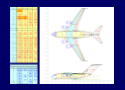
P^3 Theory of Design - A Natural Model

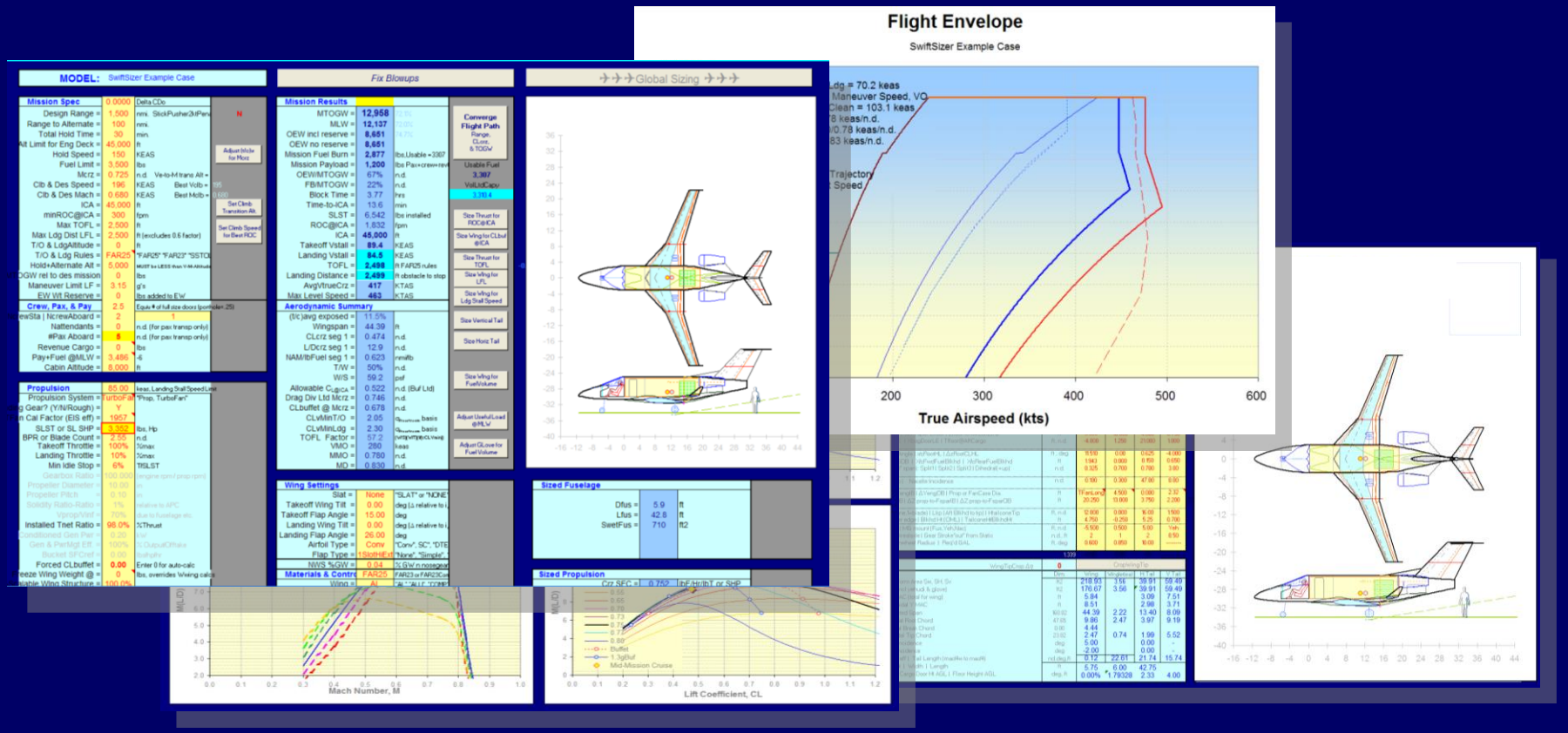
Mark A. Page

My Design History

History – *Observations from building DZYNEr*

DZYNER is my personal Airplane Design Code
It has been used for all of my designs.

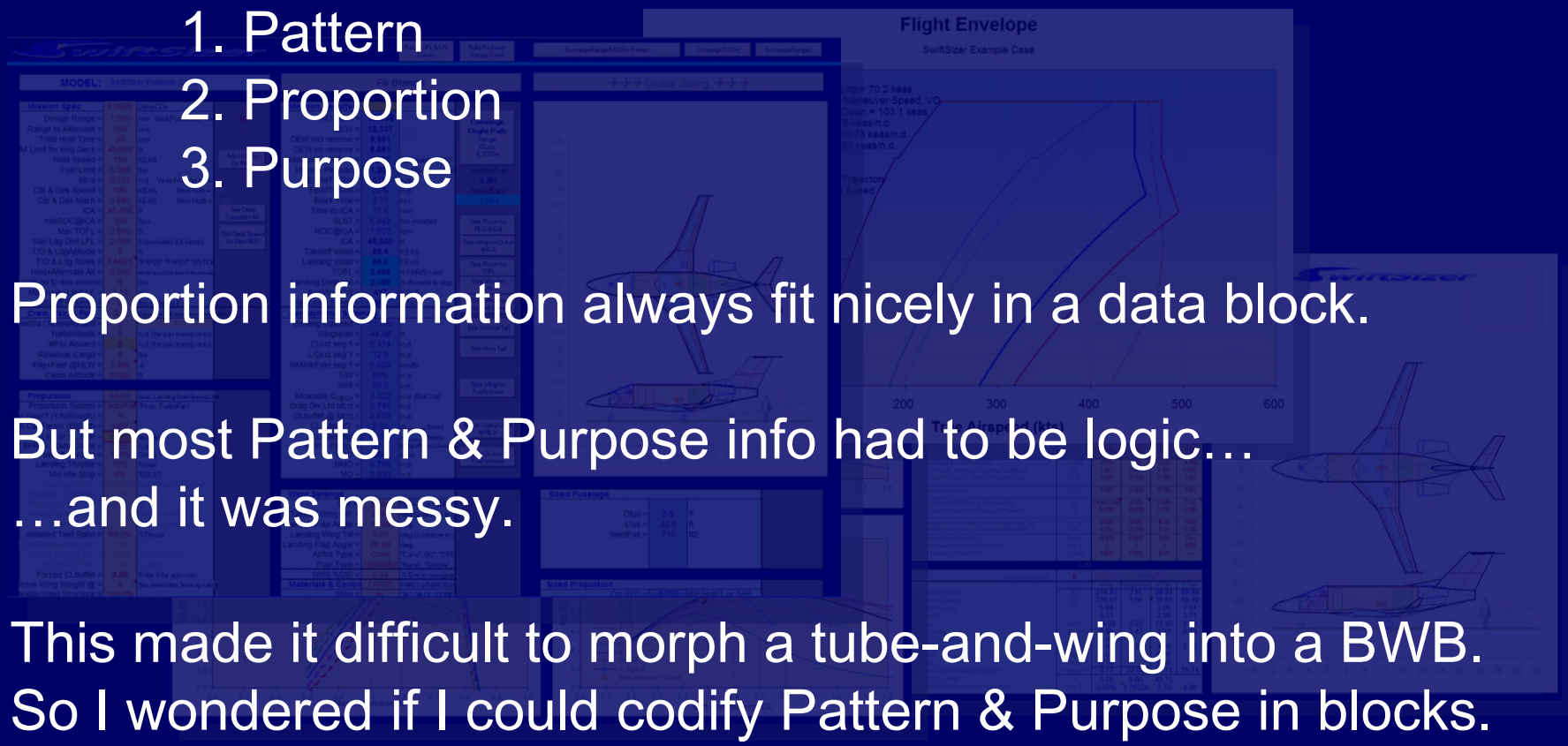




History – *Observations from building DZYNEr*

When adding new features, I'd often organize the input blocks into the same 3 categories;

1. Pattern
2. Proportion
3. Purpose



Proportion information always fit nicely in a data block.

But most Pattern & Purpose info had to be logic…
…and it was messy.

This made it difficult to morph a tube-and-wing into a BWB.
So I wondered if I could codify Pattern & Purpose in blocks.
Perhaps I could add *speciation* into the optimization process.

Species Selection

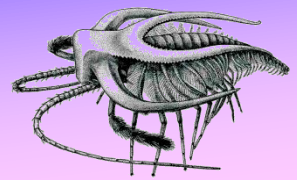
- Today, airplane species selection tends to be……
  - Reliant on the creativity of the designer.
  - Subject to bias of designer and corporation.
  - Limited by legacy design tools.
  - Unstructured process of exploration.
- But, speciation is the source of *revolutionary* gains.
- Most engineering design research is devoted to optimization within a species – *evolutionary* gains.






P^3 Theory is intended to address these limitations.

