

# Biocene 2018

Welcome to the period of *new life*



Dr. Vikram Shyam  
NASA Glenn Research Center  
21000 Brookpark rd.  
Cleveland, OH 44135



# Wouldn't it be great to live in a simulation?

- How many want a world where you are free to think and do what you want without stepping on the wants and desires of others?
- But where technology and exploration continues to grow.
- This will be a world of empathy, technological greatness and human growth the likes of which we have never seen.
- This is what I call the Biocene, the beginning of the age of *new life*

# Biocene

**Biocene** is the period of new life. When our descendants look back at this period in time, they will see evidence, in the geologic and electronic record, of anthropic climate change, growing population, and scarcity of resources. But they will also see the rebirth of human ingenuity as we overcame the challenges that faced us through nature-inspired exploration.

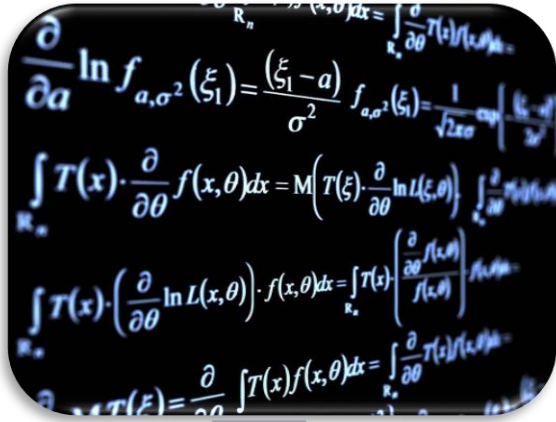
Math provides rules for all hypothetical existence – real and unreal – abstract patterns.

Physics describes the real world – reality we are aware of.

Biology turns abstraction into reality.

We can use biology to train AI and go beyond nature,

To create a future that is selfish and yet fair to all


$$\frac{\partial}{\partial a} \ln f_{a, \sigma^2}(\xi_1) = \frac{(\xi_1 - a)}{\sigma^2} f_{a, \sigma^2}(\xi_1) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(\xi_1 - a)^2}{2\sigma^2}\right)$$
$$\int_{\mathcal{R}_n} T(x) \cdot \frac{\partial}{\partial \theta} f(x, \theta) dx = M\left(T(\xi) \cdot \frac{\partial}{\partial \theta} \ln L(\xi, \theta)\right) = \int_{\mathcal{R}_n} T(x) \cdot \left(\frac{\partial}{\partial \theta} \ln L(x, \theta)\right) \cdot f(x, \theta) dx = \int_{\mathcal{R}_n} T(x) \cdot \left(\frac{\partial}{\partial \theta} f(x, \theta)\right) dx$$
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Reference 1

- Nature's rules and framework



Reference 2

- Train AI using biology's solutions and patterns



- Synthetic biology
- Simulated evolution
- Directed evolution
- Artificial Intelligence

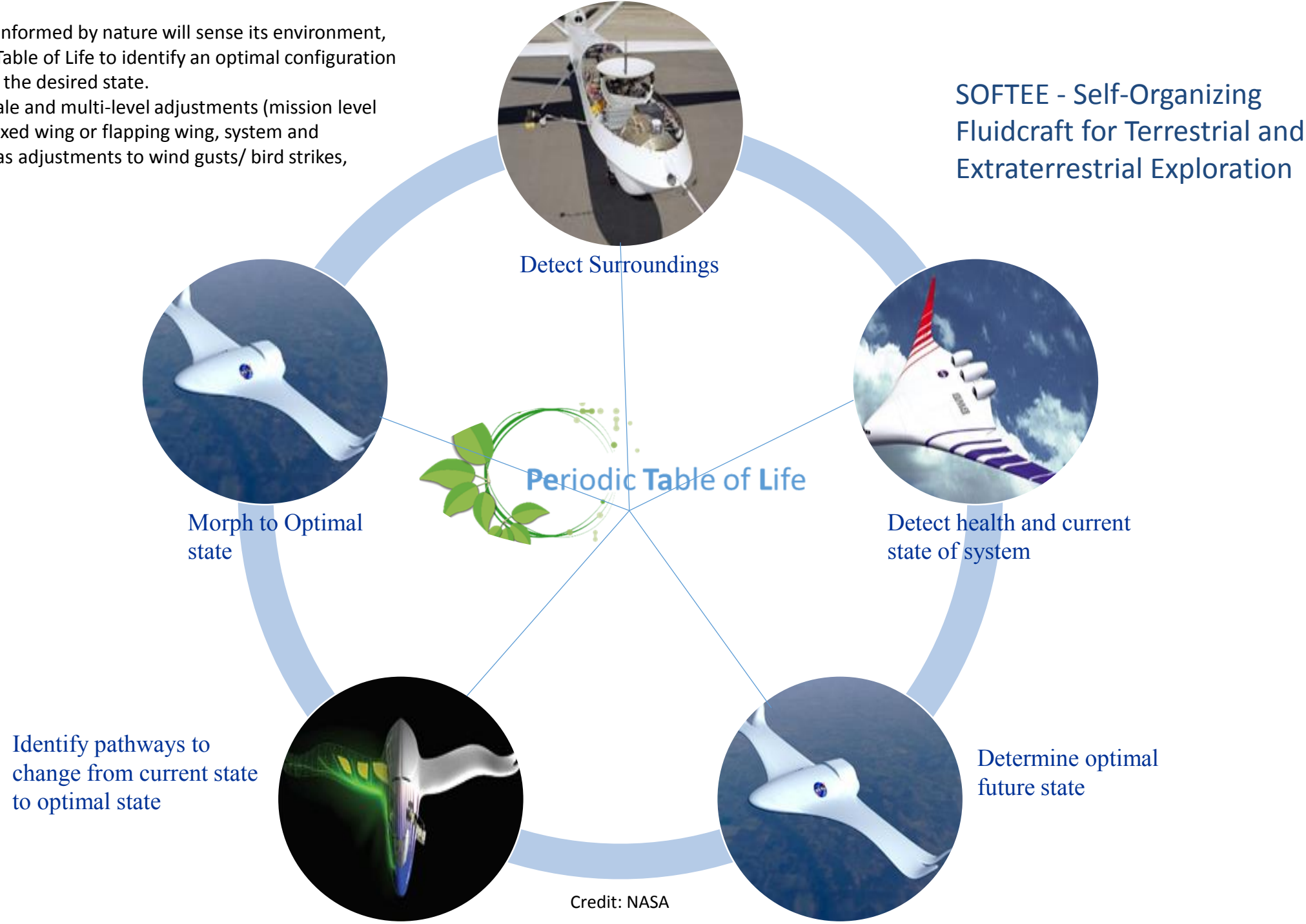


Reference 3

The next phase in human evolution



A closed loop system informed by nature will sense its environment, draw on the Periodic Table of Life to identify an optimal configuration and morph to achieve the desired state. This includes multi-scale and multi-level adjustments (mission level such as rotorcraft to fixed wing or flapping wing, system and subsystem level such as adjustments to wind gusts/ bird strikes, fouling).



