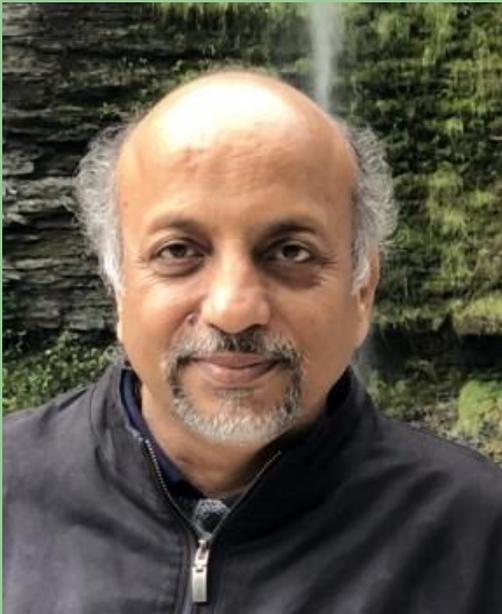


Science Education: Skills and Innovation

A Theoretician's Perspective on Convergence of Sciences and Science Education reforms for promoting innovation



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Science is for everyone.

“Science is a way of thinking more than a body of knowledge.”

- Carl Sagan

In this discussion, I would use word science in a much broader sense incorporating all branches and disciplines of Science, Technology, Engineering and Mathematics. I am a firm supporter of the idea that these are converging into each other and inseparable in mutual dependence and significance.

Science is for All, for every one, for us homo sapiens and for non-biological intelligent machines like Sophia the social humanoid robot too.

More and more people need to pursue science and master scientific skills (STEM skills).



What is Science?

- Science is the Systematic Study of Nature.
- Nature is set of all objects which are accessible or likely to be accessible in the scientific experiments.
- Scientific Study requires theorizing, testing in experiments, verifying or discarding a theory, proposing new theory and so on moving ahead.