Revolution – Cambrian Explosion

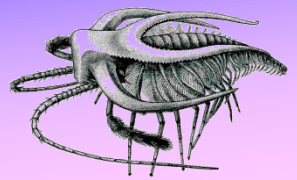


540 million years ago,
there was an explosion of new body patterns

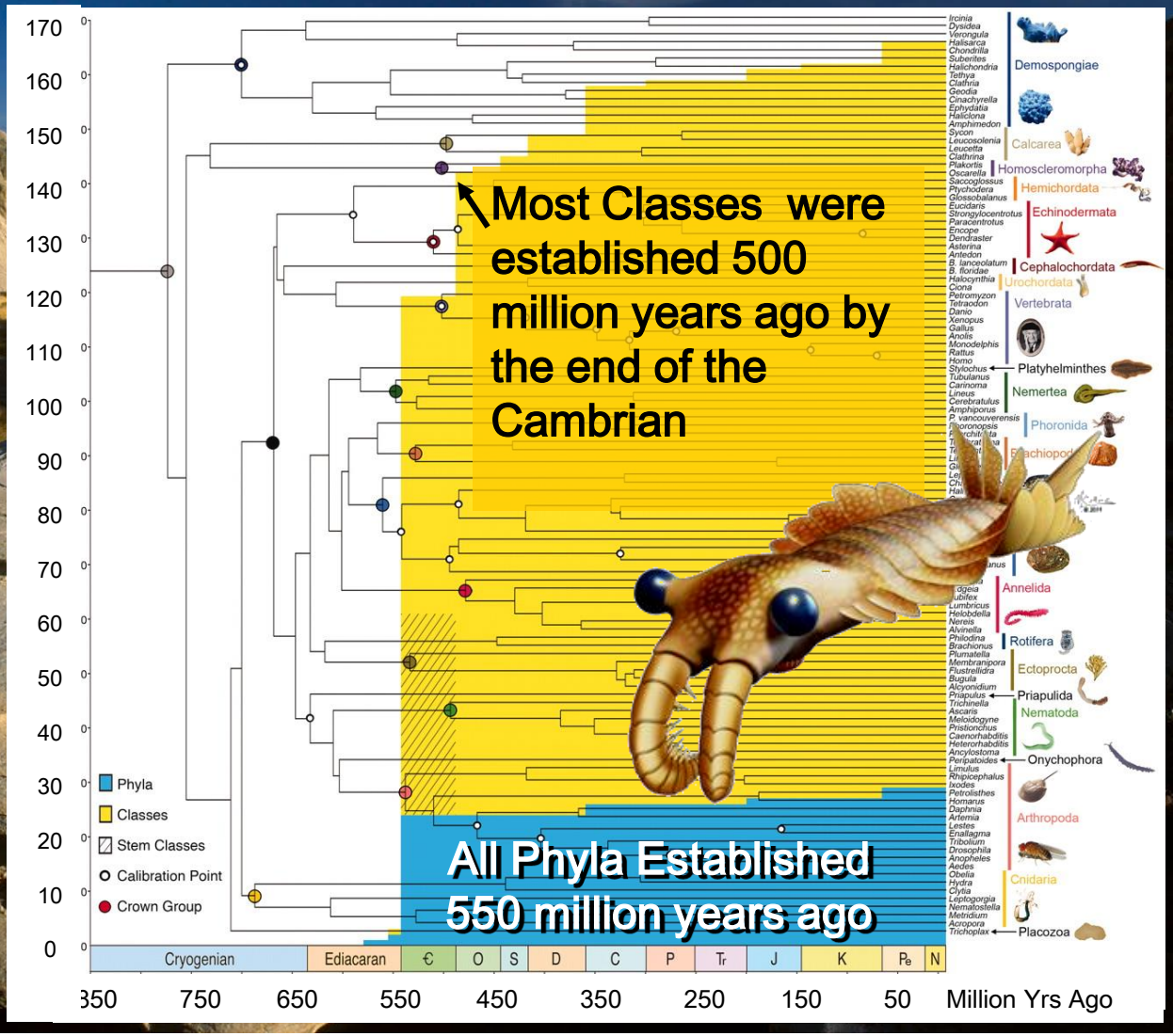
Their fossils are abundant in Toadstool Park Nebraska

Virtually all modern orders and classes
were created in this period

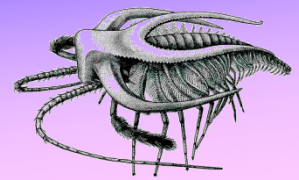
Revolution – Cambrian Explosion



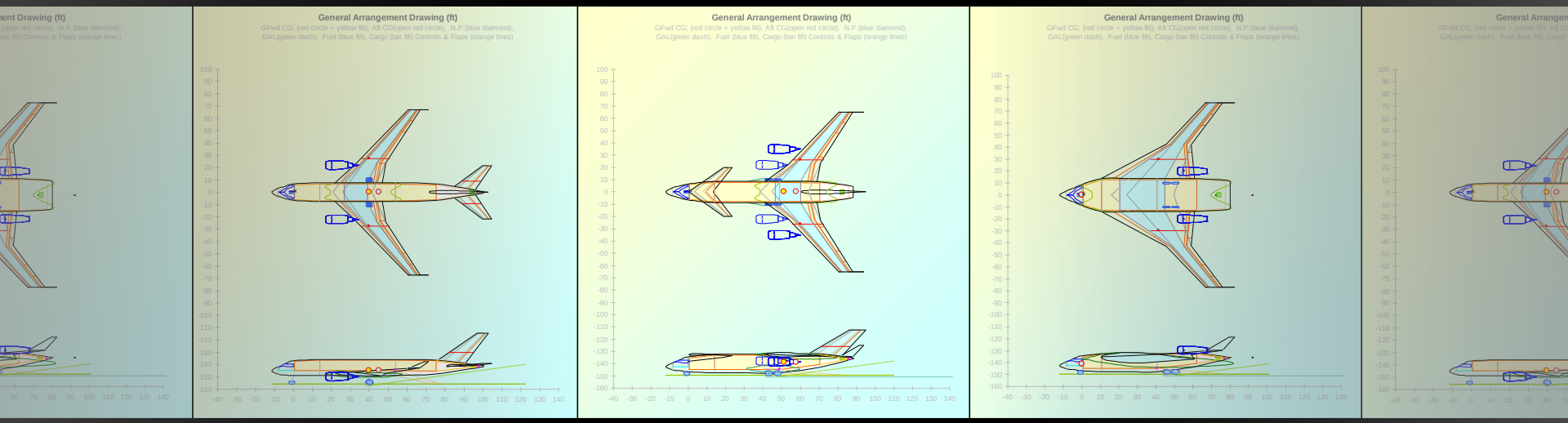
This tree shows the number of new Taxa w/branching derived from tracing molecular evolution



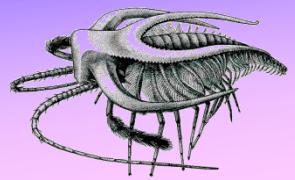
Speciation - A Natural Model for Design



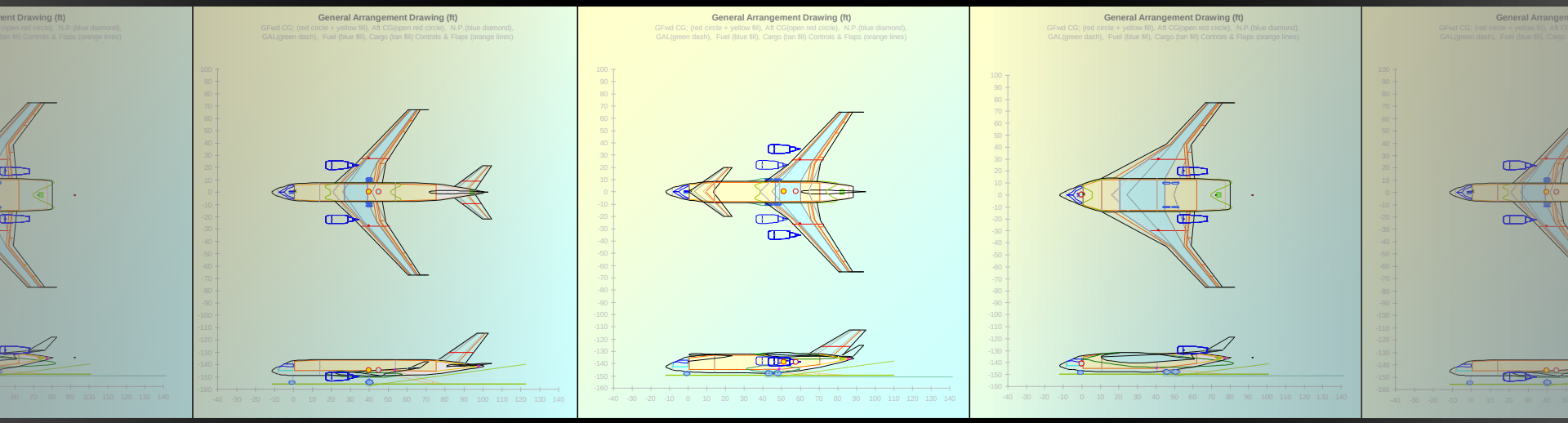
- **Objectives**
  - Use biological model to codify design.
  - Create a systematic language suitable for optimization.
  - Look for biological processes that may aid design.
  - Create an objective measure of design complexity.



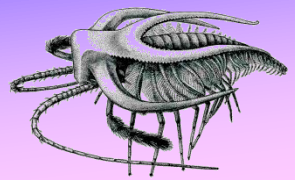
Speciation - A Natural Model for Design



- **Genetic Code = Natural Design**
  - Best adapted designs *prosper*.
  - Less adapted designs *diminish*.
  - Environment = Constraint Space.
  - Genes = Design Space.