We can cluster and classify the natural world by form, function, environment



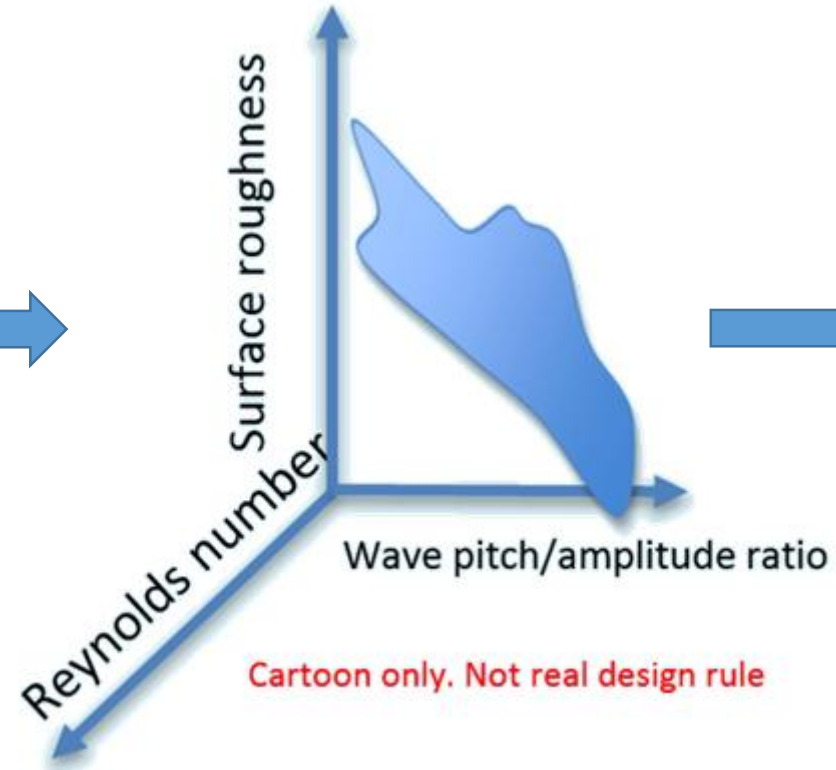
Reference 4



Reference 5



Reference 6



Reference 7



Reference 8



Reference 9

Need an automated, intelligent design tool to enable nature-inspired system design



And see patterns that emerge



Reference 4



Reference 5



Reference 6



Reference 7



Reference 8



Reference 9

Need an automated, intelligent design tool to enable nature-inspired system design

