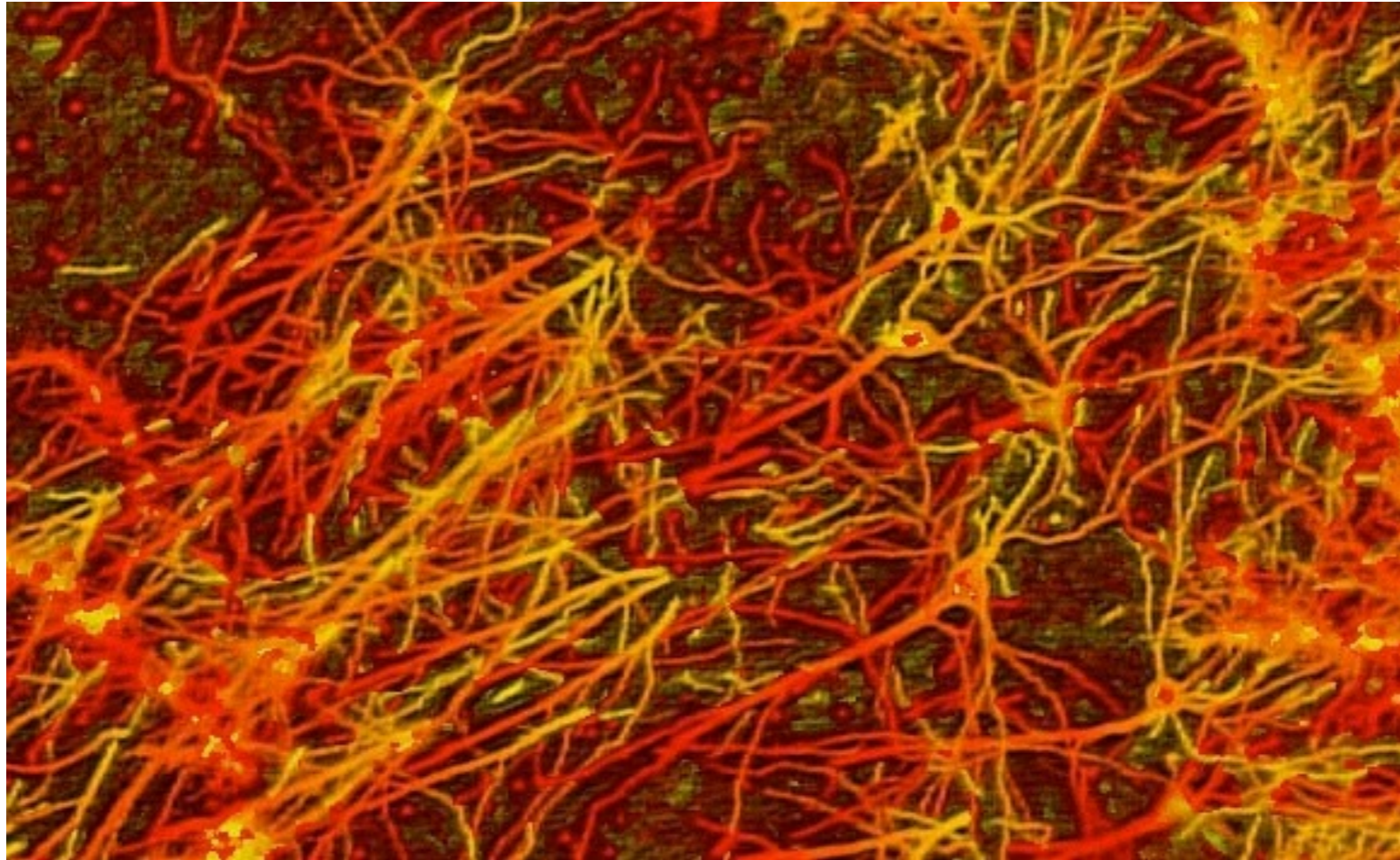
Nowadays many treatments of the microphysical origin of entropy, and of the foundations of statistical mechanics in general, begin with discussions of information and ignorance.

A strong formal connection between entropy and action arises through the Euclidean, imaginary-time path integral formulation of partition functions.

It would be wonderful to motivate that imaginary-time path integral directly and insightfully, rather than indirectly through the apparatus of energy eigenvalues, Boltzmann factors, and so forth.

Unification 7: Mind and Matter

A complex system, with striking emergent properties:









Baryon decay will be observed, and lead to a rich phenomenology.

Supersymmetry will be observed, and lead to a rich phenomenology.

The nature of the dark matter will be revealed. axions

Tangible consequences of quantum gravity will be identified, and observed.

New kinds of numbers, including some form of infinitesimals, will be used to describe space and time.

Gravity waves will be observed, and become a powerful tool in astrophysics and cosmology.