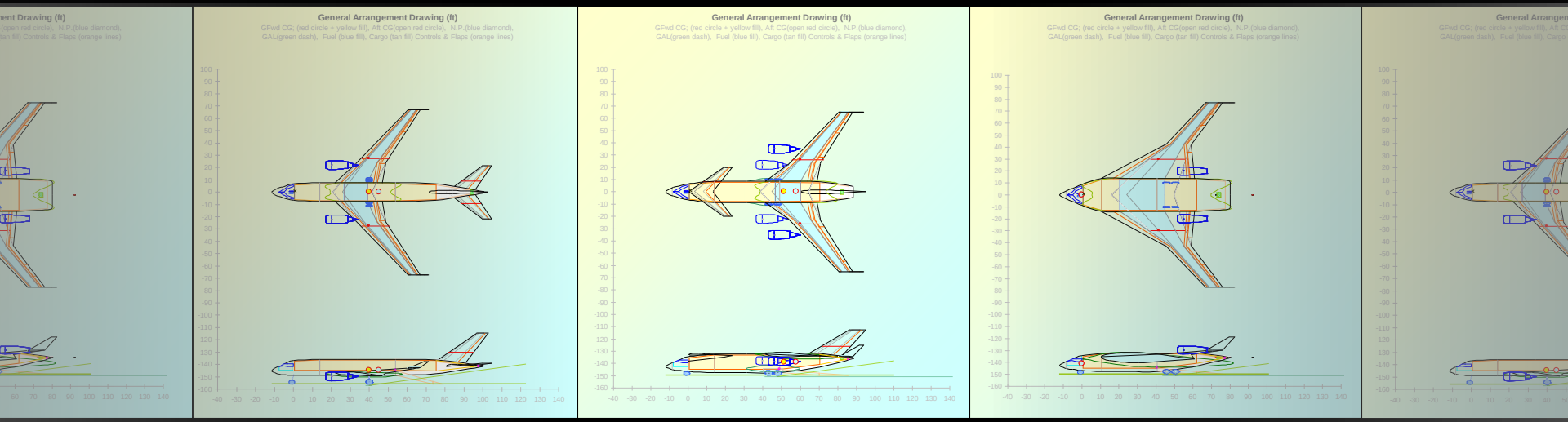
Speciation - A Natural Model for Design



- **Proposal**
  - Re-define the words in the language for system design.
  - Draft designs based on fitness of solution.
  - Expose these designs to the environment.
  - Apply existing algorithms to create the cycle.
  - Survival of the fittest

Bio-Inspired optimization as a <u>language</u>
has been used for decades

But perhaps we should step back
and ask if we're using the right <u>words</u>



Speciation - A Natural Model for Design

P³
Pattern
Proportion
Purpose

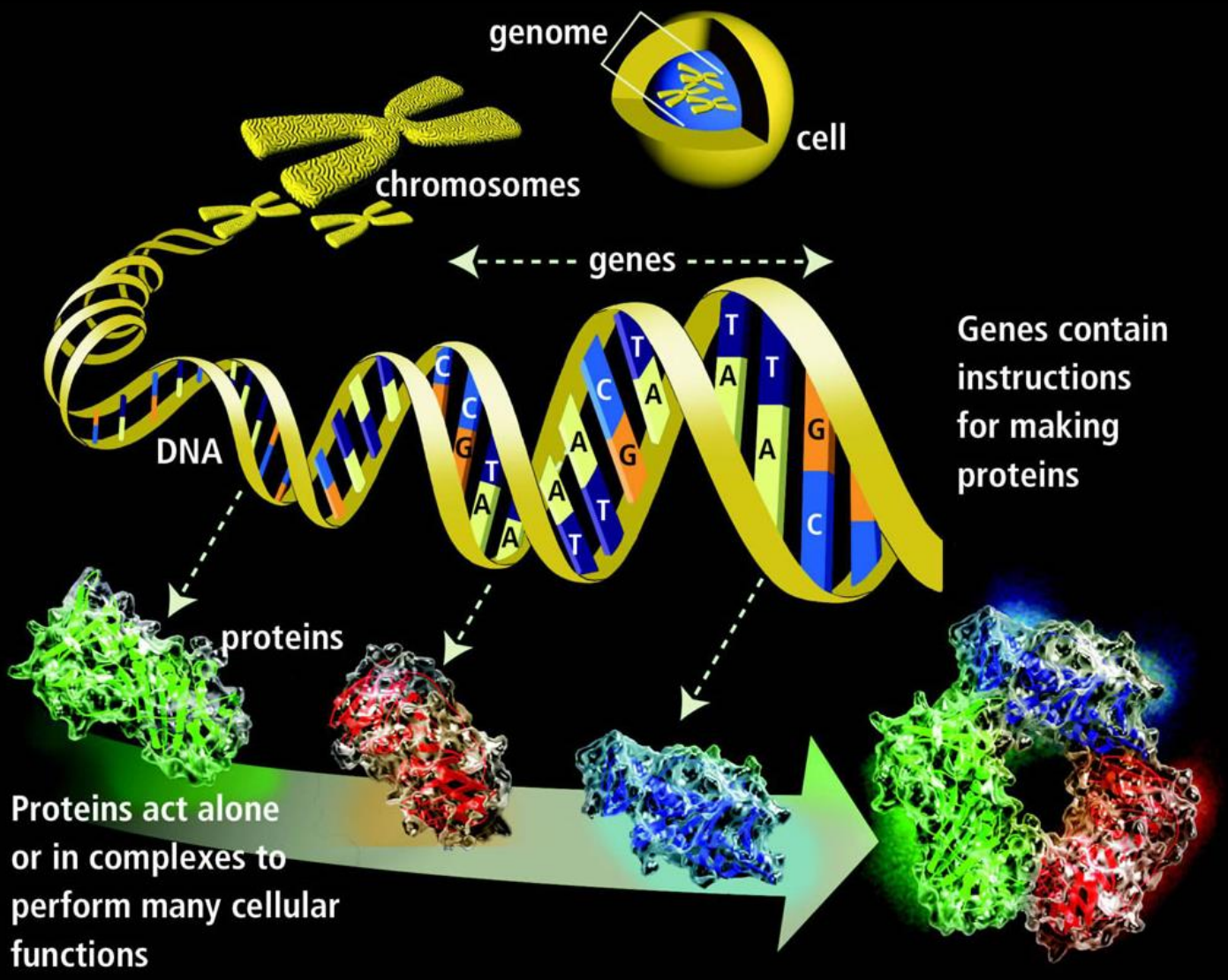
- **The Language is built from Words**
- **P³ Defines the Words as a Gene.**
- **Genes describe…**
  - **Pattern - Where am I?**
  - **Proportion - How big am I?**
  - **Purpose - What do I do?**

"It's submitted that P³ provides the minimum set of commands to code a vehicle design"

Purpose-A	Proportion-75
Purpose-G	Proportion-02
Purpose-W	Proportion-12
Purpose-W	Proportion-32
Purpose-A	Proportion-75
Purpose-G	Proportion-02
Purpose-W	Proportion-12
Purpose-W	Proportion-32
Purpose-A	Proportion-75
Purpose-G	Proportion-02
Purpose-W	Proportion-12

But first – a DNA refresher

P3
Pattern
Proportion
Purpose



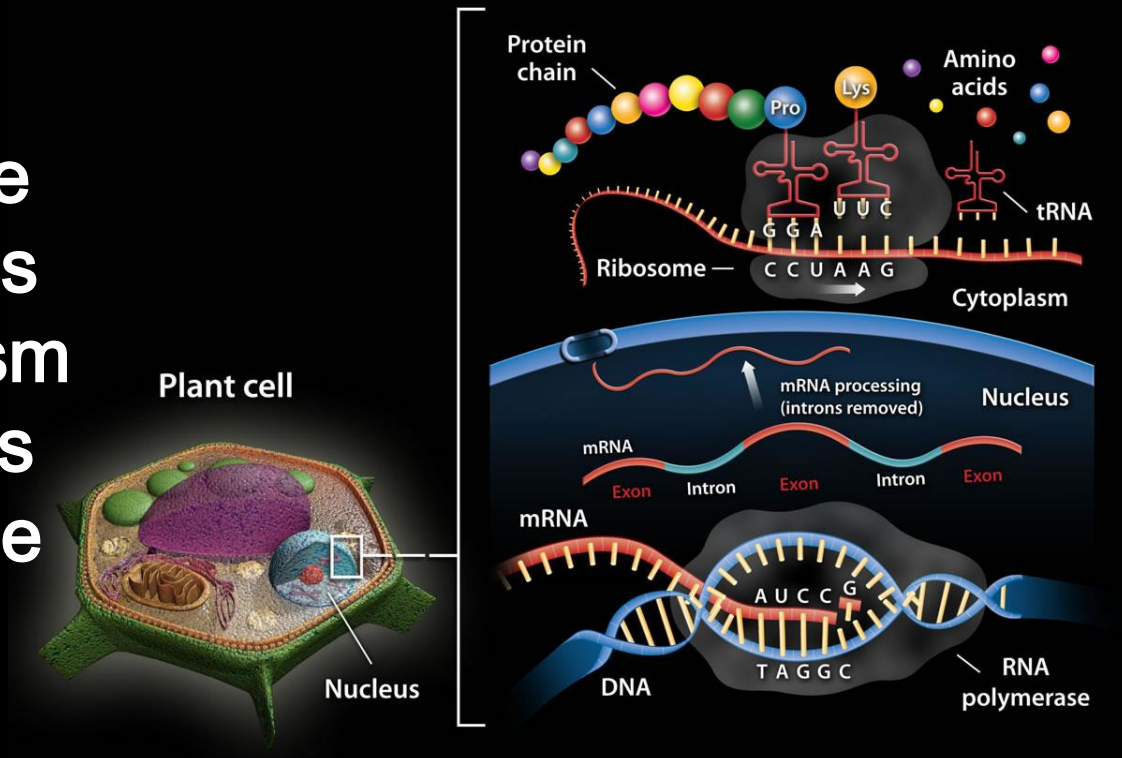
But first – a DNA refresher

P3
Pattern
Proportion
Purpose

DNA holds the code for Protein synthesis

RNA copies the gene segments and carries them to the Cytoplasm where free molecules bond to the open side of the RNA