And find gaps in our knowledge



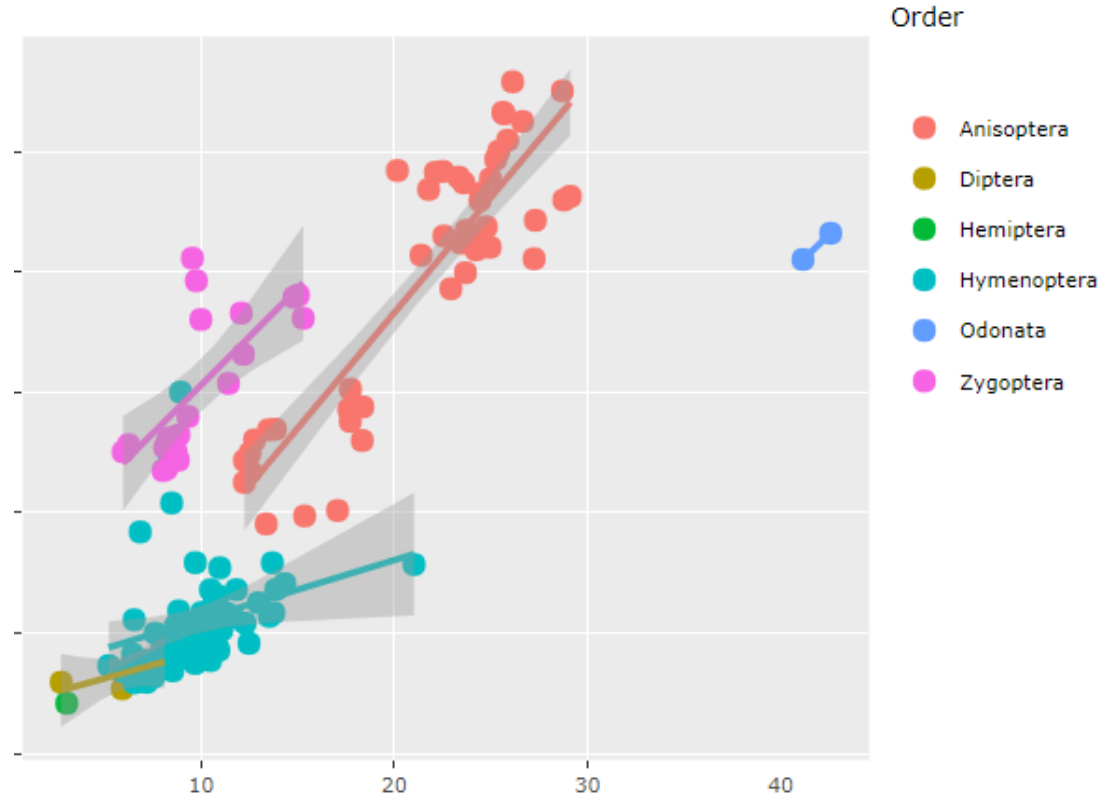
Reference 4



Reference 5



Reference 6



Reference 7



Reference 8

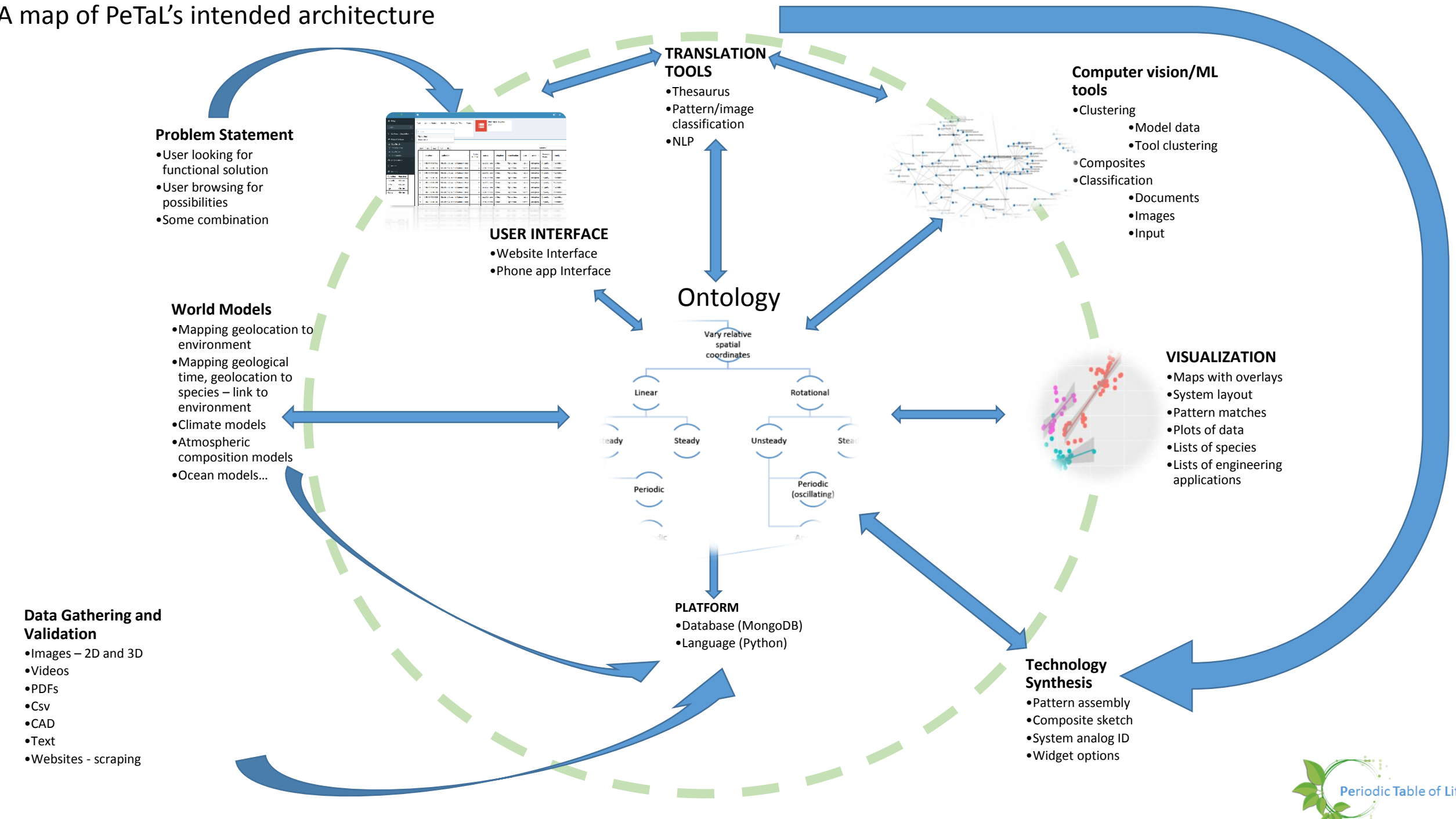


Reference 9

Need an automated, intelligent design tool to enable nature-inspired system design



# A map of PeTaL's intended architecture



# Personality and problem solving

Vikram Shyam, Robert O. Reid