The fundamental laws will no longer separate into initial conditions and dynamics.

Information will appear as a primary ingredient of physical law.

Quantum mechanics be formulated as a fundamental symmetry principle, and integrated together with other such principles.

Biological memory, cognitive processing, and emotion will be understood at the molecular level, comparable to our understanding of heredity and metabolism today.

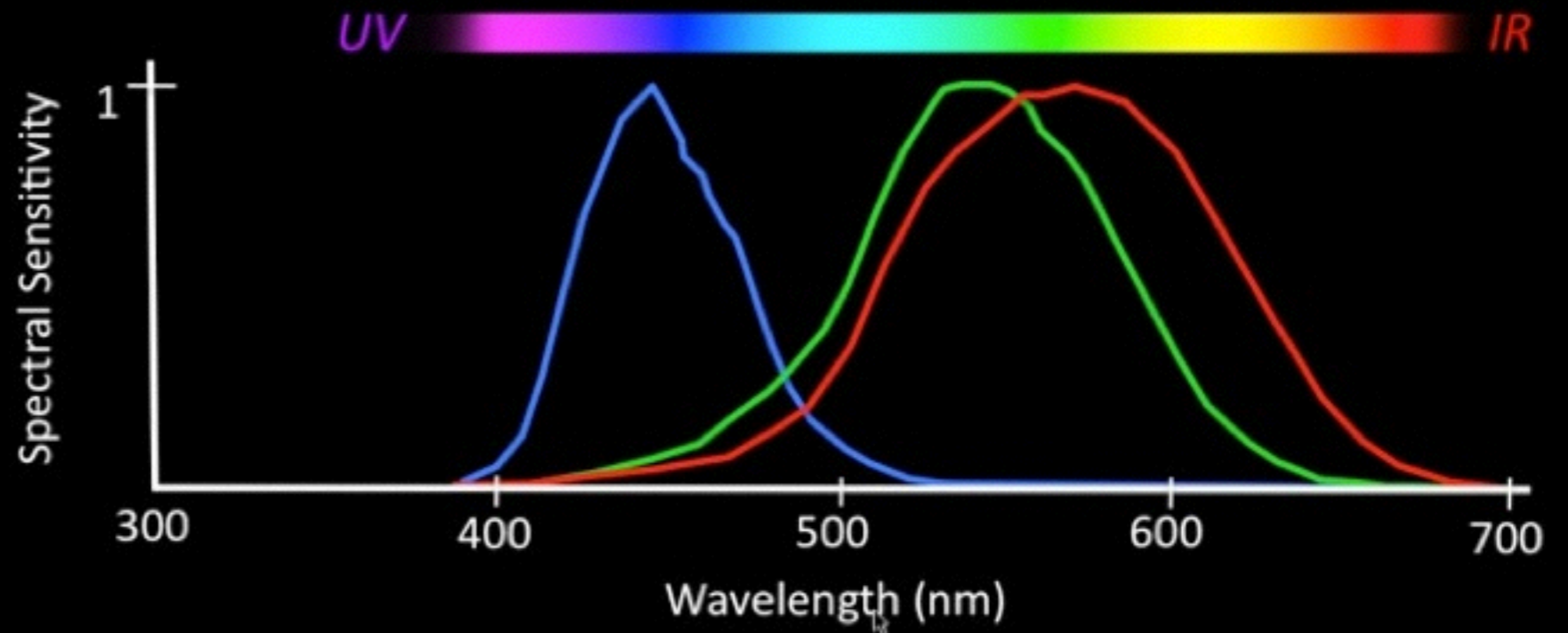
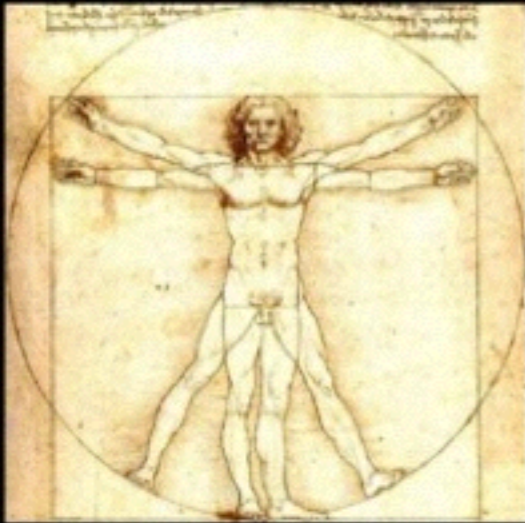
Technologies

“Indistinguishable from Magic”