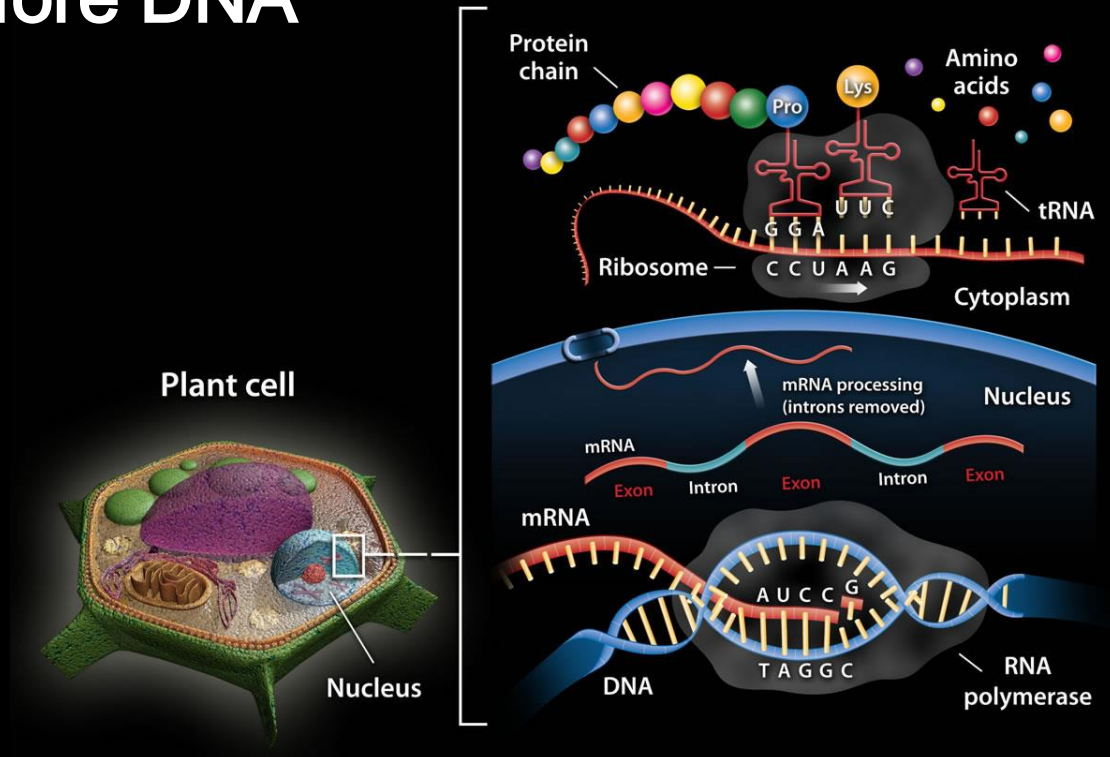
It's a Protein Factory



But first – a DNA refresher

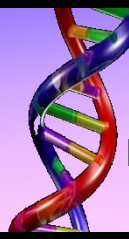
P3
Pattern
Proportion
Purpose

RNA is technically a word
RNA existed long before DNA



The Words existed before there was anything to say.
DNA is the language built of RNA-like words

But first – a DNA refresher



P3
Pattern
Proportion
Purpose

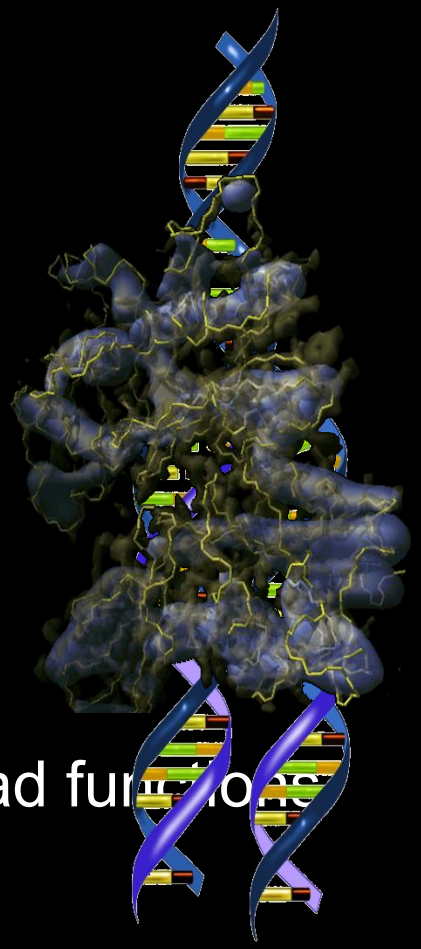
Life is built from Proteins

But what's so special about Proteins?

Proteins can be built by DNA

- Strongly bonded sugar phosphate spine
- Weak bonds across ATCG pairs

Proteins are large and geometrically complex
They look like Brillo pads



The complex geometry allows them to have myriad functions

There is a countless variety of proteins

But first – a DNA refresher

P3
Pattern
Proportion
Purpose

DNA encodes the formula for proteins,
but equally important,
it codes the pattern of assembly.

Miraculously, the pattern is written as linear commands, not a matrix.

Yet these linear commands create the matrix geometry of life

So ordinal commands, make 3D stuff….

PATTERN P^1

P^3
Pattern
Proportion
Purpose

- **PATTERN - Where am I?**
  - **What's ahead of me, beside me, and what follows me?**
  - **The pelvis always follows the last lumbar vertebrae, and it's followed by the tailbone.**

PATTERN P^1

P^3
Pattern
Proportion
Purpose

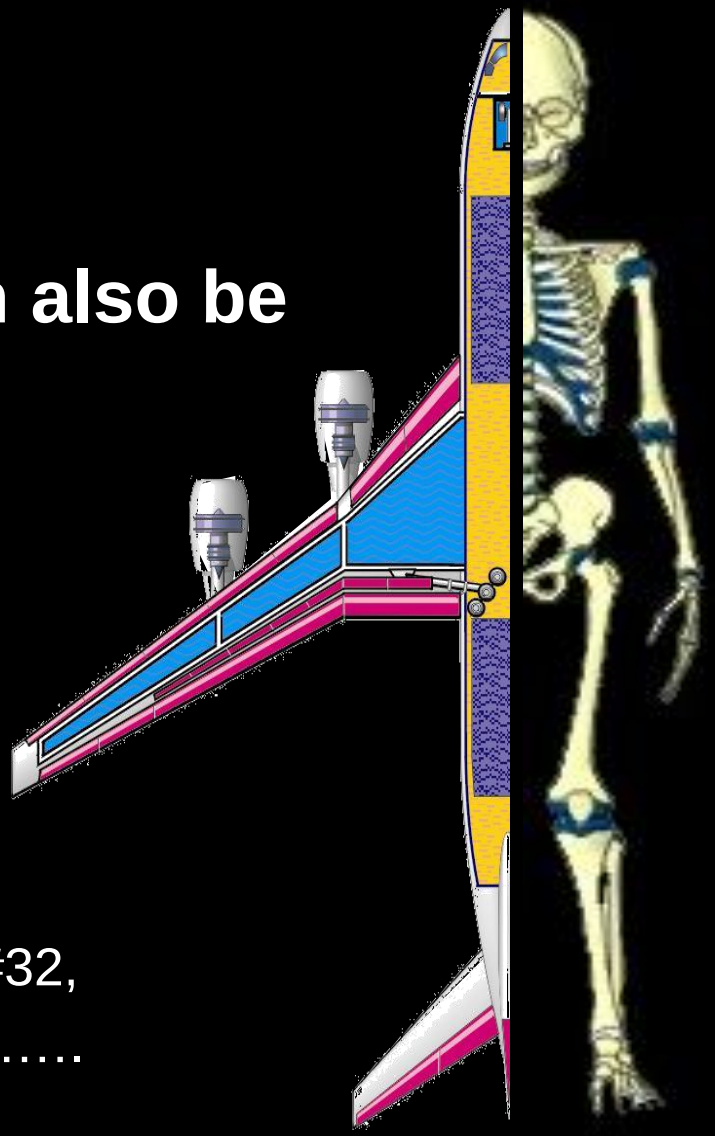
- **PATTERN**
- **Patterns are *ORDINAL***
- **They are *not* x,y,z coordinates**
  - **If this were true, legs could grow out of ear canals, or not even be connected to the rest of the body!**
  - **We never observe this in nature.**

PATTERN P^1

P^3
Pattern
Proportion
Purpose

- **PATTERN**

- **Airplane arrangements can also be described “ordinally”.**
  - Nacelle #1 connects to Pylon #1,
  - Pylon #1 connects to Wing Rib #12,
  - Rib #12 connects to Rib#11,
  - Rib #11 connects to Rib#10……
  - Rib #2 connects to Rib #1,
  - Rib#1 connects to Fuselage Frame #32,
  - Frame #32 connects to Frame # 33…….



PROPORTION P²

P³
Pattern
Proportion
Purpose

- **PROPORTION – How big am I?**
  - **Bone Proportions (Scalar value)**
    - **Vertebrae are different sizes but ~proportional.**
    - **What codes a Giraffe vs. a Deer vertebrae?**
    - **Scalars set initial proportions for a feature.**
    - **Growth Hormones act as outer-loop scalars.**

PROPORTION P^2

P^3
Pattern
Proportion
Purpose

A Giraffe is merely a stretched Gazelle.
Same number of neck vertabrae.

The substructure stretch is echoed by the pattern of the coat.