NASA Glenn Research Center, 21000 Brookpark rd. Cleveland, OH

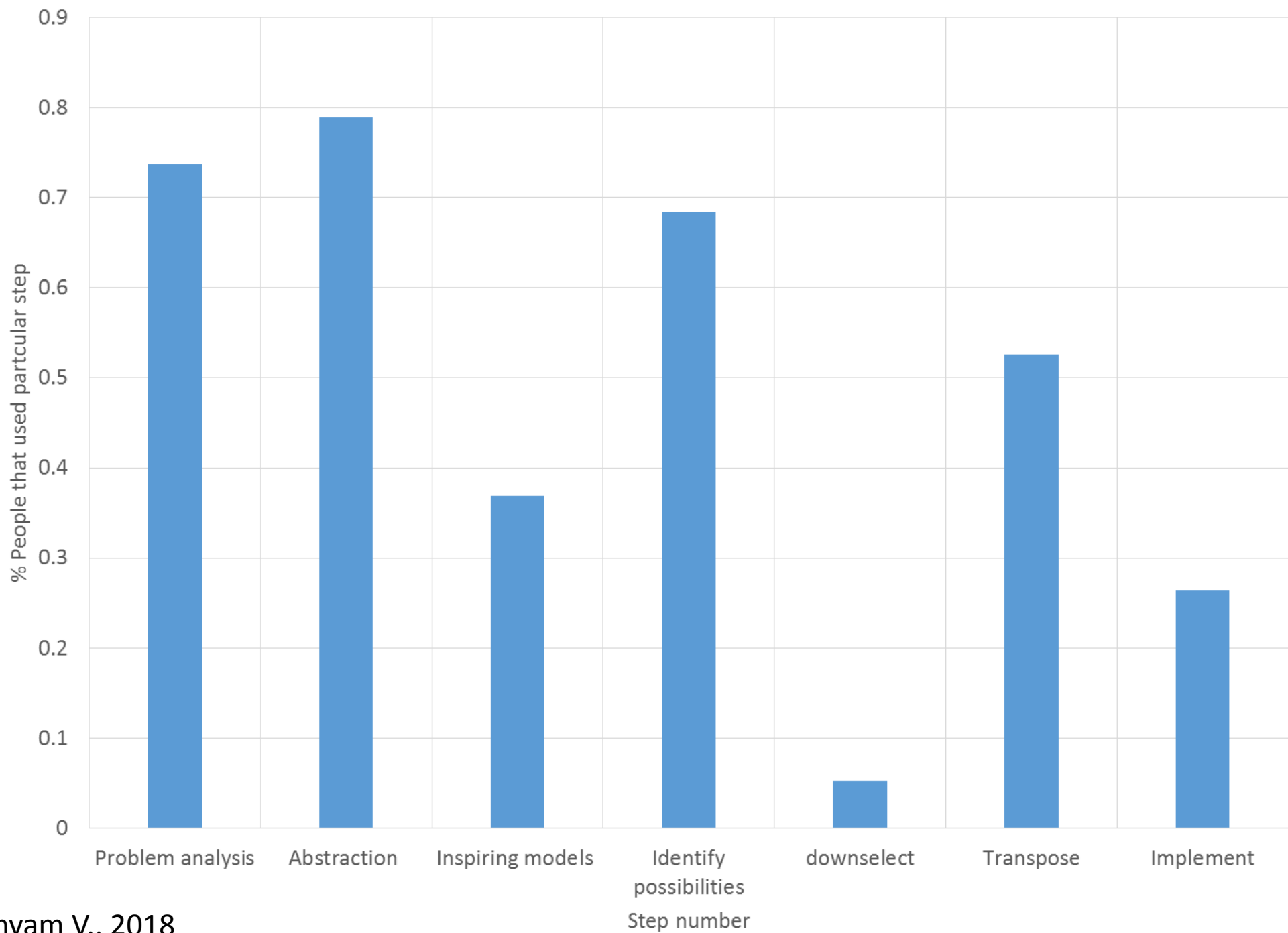
# How does personality impact decision making

- How much planning is involved?
- How many people are involved?
- How many steps? In what order?
- Do you question the problem? Should you be solving a different problem?

# Approach to problem-driven design

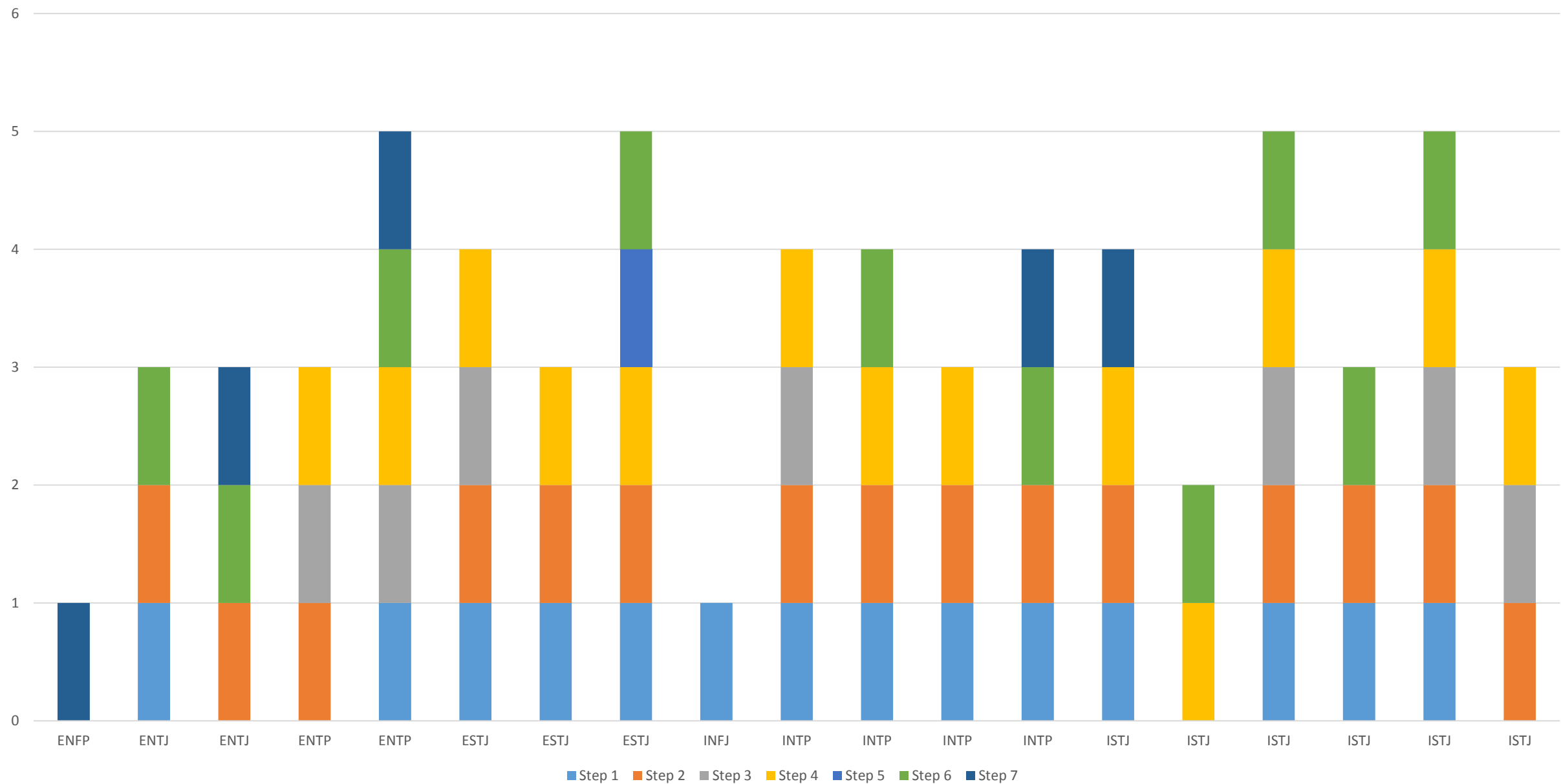
(Wanieck et. al., 2017)