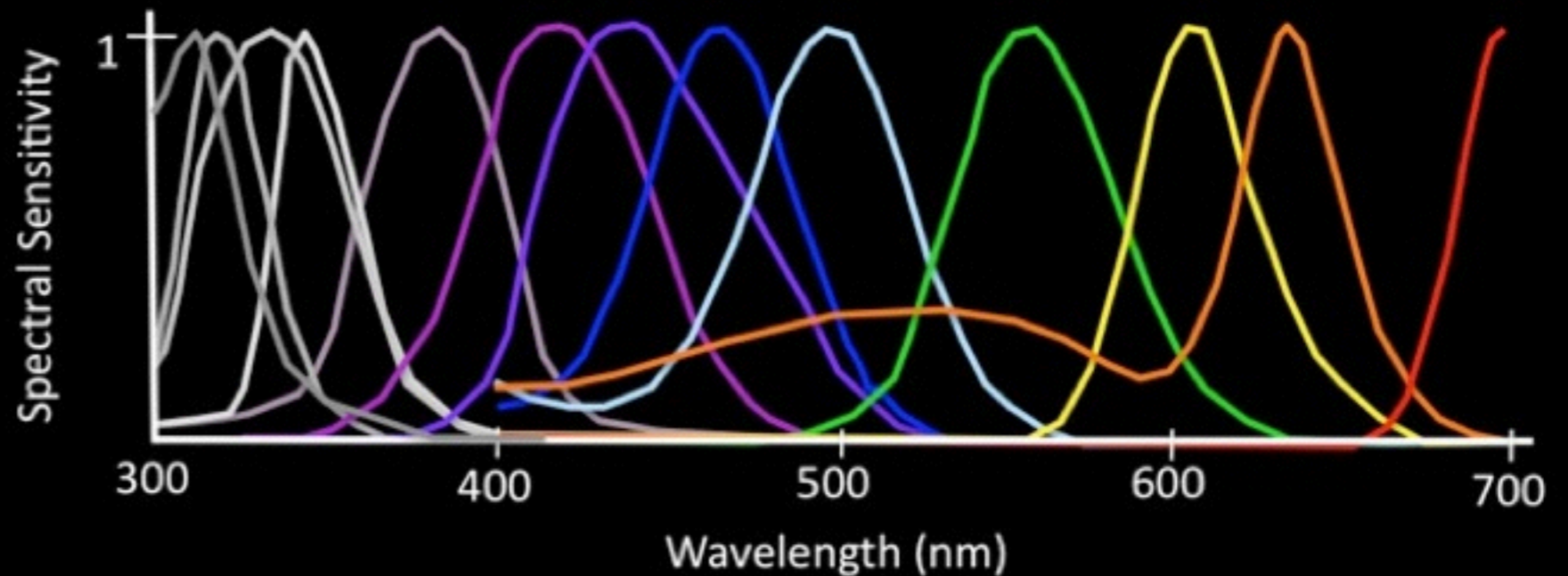
Enhanced Sensoria

Mantis Shrimp: Extraordinary Eyes

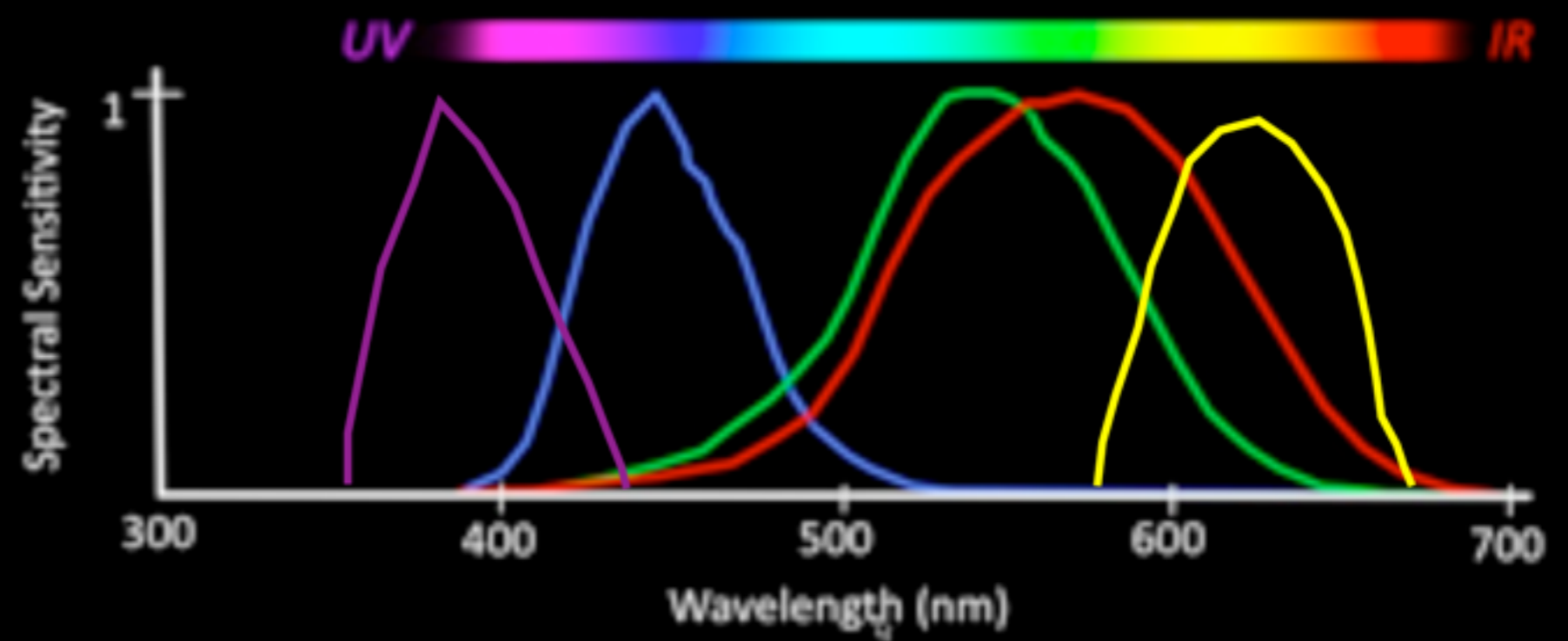
Homo sapiens