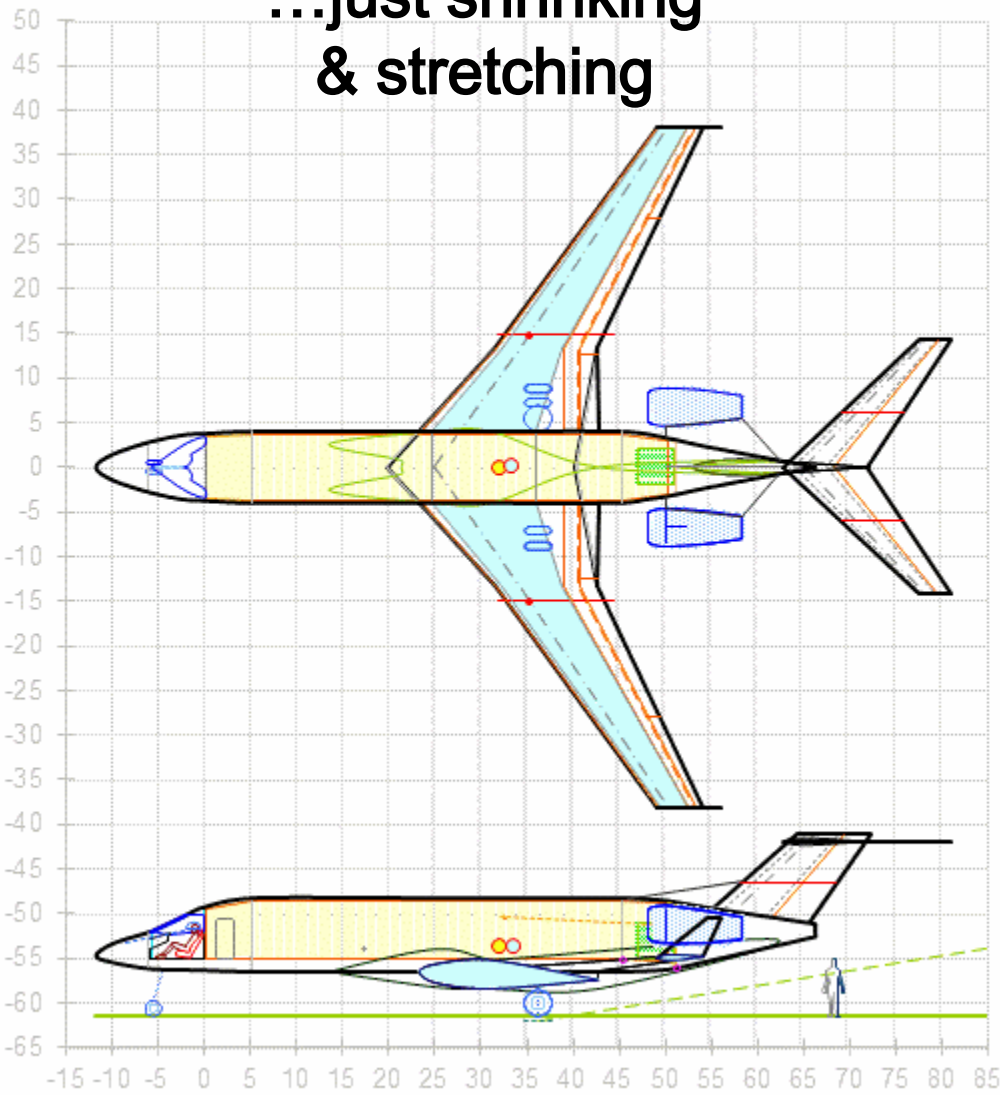
PROPO

P3
Pattern
Proportion
Purpose

A Giraffe is mer
Same number c

retch is echoed

Gulfstream to Phenom
…just shrinking
& stretching



PROPORTION P^2

P^3
Pattern
Proportion
Purpose

- **Scalars – Variation in Scalars Only = Class**
  - **All Mammals are stretched versions of each other.**
  - **No other fundamental difference.**
  - **Same internal organs.**
  - **Same developmental cycle.**
  - **Different proportions.**

PROPORTION P^2

P^3
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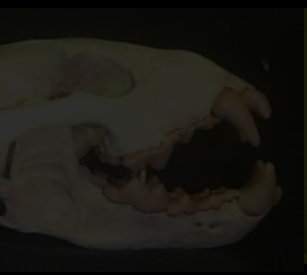
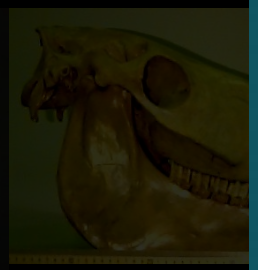
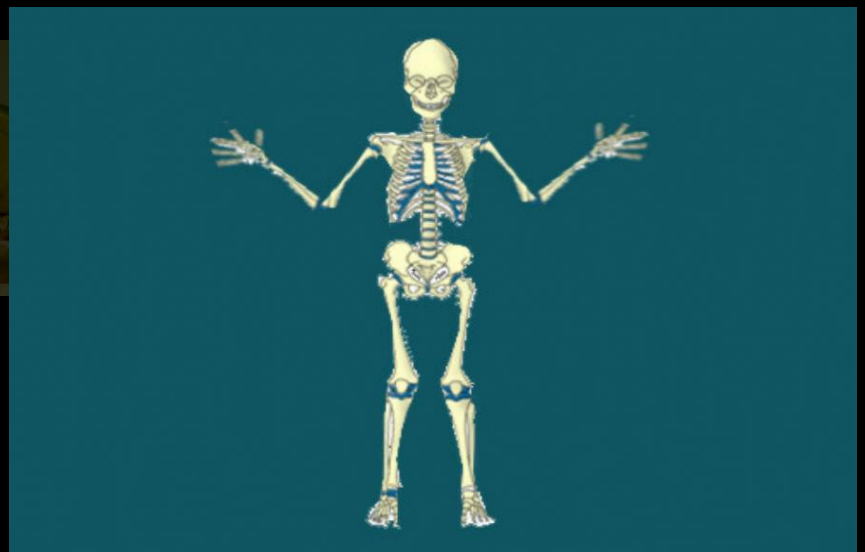
PROPORTION P^2

P^3
Pattern
Proportion
Purpose

- **Scalars – Variation in Scalars Only = ~Genus**
  - **All Mammals are stretched versions of each other.**
  - **No other fundamental difference.**
  - **Same internal organs.**
  - **Same developmental cycle.**
  - **Different proportions.**







PROPORTION P^2

P^3
Pattern
Proportion
Purpose

Common Name	Human	Common Chimpanzee	Grey Wolf	Tiger Snake	Monarch Butterfly
Domain	Eukaryota	Eukaryota	Eukaryota	Eukaryota	Eukaryota
Kingdom	Animalia	Animalia	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata	Chordata	Arthropoda
Class	Mammalia	Mammalia	Mammalia	Reptilia	Insecta
Order	Primates	Primates	Carnivora	Squamata	Lepidoptera
Family	Hominidae	Hominidae	Canidae	Elapidae	Nymphalidae
Genus	Homo	Pan	Canis	Notechis	Danaus
Species	Homo sapiens	Pan troglodytes	Canis lupus	Notechis scutatus	Danaus plexippus

Foundational Chemistry differences live here

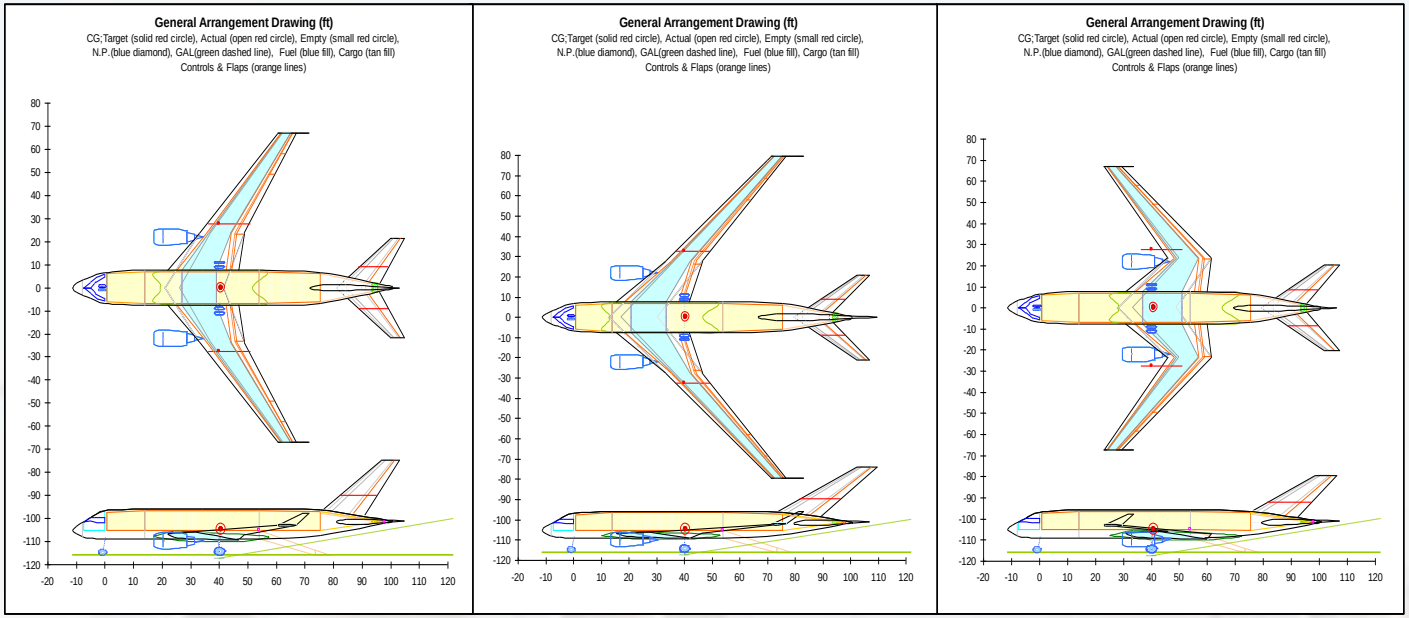
Pattern differences live here

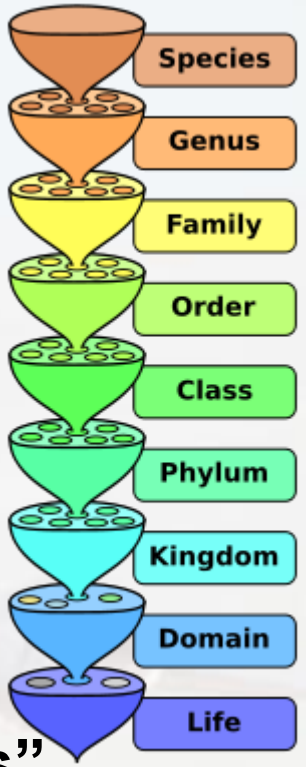
Proportion differences live here

PROPORTION P^2

P^3
Pattern
Proportion
Purpose

➢Same CLASS – Like Mammals; Variation in Scalars Only





Many airplanes are from the same “Genus”