- Step 1: Problem analysis (analysis) – What is the problem you are solving? How many components? Any constraints?
- Step 2: Abstraction of the Technical Problem (abstraction) – Other ways of phrasing the problem? Can you zoom out and try achieving a higher level result with another technical approach?
- Step 3: Transposition to inspiring models (transfer) – ask the question, how would nature do xyz...how would neighbors do xyz
- Step 4: Identification of potential models (application) – select possible options
- Step 5: downselection of model(s) of interest (analysis) - Based on constraints, how many objectives does this model achieve? Downselection
- Step 6: Transposition to technology (transfer) – Figure out how to replicate the model for your situation/problem
- Step 7: Implementation and test of the concept (application) - apply the new approach and compare with what you were doing before.

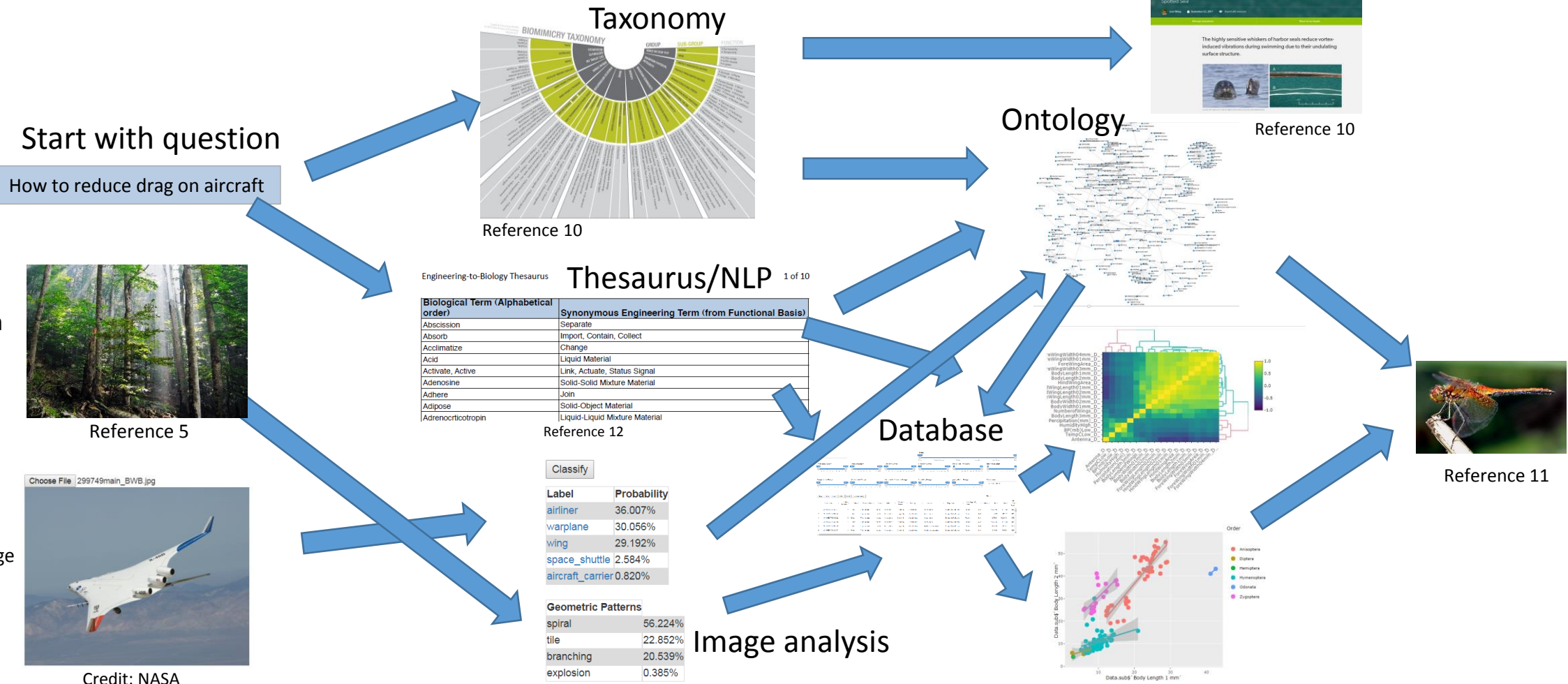




Problem solving steps and MBTI

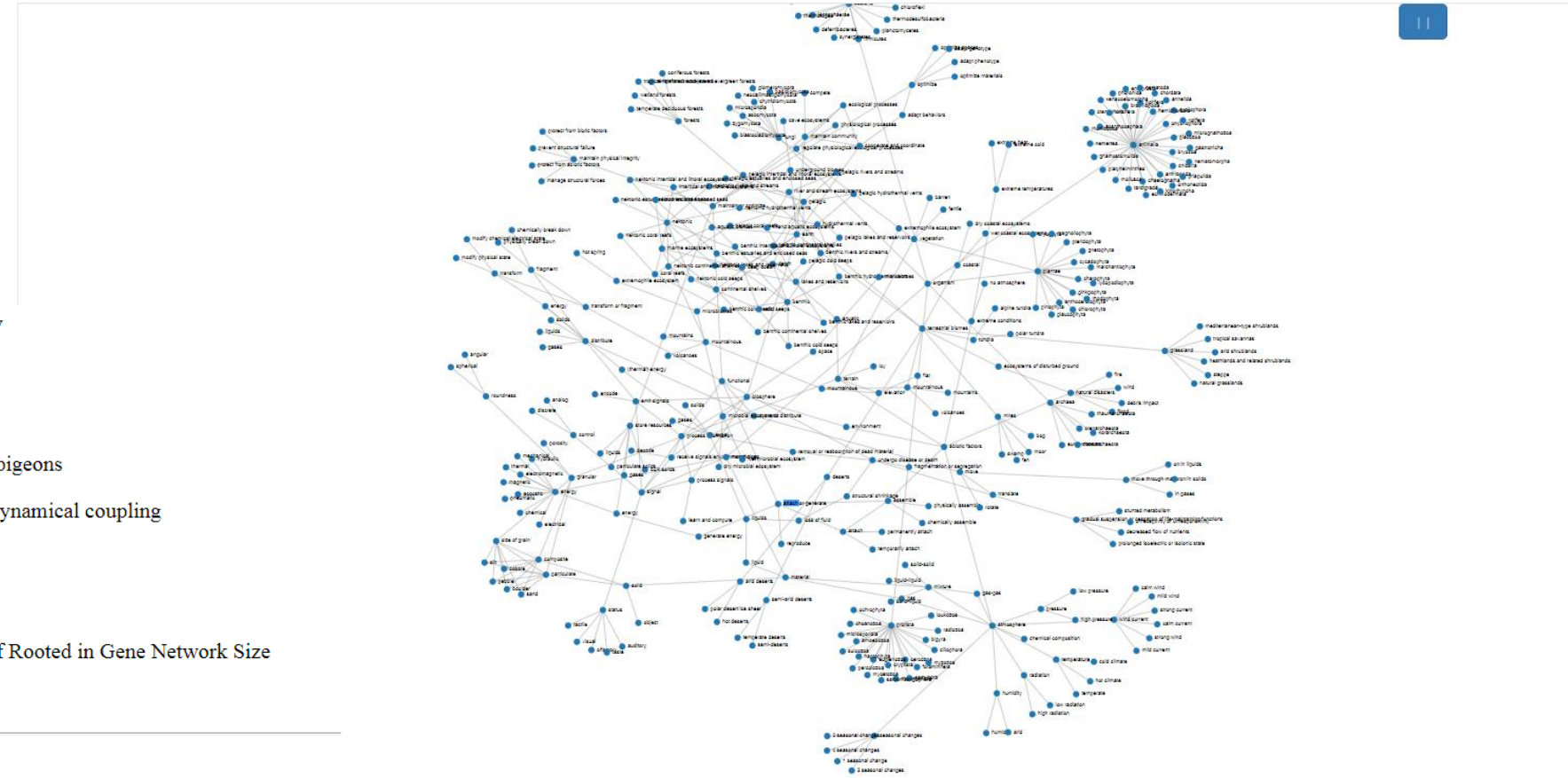


# Bio-inspiration – quantum biology



An AI brain that keeps track of all paths and collapses on to the ‘best’ one based on the ‘photon’ that hits

## Ontology Graph Visualization



- E. coli superdiffusion and Chemotaxis-Search Strategy, Precision, and Motility
- Thermal adaptation of viruses and bacteria
- Tradeoffs in bacteriophage life histories
- Feather bacterial load shapes the trade-off between preening and immunity in pigeons
- Cilia internal mechanism and metachronal coordination as the result of hydrodynamical coupling
- Dynamics and mechanics of the microtubule plus end
- Sympatric speciation under incompatibility selection
- Evolution of Competitive Ability: An Adaptation Speed vs. Accuracy Tradeoff Rooted in Gene Network Size
- Tradeoff s and Negative Correlations in Evolutionary Ecology

## Related

- Superclasses
- Subclasses
- [material](#)
- [energy](#)
- [signal](#)
- [organism](#)
- See Also

# Image Classifier

Choose File IMG\_0778.JPG



Classify

| Label           | Probability |
|-----------------|-------------|
| accordion       | 65.480%     |
| drum            | 18.769%     |
| chain_mail      | 2.187%      |
| shield          | 1.563%      |
| vending_machine | 0.868%      |

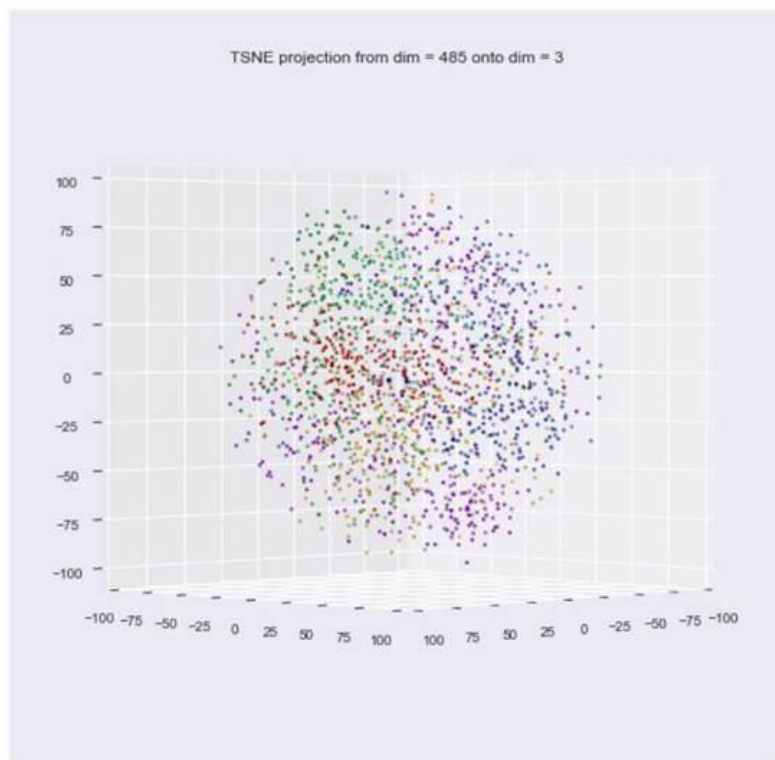
## Geometric Patterns

|           |         |
|-----------|---------|
| tile      | 65.250% |
| branching | 26.661% |
| spiral    | 6.683%  |
| explosion | 1.406%  |

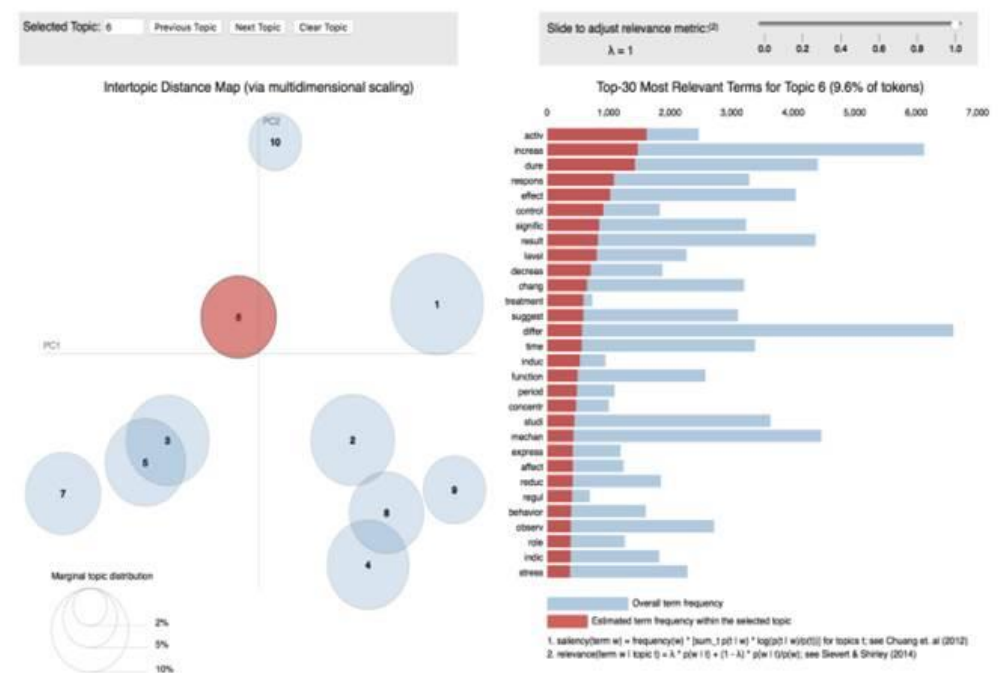
- An image is decomposed into constituent patterns
- Features are recognized
- These help determine relationship between form and function and in defining systems and subsystems
- This can help identify solutions by connecting the ontology to the elements in the image