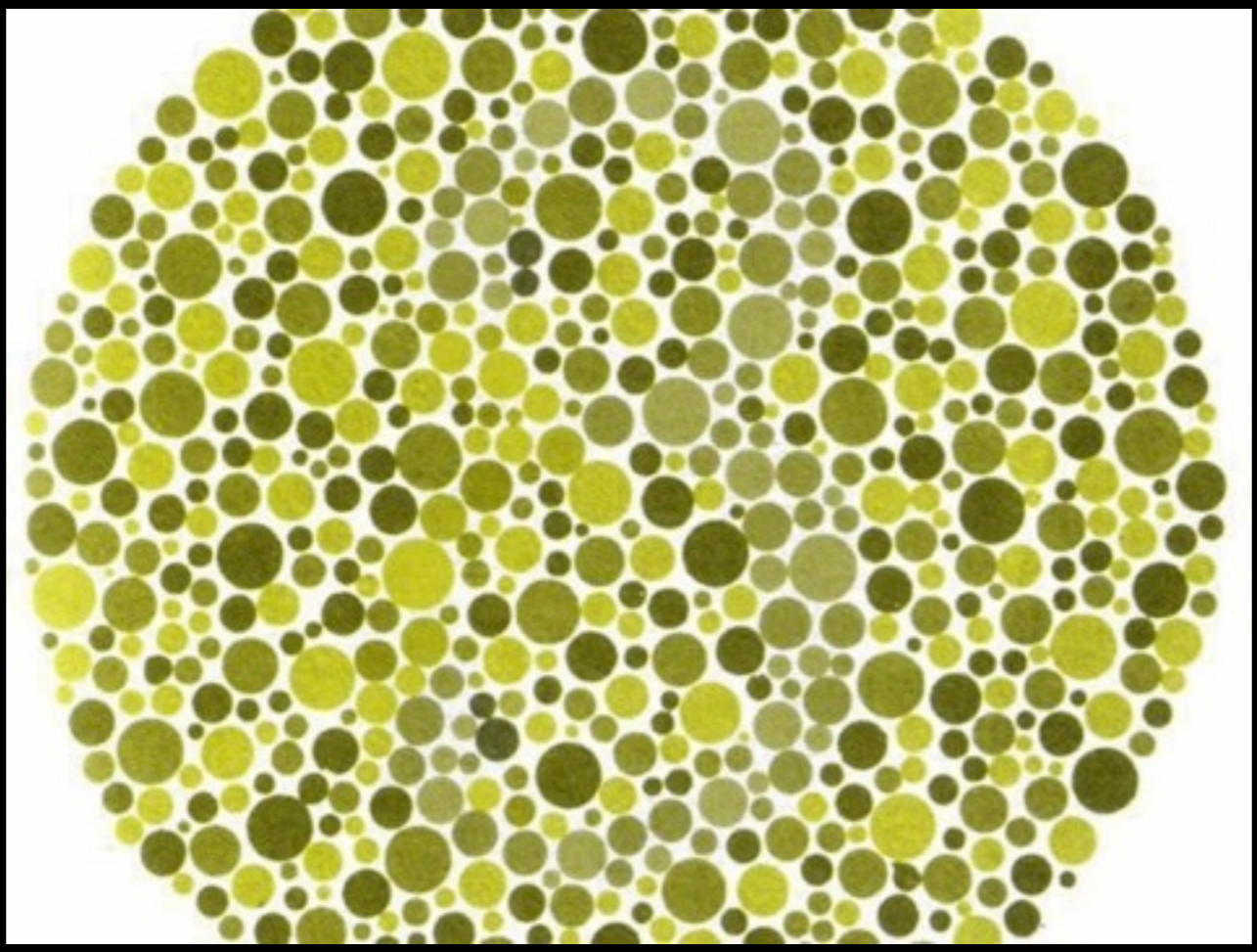
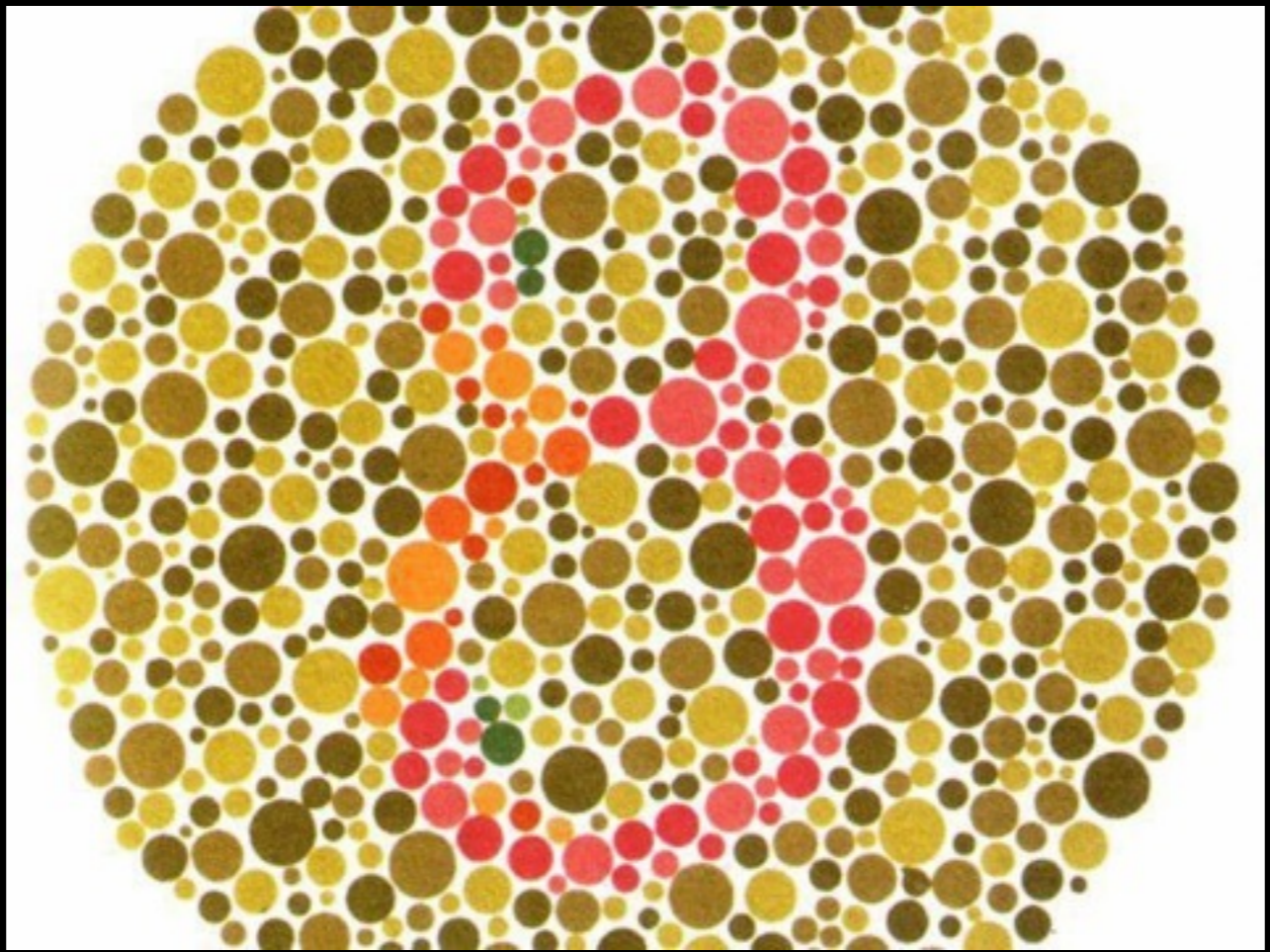