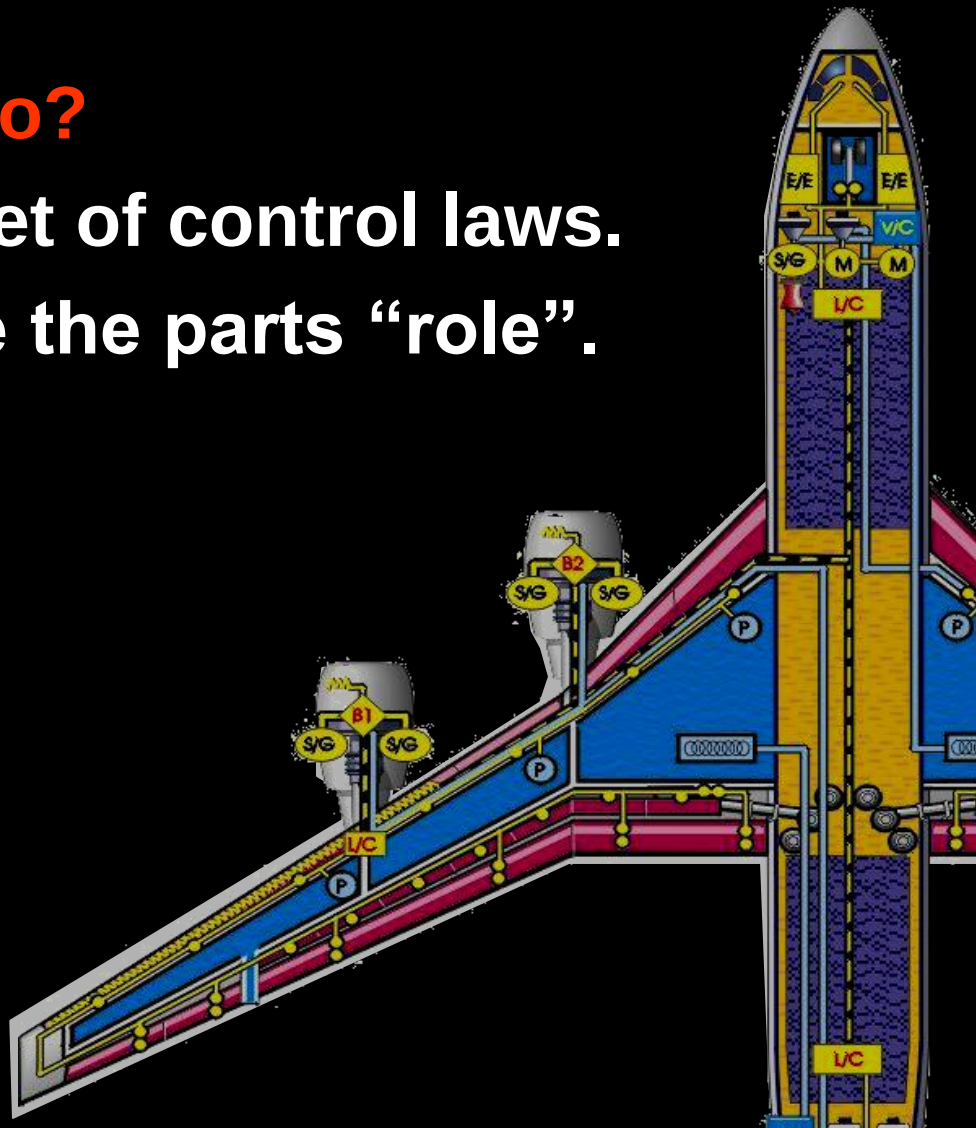
Perhaps all airplanes are in the same “Class”


SINGAPORE AIRLINES

PURPOSE P^3

P^3
Pattern
Proportion
Purpose

- PURPOSE – What do I do?
  - Each block obeys a set of control laws.
  - These laws determine the parts "role".
    - Structure.
    - Seating.
    - Propulsion.
    - etc…….



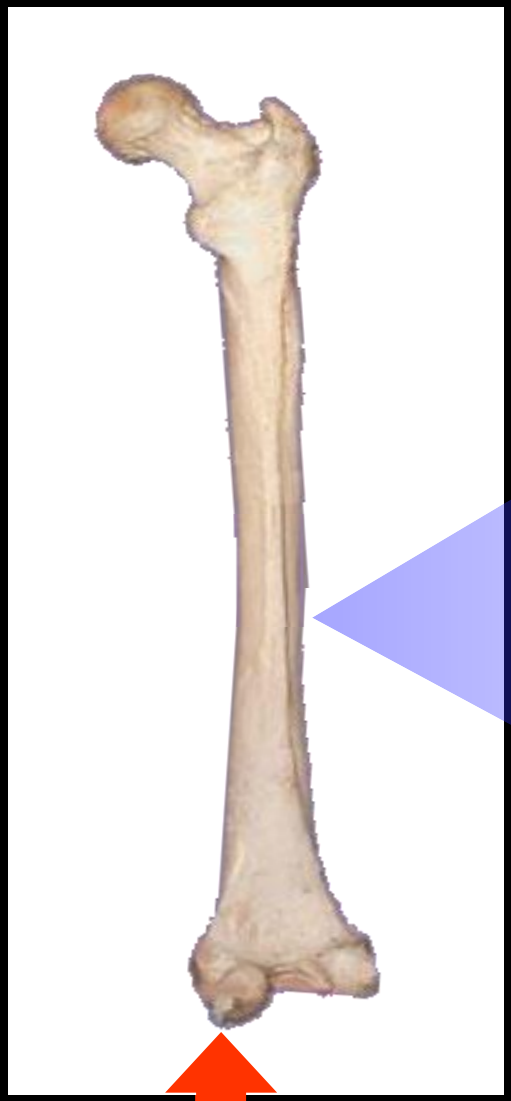
PURPOSE P^3

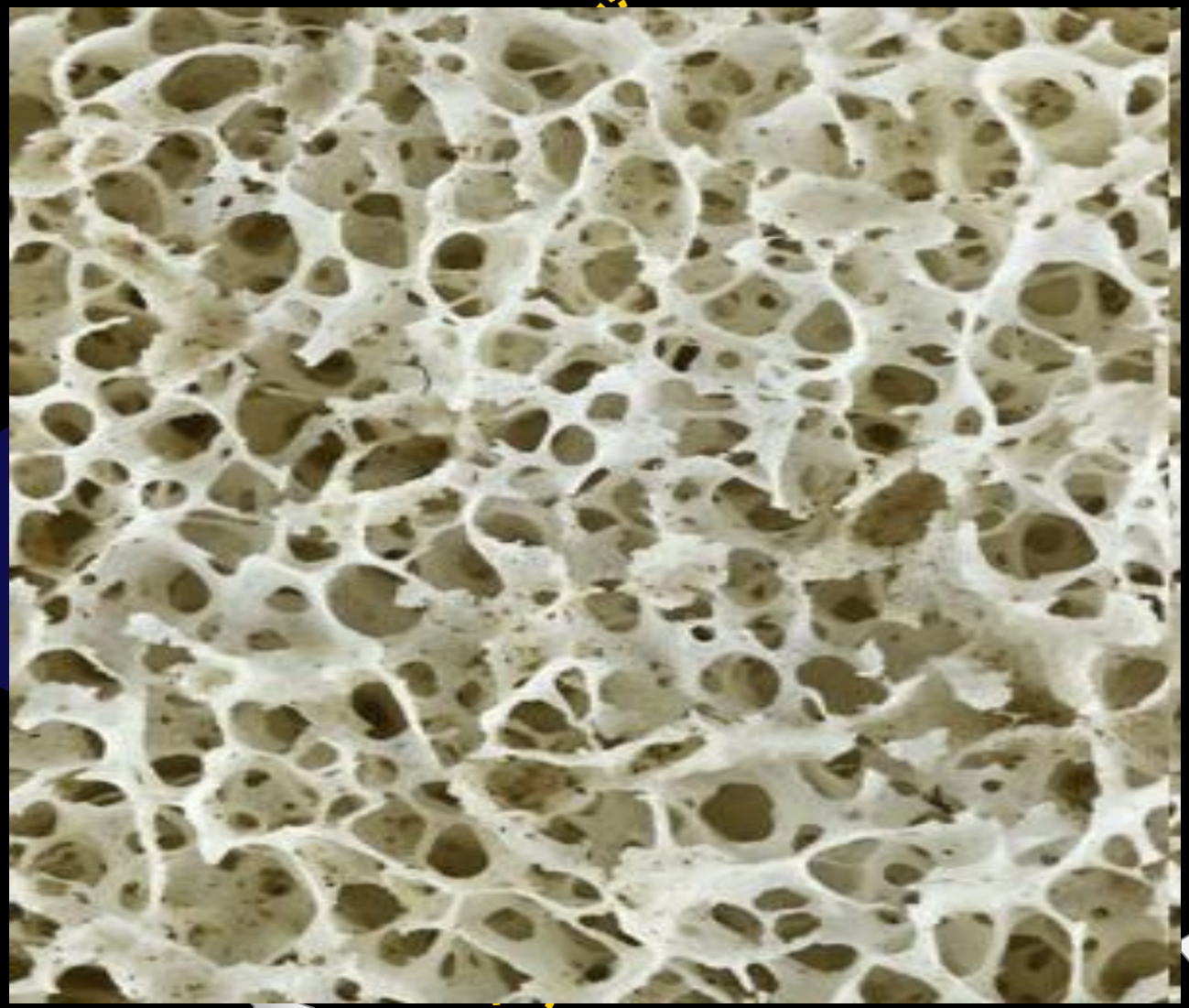
P^3
Pattern
Proportion
Purpose

- PURPOSE = Internal Control Law (ICL)
- Bone Example
  - Bone Cell ICL
    - If cell strain > X, then cell wall binds calcium.
    - Slowly release calcium as well.
    - Therefore, calcium uptake sets a strain limit.
    - Disuse releases calcium for other bones.