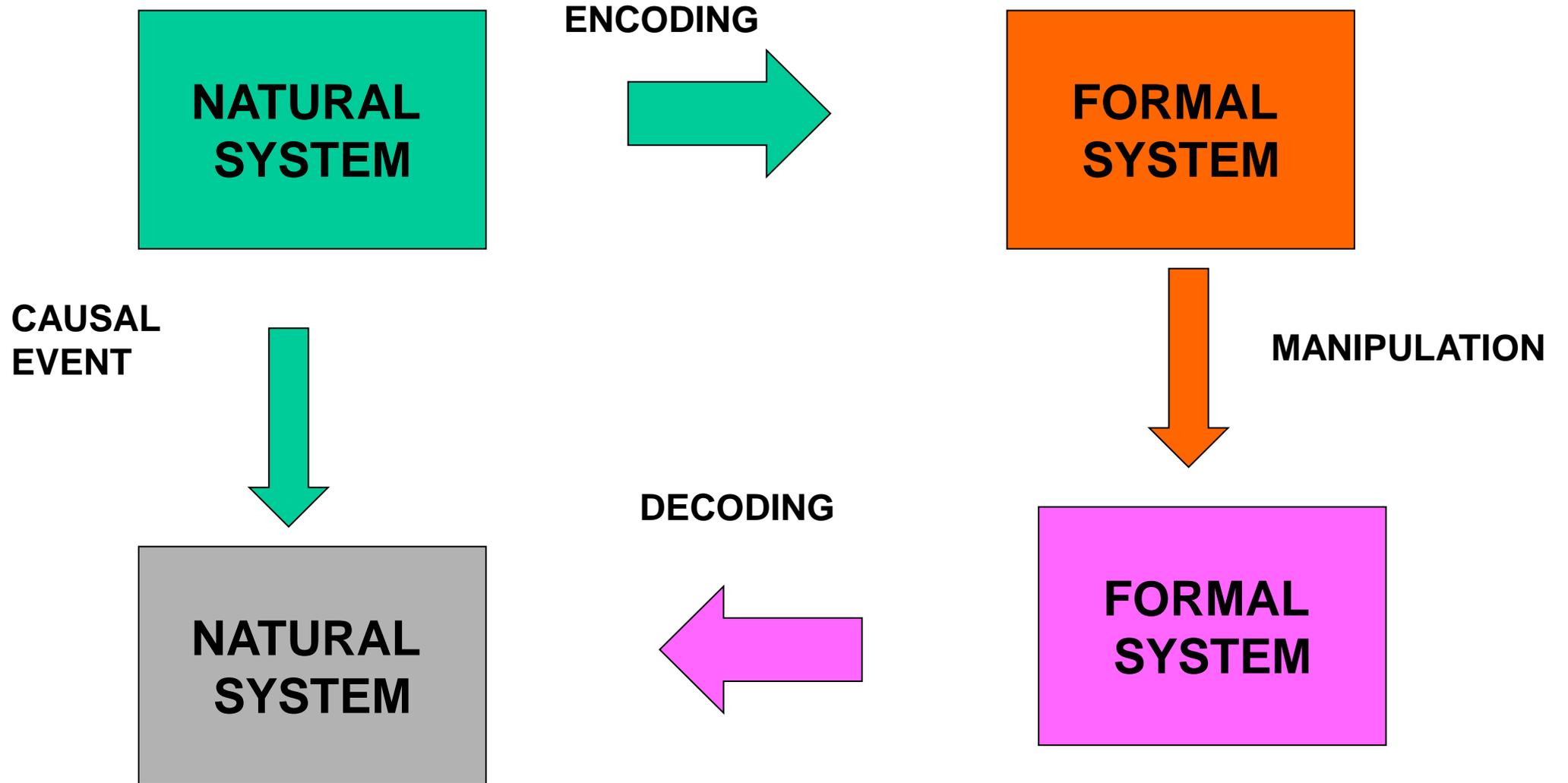


Theoretical Science

- Theoretical Framework consists of conceptual and mathematical structures that shape the way we see the natural system.
- **FACTS, DATA, MODELS, ETC. ONLY HAVE MEANING IN THE CONTEXT.**
- **Semantic Character of a Physical Theory**
 - physics equations have syntax & semantics



THE CLASSICAL THEORETICAL SCIENCE - A SCIENCE OF FRAMING

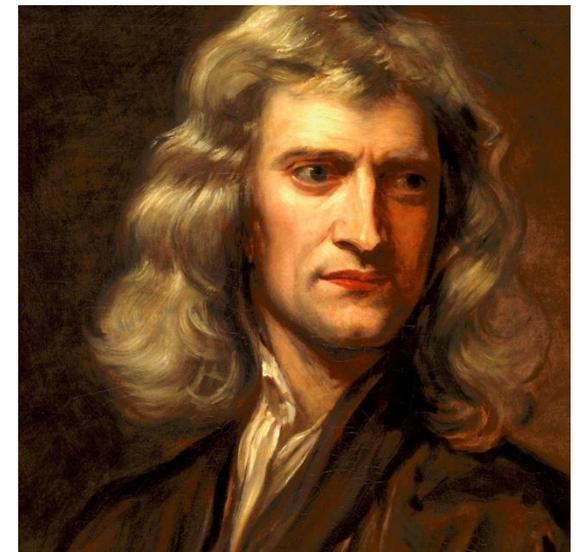
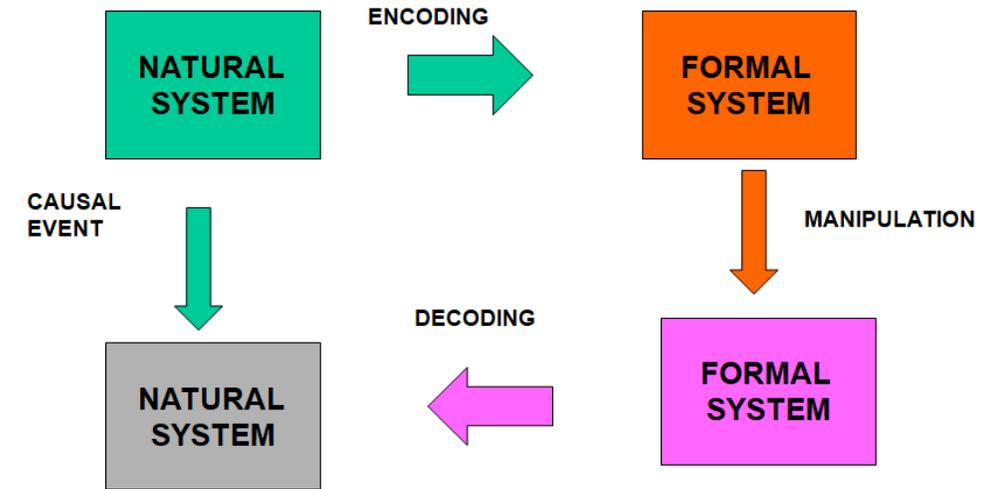