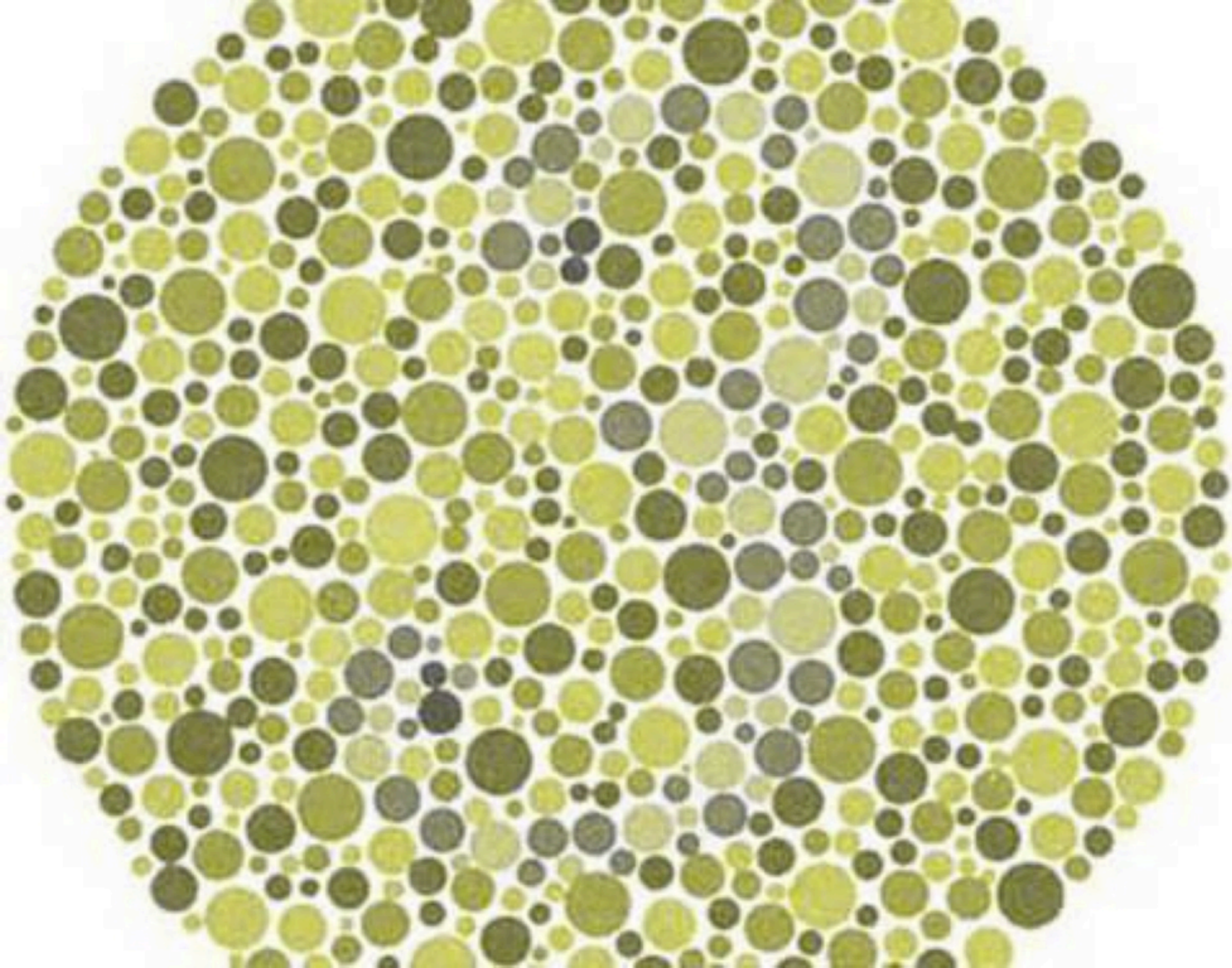
Neogonodactylus oestedii



Homo sapiens ++

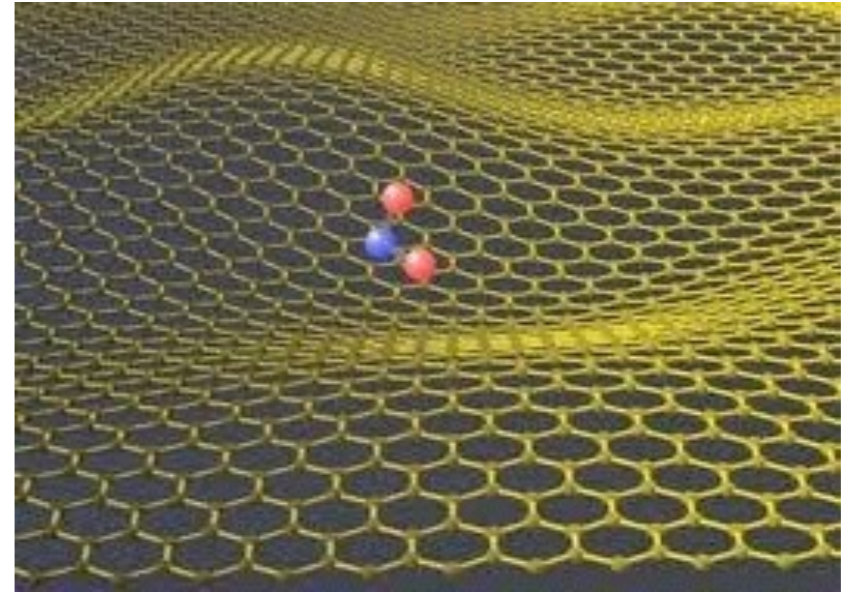