# Topic modelling and classification



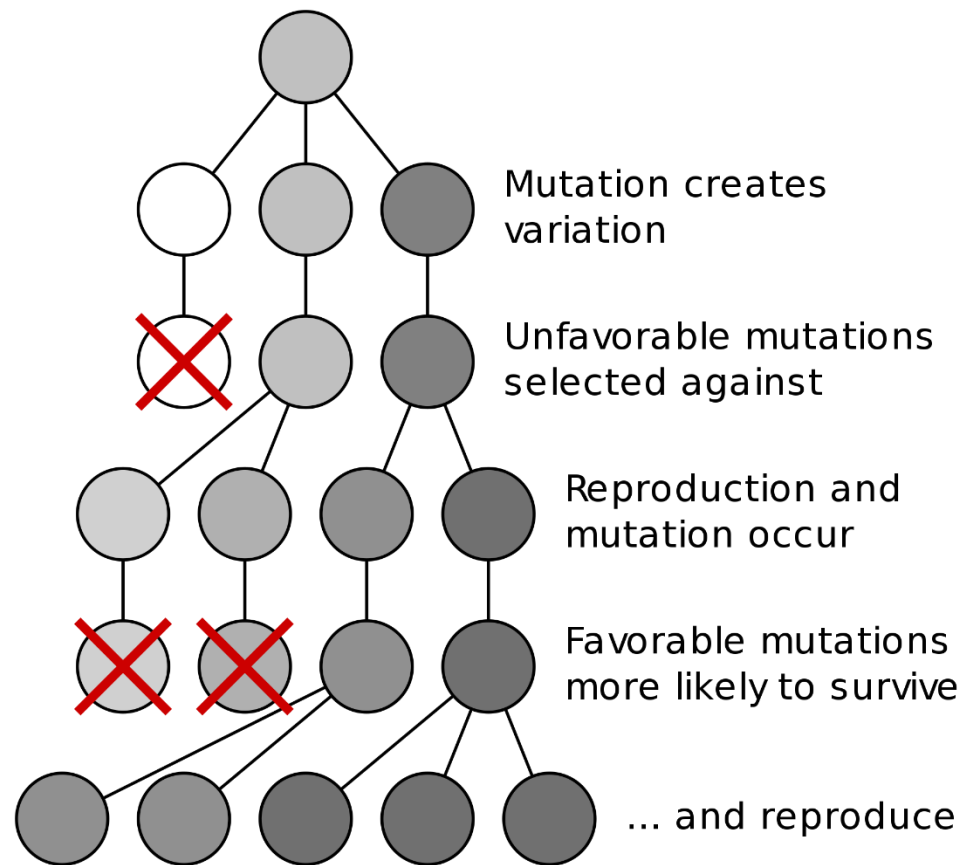
**Figure 1. TSNE Topic Clusters projection.** Visualizing the documents as projected downward onto three dimensions.



**Figure 3. pyLDAvis topic choice 6.** Here is an initial launch of the cluster tool. The relevance slider is set to 1, presenting the top 30 relevance terms according to the relevance metric<sup>3</sup>

Automated clustering of source texts and creation of 'clusters'. New articles can be sorted into these clusters. Clusters linked to ontology through thesaurus

# Bio-inspiration - evolution

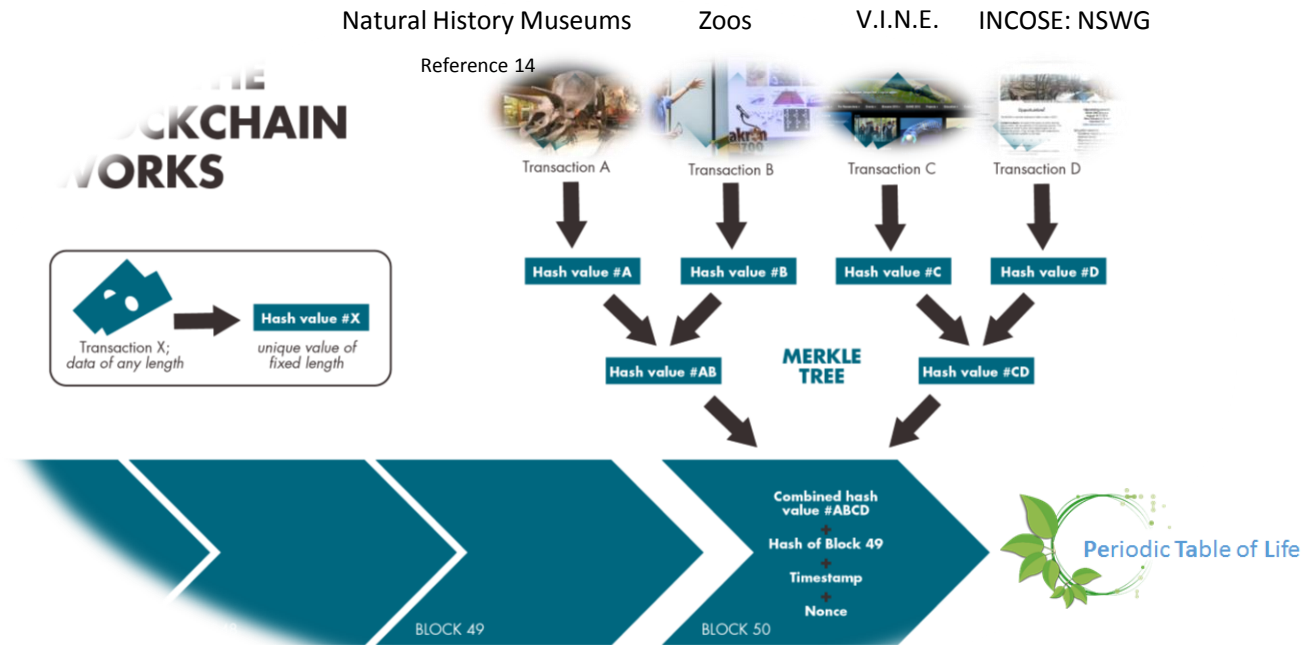


Creative Commons

- Tools that are used often, produce reliable results and have not been modified may remain in the genome (PeTaL)
- Tools that have spawned new tools or that have not produced reliable results are deprecated (selected against)
- Pathways that are cumbersome or inefficient are weighted down (extinct)



# Giving credit to nature and its stewards – Use blockchain to track changes, use tools, and reward contributions while protecting IP



Reproduction of an original figure in "The Great Chain of Life"

Reference 13

Bring natural resources into the development pipeline  
Use revenue generated to support research, conservation and education

# Data Challenge

- Citizen Science: ways we can engage the public to build a robust database
- Technology Development: Ways to use datasets in AI tools and ways to generate data suitable for machine learning
- IP Business – Ways to fairly use/license ideas, data and technology