Free Fall and Gravitation

- Free fall of an apple.
- Newtonian Mechanics as Theoretical Framework
- Apple as a Particle encoded to a Location in Space (Galilean).
- Implication of Gravitational Force
- Deriving expression for time of flight
- Performing Experiment and checking the Agreement

Believing in it as a Faith not as a Tentative Truth





What is Science – Moving ahead

Newtonian Theory is not capable of explaining all Gravitational Phenomenon

Effect of Gravitation on Light

General Theory of Relativity

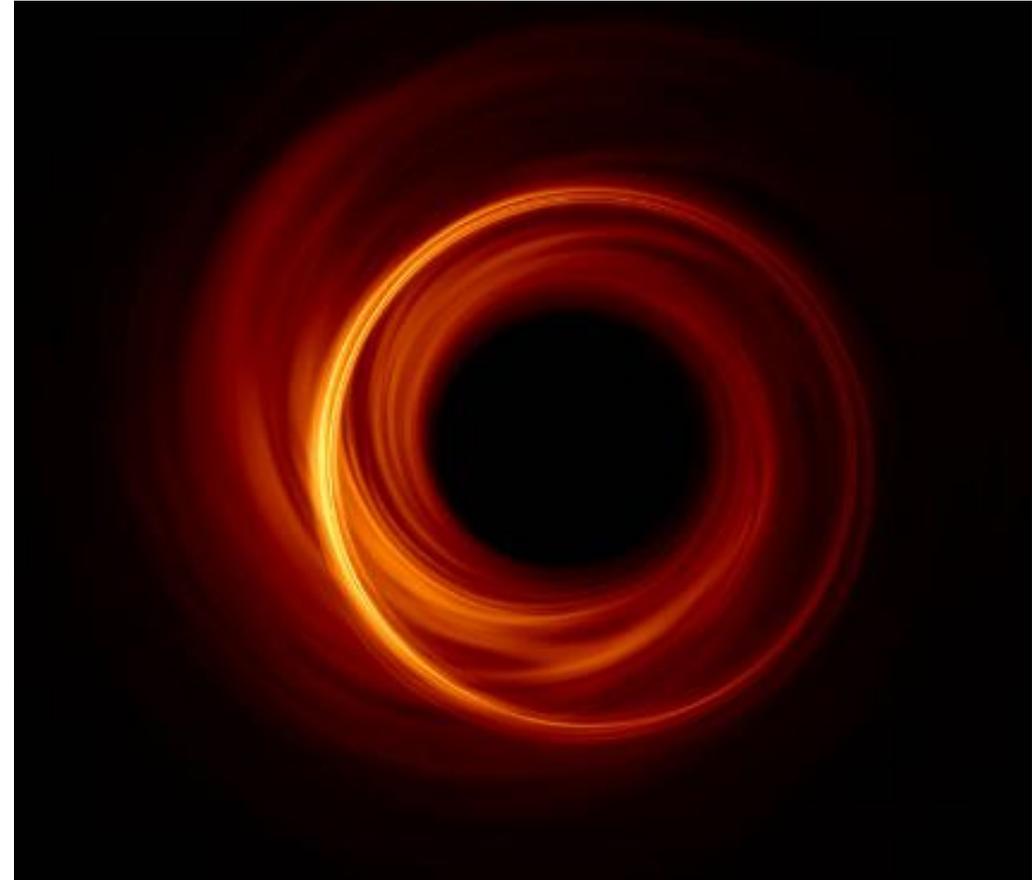
New concept of Space and Time

No Gravitational Force, Curvature of Space-time Causes Fall of an Apple.