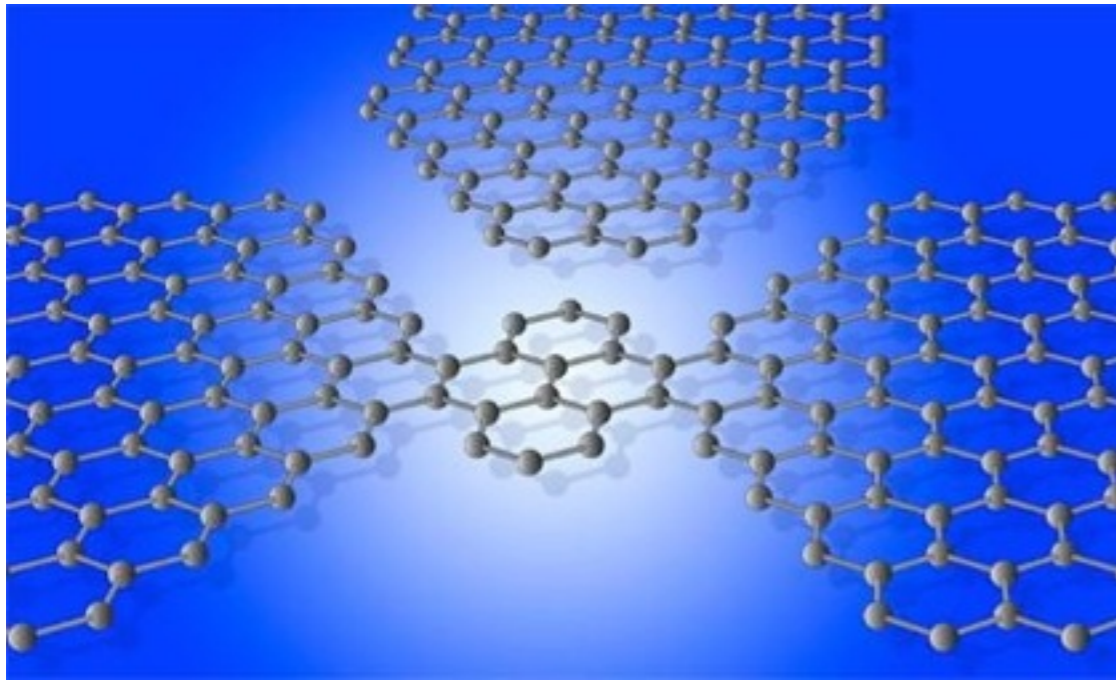






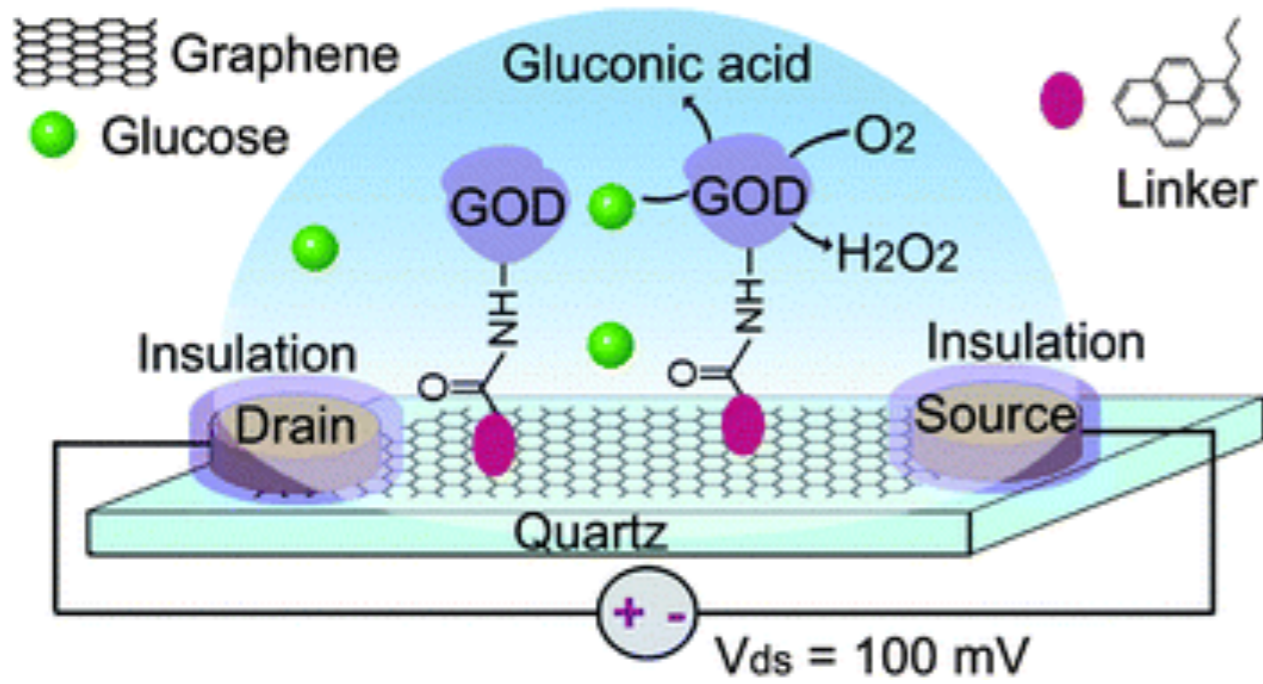
Making Things (Micro)