# Short term work ahead

- UI for topic modelling tool and interfacing with main PeTaL interface
- PeTaL UI
- Focus on challenge to demo system

# VINE Clusters – Thursday - Auditorium

- Develop Applications that generate function data for PeTaL
- Develop tools and processes that add to PeTaL AI suite

| Technology Cluster                                                     | Description                                                                                                                                                                                                                                                                                                                                                                                                            | VINE Catalyst(s)                  |
|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| Big Data, Artificial Intelligence, Machine Learning, Sensors, Robotics | Develop ways to generate data for PeTaL, Develop machine learning tools (share with PeTaL) to recognize patterns in nature that, ML for system architecture layout and design, Algorithms for fault detection, prediction of life, performance. Develop sensors using PeTaL, generate data from application research                                                                                                   | Herb Schilling, Calvin Robinson   |
| Synthetic Biology, Artificial Evolution and Human Persistence in Space | Ways to manipulate the structure of life in a safe, controlled manner using biomimetic principles to perform functions and exhibit behaviors not found in nature. Ways to enable human presence in space with minimal support from Earth. Includes protection from radiation and other environmental factors in space, Life support systems, space medicine, space law and unforeseen issues. Generate data for PeTaL. | Anita Alexander, Marjan Eggermont |
| Multi-functional Materials, Structures, Processing                     | Development of materials and structures that serve more than one function (structural integrity and power storage, propulsion and fuel, sensor and actuator, ice-phobic and drag reducing). Generate data for PeTaL.                                                                                                                                                                                                   | Chris Maurer                      |
| Hybrid and alternative manufacturing, design and architecture, ISRU    | Applications and advances in additive manufacturing, nanotechnology and subtractive manufacturing to achieve reusable recyclable materials and structures, biomimetic architecture, design. Applications of natural systems to in-situ resource utilization - use local (on earth and in space) resources sustainably, efficiently and using nature's principles. Generate data for PeTaL.                             | Emil Reyes/ Andrew Trunek         |
| Information, Communication, Education                                  | Disseminate information to and from biomimetic community. Develop education tools, identify opportunities to implement PeTaL and other tools for education and business. Generate data for PeTaL.                                                                                                                                                                                                                      | Marjan Eggermont                  |
| Systemology, systems engineering                                       | Develop, assess and implement processes for systematic bio-inspiration. Identify pathways for incorporation of natural principles in systems engineering. Develop design challenges to tie-in other clusters.                                                                                                                                                                                                          | Jacquelyn Nagel/ Curt Mcnamara    |
| Energy conversion, power, propulsion, mobility                         | Ways to harvest, convert, distribute and use energy and power for aeronautics and space, Ways to move and to enable motion including aerodynamics, surface mobility, hydrodynamics, gears, mechanisms. Generate data for PeTaL.                                                                                                                                                                                        | Tim Peshek                        |

# PeTaL Team and Contributors

## NASA

- Nick Bense, Northeastern University
- Bishoy Boktor, Middle Tennessee State University
- Alexandra Calvin, Kent State
- Jonny Dowdall, Michigan State University
- Manju Johnny
- Victoria Kravets, Georgia Tech
- Angeera Naser, University of Texas, Dallas
- Isaias Reyes
- Nikhitha Sakhamuri
- Brian Whiteaker, University of California, San Diego
- Paht Juangphanich, Pathways intern
- Ezra McNichols, NASA GRC /LTE

## External

Dr. Marjan Eggermont

Dr. Jacquelyn Nagel – biosearch tool and thesaurus

Dr. Julian Vincent – trade-off articles

## VINE coordinator

- Colleen Unsworth, NASA PhD fellow/U Akron
- Amanda vonDeak (former member)

## Mentors/Advisors

- Timothy Peshek, NASA GRC – In-space power, data analytics
- Calvin Robinson, NASA GRC – Computer Science/ project lead
- Herb Schilling, NASA GRC – Computer Science
- Vikram Shyam, NASA GRC – P.I.
- Laura Stokely, NASA GRC – Project manager
- Andrew Trunek, NASA GRC – Materials and ISRU

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ARMD/AATT

NASA GRC Office of Education

Sally Ride Scholarship, SMD/NASA



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Learn systematically from history to predict and shape our future

Synthetic Biology,  
artificial evolution...