PURPOSE P^3

P^3
Pattern
Proportion
Purpose

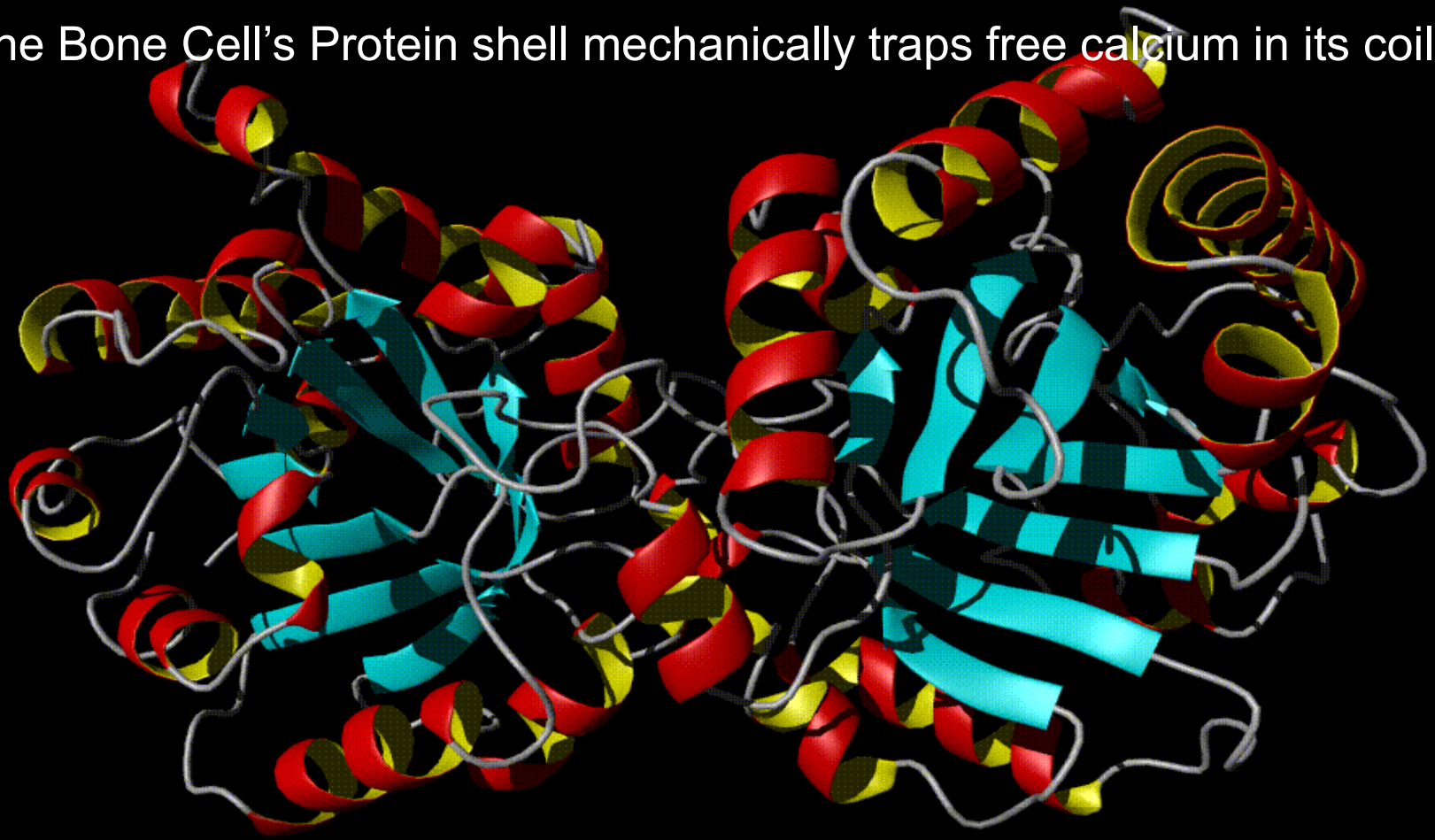




PURPOSE P^3

P^3
Pattern
Proportion
Purpose

The Bone Cell's Protein shell mechanically traps free calcium in its coils



Protein Structure = Mechanical ICL

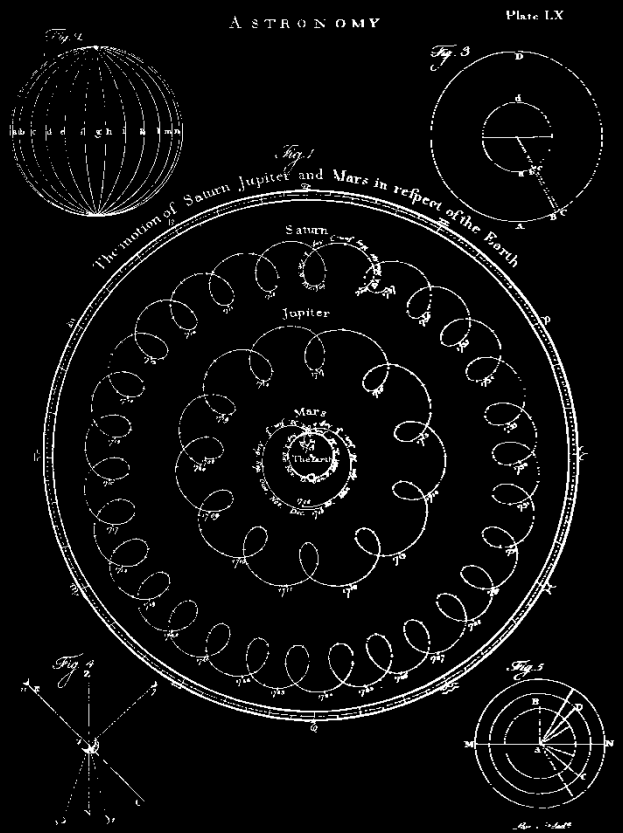
PURPOSE P^3

P^3
Pattern
Proportion
Purpose

Cartilage cells have a different ICL that cause their protien (Collagen) to spread under excess pressure and make a smooth surface.

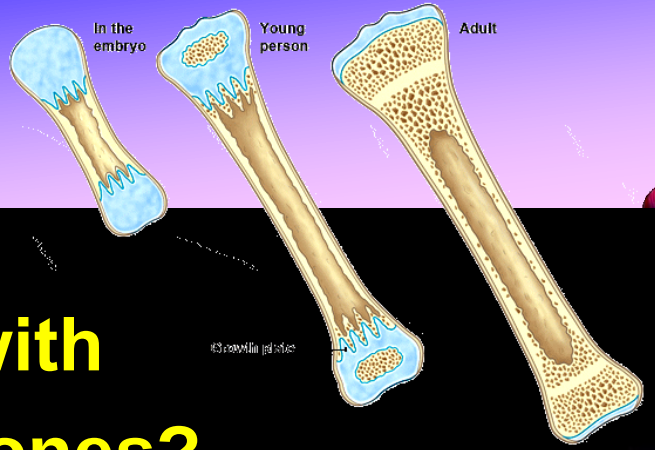
Cartilage is 5 times more slippery than ice.

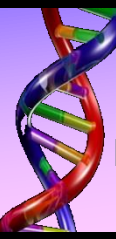
With synovial fluid, this combo is 15 times more slippery than ice and far more slippery than Teflon.



With repeated flexing
The knee-joint's ICL's fom a perfect Epicycloid
Similar to the orbit of Mars as observed from Earth

PURPOSE P^3





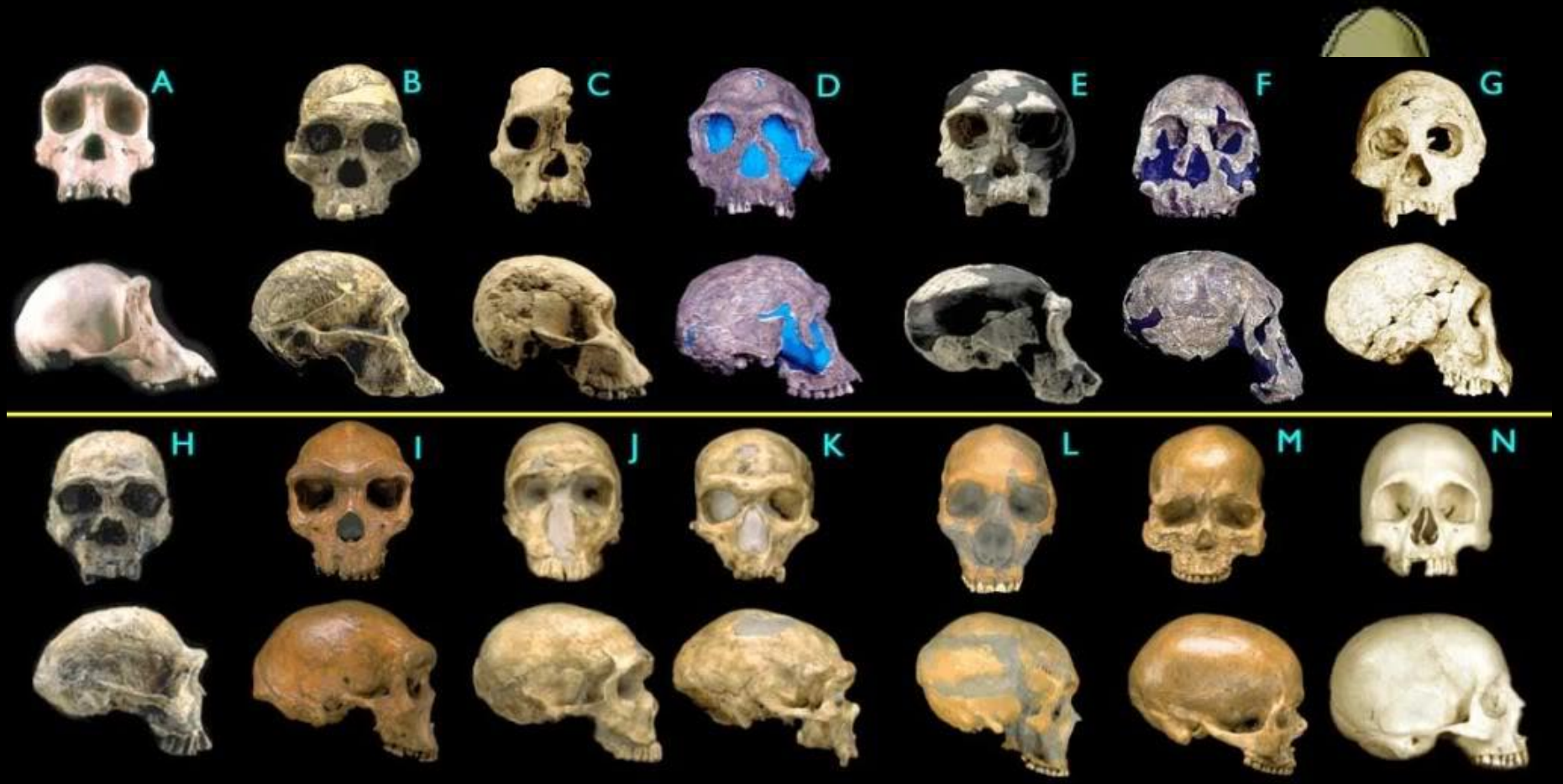
P^3
Pattern
Proportion
Purpose

- **Why are baby's born with beautifully sculpted bones?**

- Bones start out as ~identical tubes.
- Muscle & tendon connections established.
- None of the features yet sized for loads.
- Baby kicks & wiggles – loads bones.
- ICL's add bulk where needed.
- Bones develop refined structure.