Discovery of Electron

Birth of Quantum Mechanics

Quantum Theory of Gravitation





What is Science?

- Science as a **Body of knowledge**.
- Science as a **Process of doing science** : The processes of doing science are the science process skills that scientists use in the process of doing science.
 - Observing, Making a Hypothesis, Testing the Hypothesis, Making an inference or conclusion
 - Observing, Theorizing, Testing, Looking beyond
 - Encourages creativity, Develop Analytical thinking skills, Develops love for a learning, Broadens perspective, Improves Communication Skills
- Science as an Attitude: The third dimension of science focuses on the characteristic **attitudes and dispositions of science**. These include such things as being **curious and imaginative**, as well as being enthusiastic about **asking questions and solving problems**.
- Another desirable scientific attitude is a **respect for the methods and values of science**. These scientific methods and values include seeking to answer questions using some kind of evidence, recognizing the importance of rechecking data, and understanding that scientific knowledge and theories change over time as more information is gathered.
- Science is thus a **Tentative Body of Knowledge**.



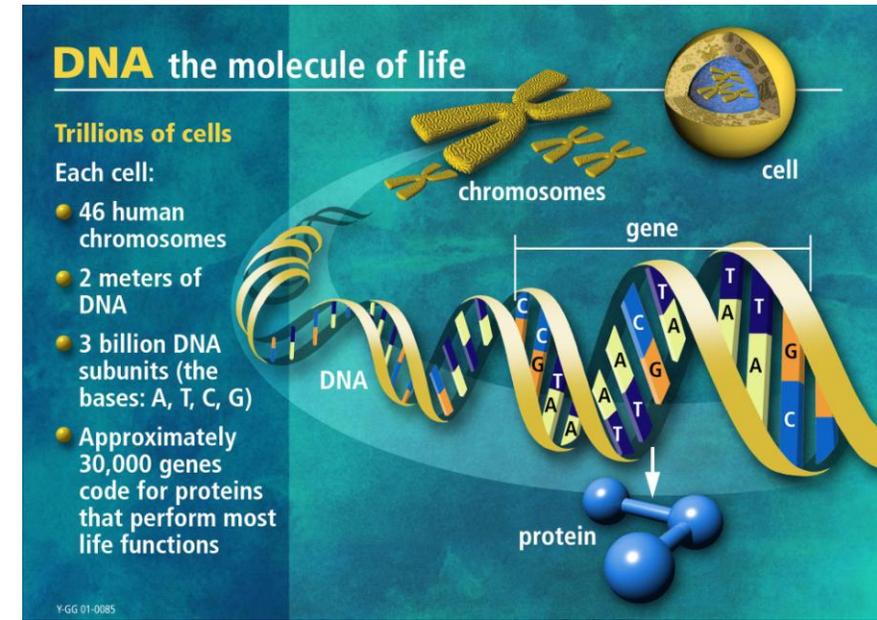
What is Experimental Science?

- Science is the Systematic Study of Nature.
- Nature is set of all objects which are accessible or likely to be accessible in the scientific experiments.
- Scientific Study requires theorizing, testing in experiments, verifying or discarding a theory, proposing new theory and so on moving ahead.
- Scientific experiments involve observations (sensory and beyond senses through scientific techniques and tools), measurement of quantities or identification of patterns and relationships, testing hypothesis, understanding and then expanding parameter space, Improving precision and repeating experiment or designing better experiments.
- A scientist is also a technician, a person who is skilled in the use of particular techniques and procedures to solve practical problems, often in ways that require considerable ingenuity and creativity. Technicians typically work with complex instruments and equipment, and require specialized training, as well as considerable practical experience, in order to do their job effectively”.
- How do we produce more students with Strong Preparation in STEM along with habits of mind vital for a 21st Century Workforce?