Molecular design: replacing chemistry labs with
computer farms

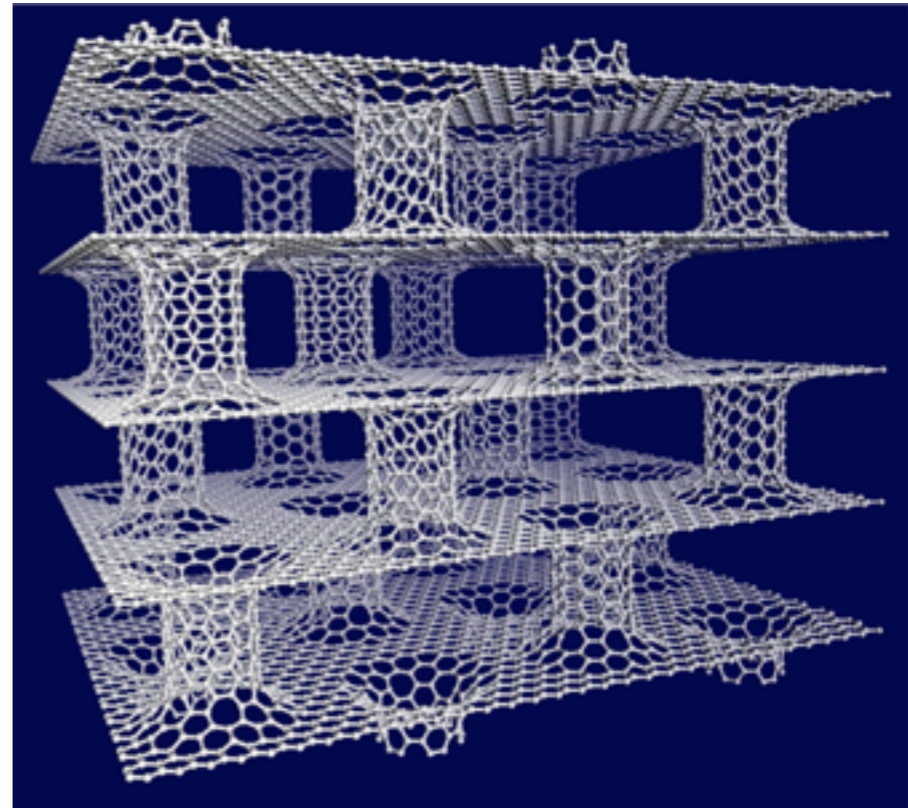


transistor

'nose' membrane



GOD detector



architecture

Manipulating nuclei, like atoms

Lise Meitner



Deutsche Bundespost

Berlin

130

Making Things (Meso)

3D, fault-tolerant, self-repairing computers

Self-assembling and self-replicating “bio-machines”

Making Things (Macro)

Whole-planet brains (Stapledon)

Whole-sun energy gathering (Dyson) [250]

(We'd better start working on this soon!)

Changing Minds

Distributed intelligence

Spatially expanding sensorium

With understanding and growing power, perhaps
wisdom:

emergent humility

complementarity

... to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

— I. Newton

*Do I contradict myself?
Very well, I contradict myself.*

*The world is large –
It contains multitudes.*

*If you're not bedazzled
You're not really looking.*

Quantum Minds

Quantum notions of history, inference and causality

Quantum AI, with qualitatively new abilities to:

manipulate time

embrace contradictions (complementarity)

understand quantum mechanics