Hybrid Manufacturing

Data  
Science/Analytics

3D Scanning

Art and Design

Biophysics

Anthropomimetics

Biomimetics

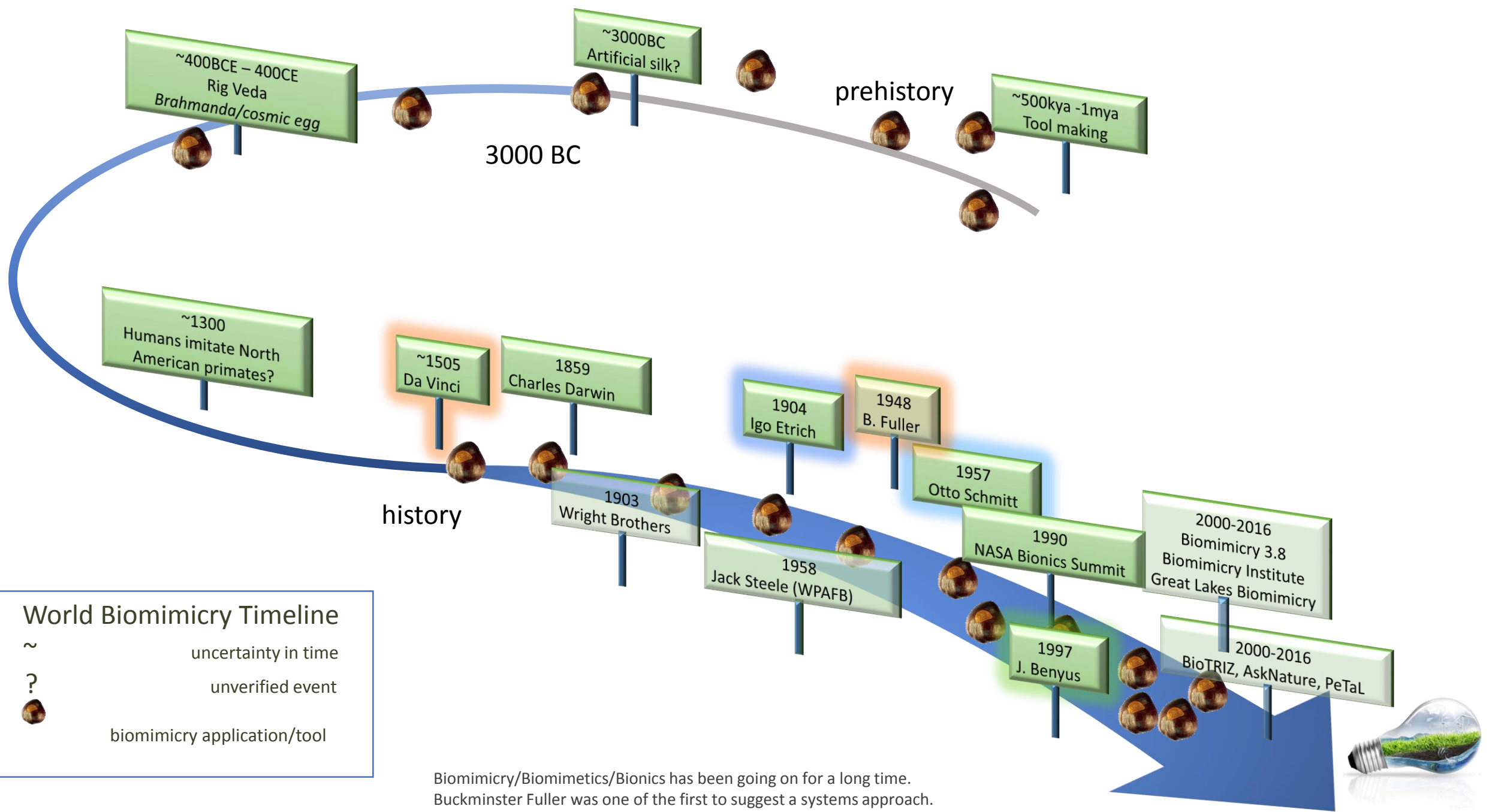
Paleomimetics

Physioteleology

Healthy, Relevant,  
Sustainable Future

Physiomimesis

26

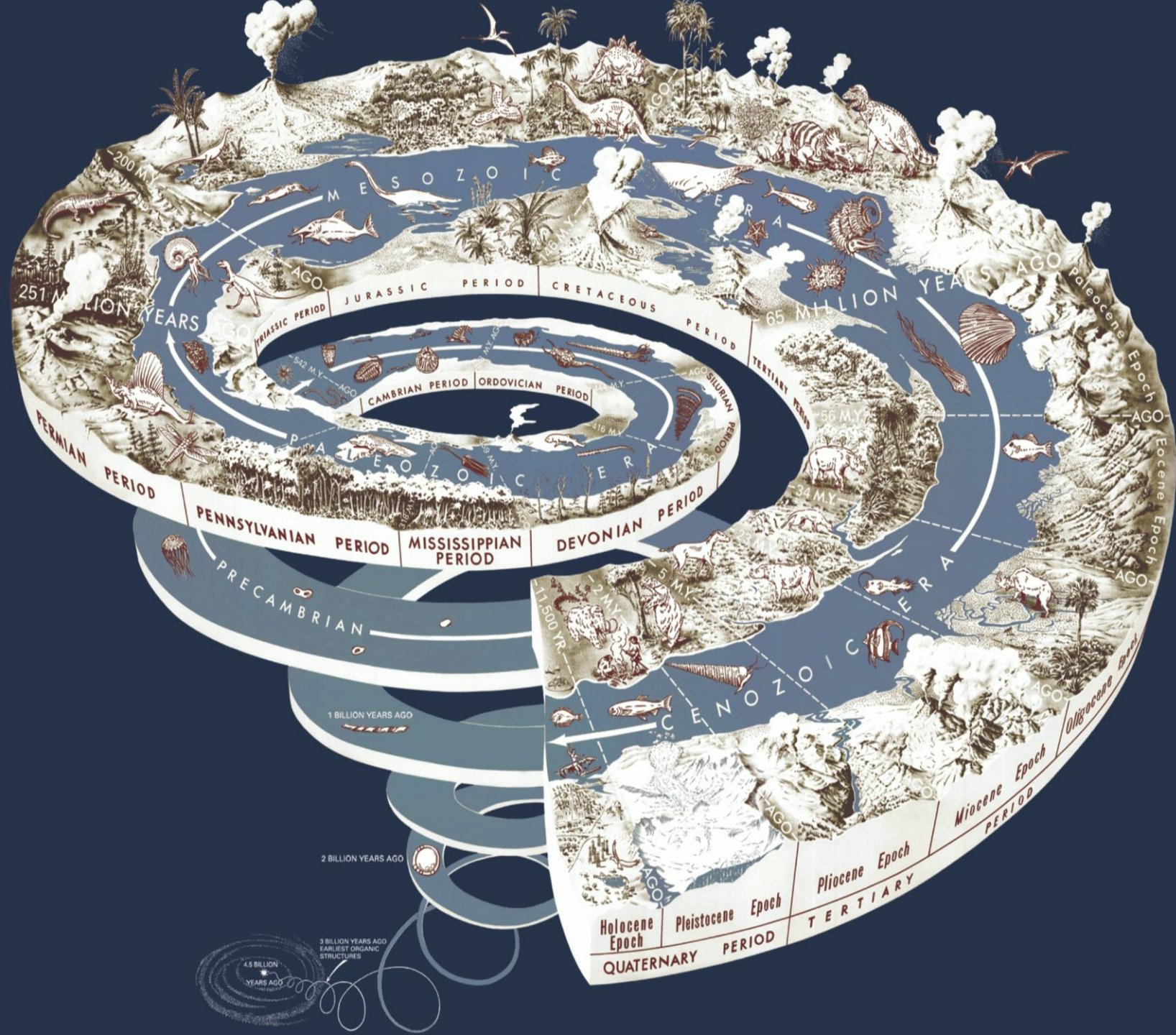


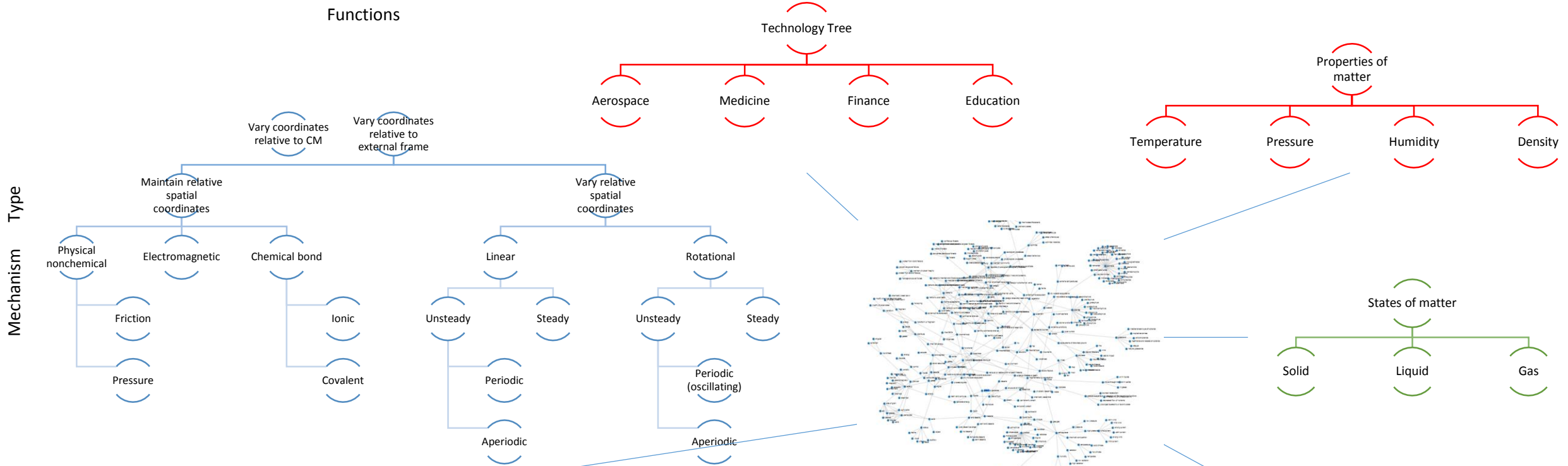
Biomimicry/Biomimetics/Bionics has been going on for a long time.  
Buckminster Fuller was one of the first to suggest a systems approach.  
Advent of internet, new forms of media helped popularize practice thanks to people like Janine Benyus.



Camels often sit down carefully –  
perhaps their joints creak? Early oiling might  
prevent permanent Harm

Cambrian, Ordovician, Silurian, Devonian,  
Carboniferous, Permian, Triassic, Jurassic,  
Cretaceous, Palaeocene, Eocene,  
Oligocene, Miocene, Pliocene, Pleistocene,  
Holocene





**Biomes**

**Morphology**