Power of Experimental Science

- X-Ray Diffraction (Physics) to Structure of Building block of Life –DNA
- Understanding of DNA to Genomic Database
- Bioinformatics and Gene Editing
- *“In the future, a new generation of artists will be writing genomes as fluently as Blake and Byron wrote verses.” - Freeman Dyson*
- Homo sapiens to Homo Evolutis



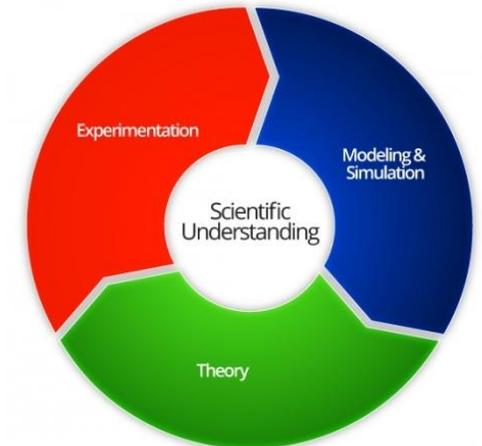
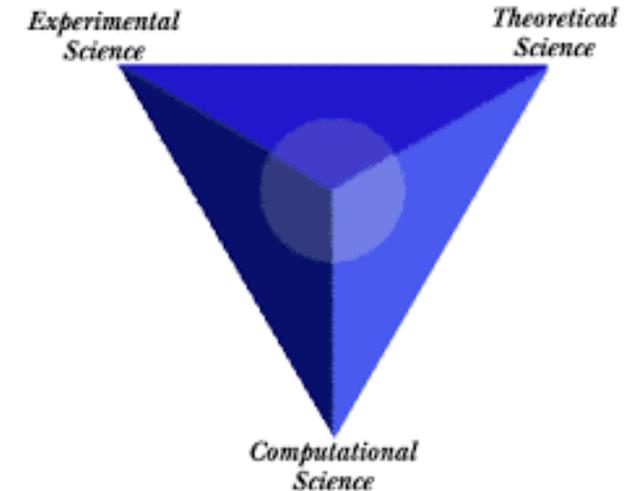
The Human Cognome Project seeks to reverse engineer the human brain, paralleling in many ways the Human Genome Project and its success in deciphering the human genome. The HCP is a multidisciplinary undertaking, relevant to, among others: biology, neuroscience, psychology, cognitive science, artificial intelligence and philosophy of mind.



Science –Triangle (Entry of Computational Science)

- Experimental Science : Observing, Quantifying, Interpreting, Drawing inferences and conclusions, Checking with Theory, Communicating, Looking for Better Precision in Experiments and Designing new experiments
- Theoretical Science – Classifying, Constructing Theoretical Framework Encoding, Studying Implications, Decoding, Predicting, and looking for verifying/ nullifying the theory, Communicating.
- Computational Science: Applying computational techniques in theoretical and experimental study, Simulation and Modeling, Big Data Analytics, Algorithm Development, Virtual Reality, Augmented Reality, Applications of AI and Machine Learning, Development of Quantum Algorithms and Quantum Computing
- Modeling and simulation should never be viewed as a substitute for real-world experimentation.

Science: the study of how nature behaves





Technology Driven Changes

- Information Communication Technology Revolution
- Globalization, Emergence of BRICS
- Technology for everyone -Anyone, Anywhere, Anytime, Any device
- Flat world, HCI
- Understanding science has become far more important as “technological determinism “ is prevailing in current time which means that change as it unfold is determined by advances in Science and Technology more than change happening because of change ushered in by other philosophies or by aspiration of society.



Converging Technologies

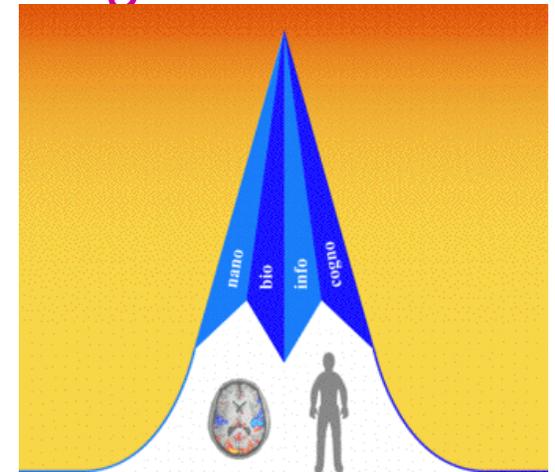
- “There is Plenty of Room at Bottom” – R. P. Feynman
- *Synergistic combination of four major converging technologies each of which are currently progressing at a rapid rate:*

(a) nanotechnology;

(b) biotechnology and biomedicine;

(c) information & comm. technology;

(d) cognitive and neuroscience.



NBIC is an opportunity to *energize the interdisciplinary connections between biology, chemistry, engineering, materials, mathematics, physics, and computer science* in education.

It will give birth to new fields that are only envisioned at this moment...



Innovate for resolving socio-economic problems

From Poverty to Abundance

Unsafe water	Pure water
Expensive energy	Cheap energy
Ignorance & isolation	Ubiquitous information
Disease	Healthcare available
Material deprivation	Material abundance
Pollution	Clean environment
Under employment	Experience economy

Access Strategies

Decentralize technology

Adapt designs

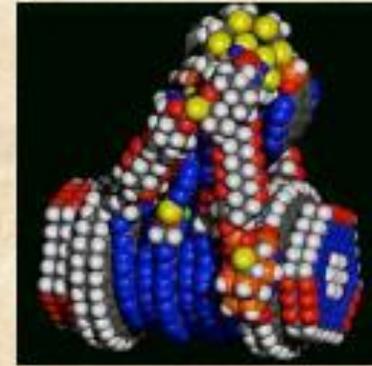
Open access

Share knowledge

Verify safety

Recycle resources

Facilitate transitions



Science can help us in coping cultural pessimism *the belief that our society is getting worse and worse, and any day now it'll collapse*



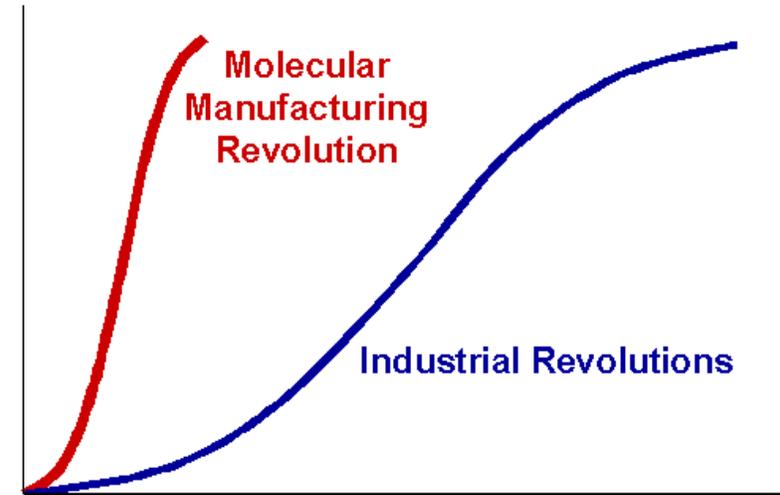
Science for Overcoming Human Shortcomings

- In perception we are easily distracted.
- Our memories are notoriously selective and defective.
- Social influences produce groupthink.
- Our capacity for conflict and violence is enormous.
- Our thinking categories are often skewed and our heuristic judgement about risks is distorted.
- We make decisions from simplistic models and think we are rational.
- We can learn only so fast.
- Emotions cloud our judgments.
- We have often let short-term gain outweigh longer term benefits for society.
- Our individual disciplines have been quite systematic in discovering these limitations, but not comprehensively focused on overcoming or ameliorating them.



The Developmental Spiral

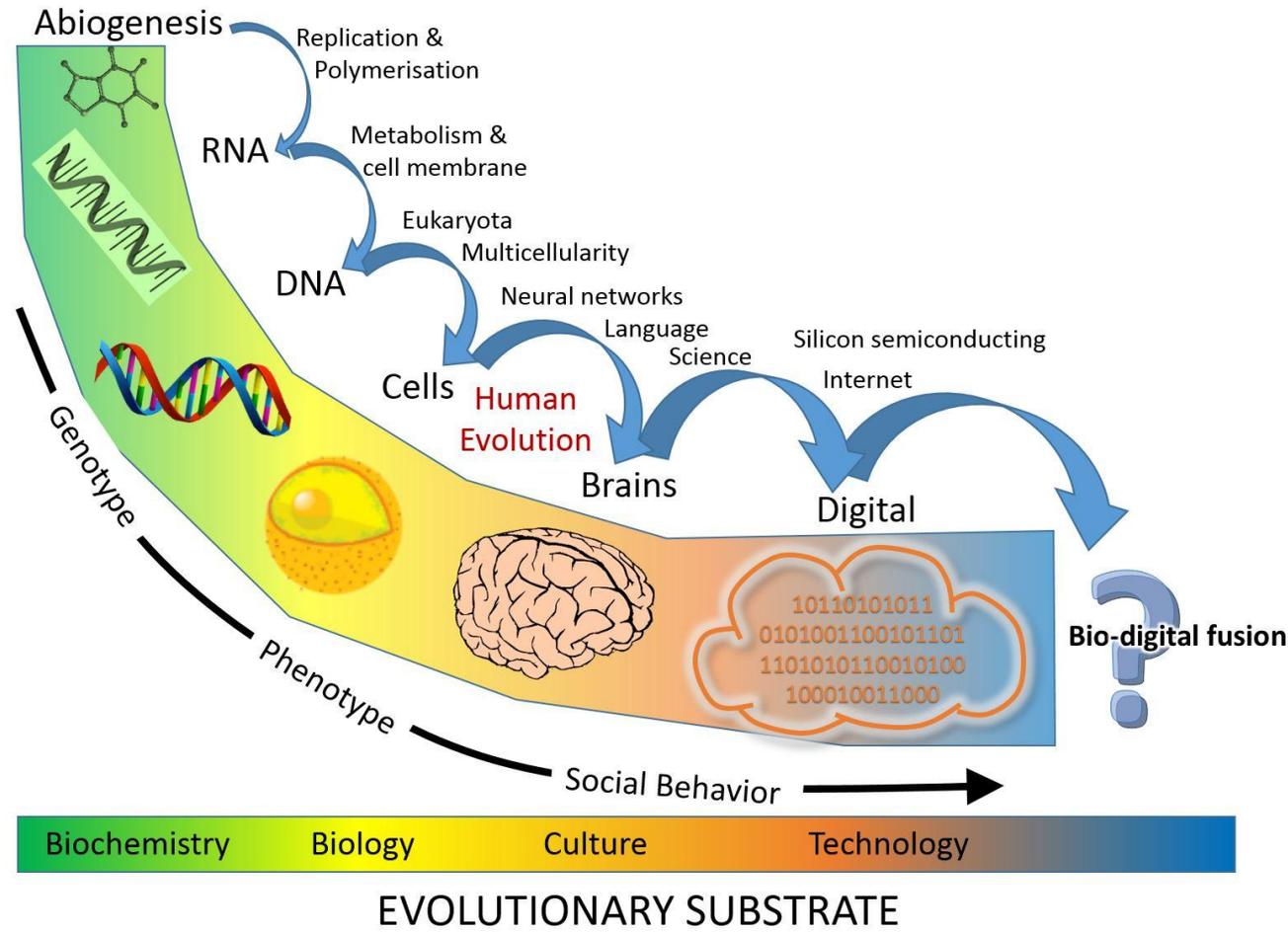
- *Homo Habilis* Age 2,000,000 yrs ago
- *Homo Sapiens* Age 100,000 yrs
- Tribal/Cro-Magnon Age 40,000 yrs
- Agricultural Age 7,000 yrs
- Empires Age 2,500 yrs
- **Scientific Age 380 yrs (1500-1770)**
- **Industrial Age 180 yrs (1770-1950)**
- **Information Age 70 yrs (1950-2025)**
- **Symbiotic Age 30 yrs (2025-2050)**
- **Autonomy Age 10 yrs (2050-2060)**
- **Tech Singularity ≈ 2060**



Singularity is a point in time where there is no turning back from an inevitable human-machine civilization where our experiences shift from real reality to virtual reality and where our intelligence becomes nonbiological and trillions of times more powerful.



the Posthuman



What is a *posthuman*?
 How different does someone have to be before they are post-human?

based on: Gillings, M. R., Hilbert, M., & Kemp, D. J. (2016). Information in the Biosphere: Biological and Digital Worlds. *Trends in Ecology & Evolution*, 31(3), 180–189. <http://escholarship.org/uc/item/38f4b791>



What needs to be done in schools/ colleges?

- Broad and deep curriculum be designed for all students;
- A teaching staff with advanced content knowledge;
- A positive school culture which encourages inquiry centric learning with research and opportunities to interact with professionals in order to develop skills, and gain confidence for innovation;
- Deliberate fostering of learning experiences using technologies
- Emphasize usefulness of science literacy in popular non-STEM careers
- Life Long Learning initiatives keeping people in touch with science
- A mission-focused administrative structure with a flattened hierarchy that invited collaboration with and among teachers and students;



Challenges faced by Persons with Disabilities

- All subject areas have their own 'culture' and set of academic expectations which students must grapple with, and disabled students are no exception.
- It is probably true to say that the majority of staff in mainstream schools and universities have not had many students with disabilities attending their courses.
- One of the biggest concerns of staff is the area of safety in the laboratory, on field study and in workshops.
- Generally, disabled people are more safe as they know their limitations and are inclined to be more deliberate and forward thinking when doing particularly unusual or extreme experiments.



Disable Friendly Experimental Science Education

- All experiments at all levels of school, college or higher education have to be vetted for safety and have a 'risk assessment' made for each one.
- If a disabled student is going to use such an experiment then the person responsible for the experiment might need to make additions to the details about any extra precautions that need to be made.
- Because everyone is different, there are no general comments that can be attached to all experiments to cover all eventualities. That is true for any group of students.
- There might be a very few experiments that some students with disabilities will not be able to do but that does not make them non-scientists.

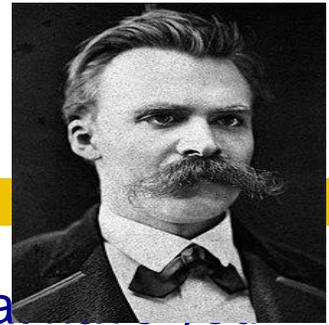


Transform Disabled Person Able Science Student

- Polio Affected Persons (Difficulty in walking)
- Dyslexia (Learning disability) (Graham Bell, Alva Edison, Faraday, Maxwell, Galileo)
- Blind
- Hearing Impairment
- Attention Deficit Hyperactivity Disorder (ADHD)
- Muscular Dystrophy (Cannot use hand to write)
- --



Message of Nietzsche



“I teach you the Übermensch. Man is something that shall be overcome. What have you done to overcome him? ... All beings so far have created something beyond themselves; and do you want to be the ebb of this great flood, and even go back to the beasts rather than overcome man? What is the ape to man? A laughingstock or established embarrassment. And man shall be that to Übermensch: a laughingstock or painful embarrassment. You have made your way from worm to man, and much in you is still worm. Once you were apes, and even now, too, man is more ape than any ape... The Übermensch is the meaning of the earth. Let your will say: the Übermensch shall be the meaning of the earth ... **Man is a rope, tied between beast and Übermensch**—a rope over an abyss ... what is great in man is that he is a bridge and not an end..”

-- **Friedrich Nietzsche** in *Thus Spoke Zarathustra*

Evolution didn't design us to be happy, but design us to pursue science and make world better. We may play a role in evolution and spread of intelligence in the Universe.



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