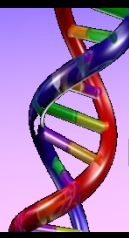
PURPOSE P^3

P^3
Pattern
Proportion
Purpose



except that its growth applies pressure that inflates the cranium?

PURPOSE P^3



P^3
Pattern
Proportion
Purpose

- There are only about 30,000 instructions in our genome

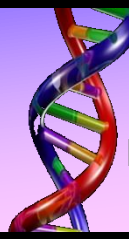
- How is it possible that so few instructions can build something as complex as a fully-formed human?

- **It's amazing**

- Actually, the genome *doesn't* describe a fully-formed human,
- Instead, it describes the machine that makes the human

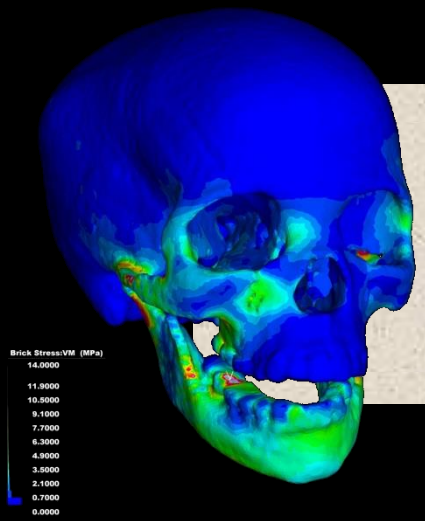
- The internal control laws build most of the complexity when subjected to the demands of the womb… ….and the world

PURPOSE P^3



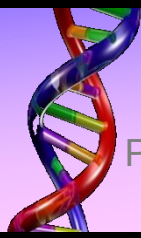
P^3
Pattern
Proportion
Purpose

- Internal Control Law (ICL) – Bone Example
  - Bone Cell ICL
    - Totally controlled by "dumb" protein geometry.
    - ICL causes "optimized" structures to appear.
    - ***BUT the structure wasn't in the genetic code!!!***
      - Only the ICL making the structure is coded.



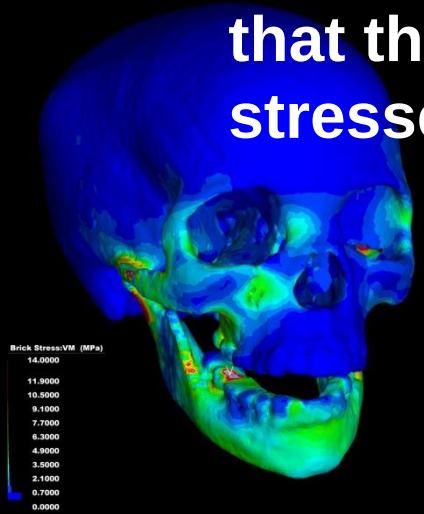
Genes design the *machine*
that designs the organism
VERY EFFICIENT CODE.

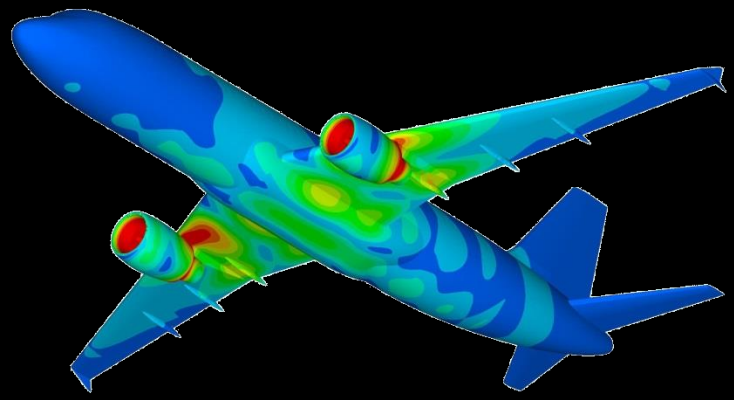
PURPOSE P^3



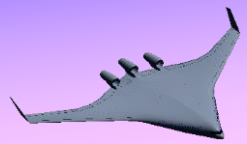
P^3
Pattern
Proportion
Purpose

- **Airplane Structure ICL**
  - If strain > X, then increase thickness.
  - Thickness adjustment sets a strain limit.
  - Unloaded structure stays at minimum gauge.
  - Airplane “lives a life” gets loaded, and sized.
  - Like an FEA with 20 thou thickness everywhere that thickens the skin in proportion to the local stresses

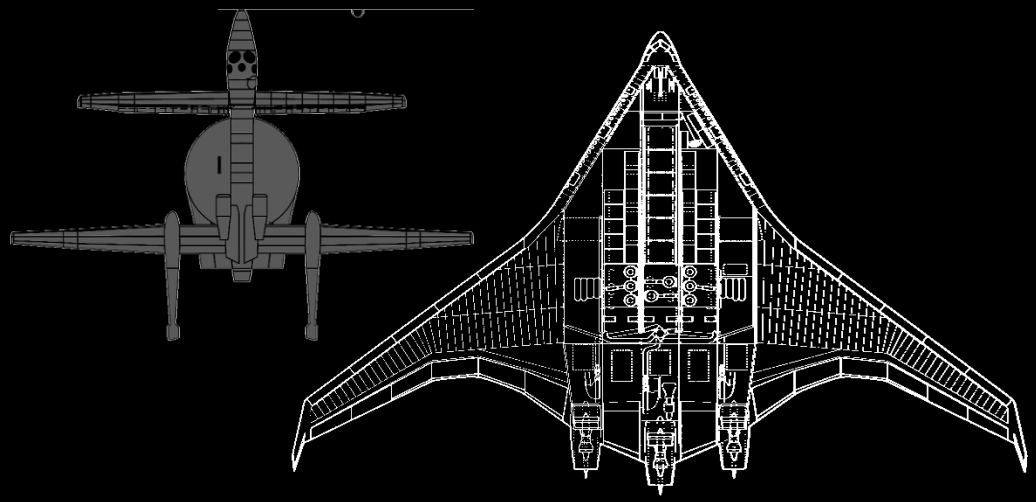




Speciation - A Natural Model for Design

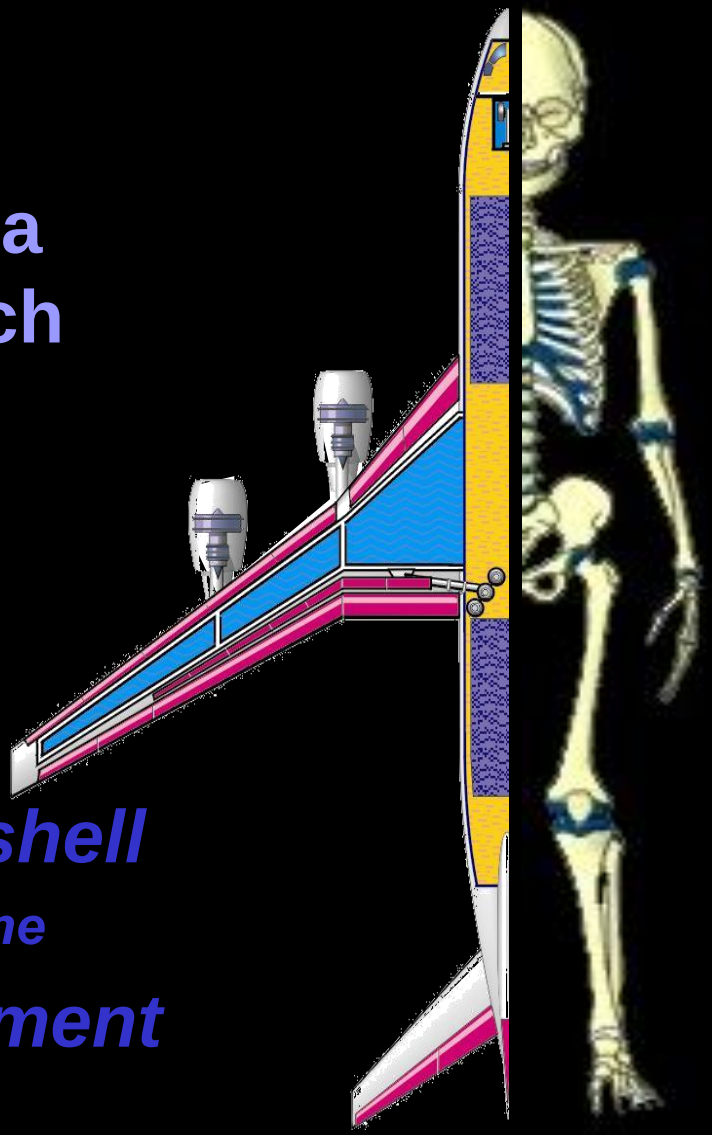


- **Steady Advances in Technology**
  - New ICL's – new alloys, fuels…..
  - Optimized Scalars – airfoils, planforms…
- ***Revolutions*** **come from new** ***PATTERNS***
  - Cambrian explosion.
  - Genus change.
  - Mammals vs. crustaceans.

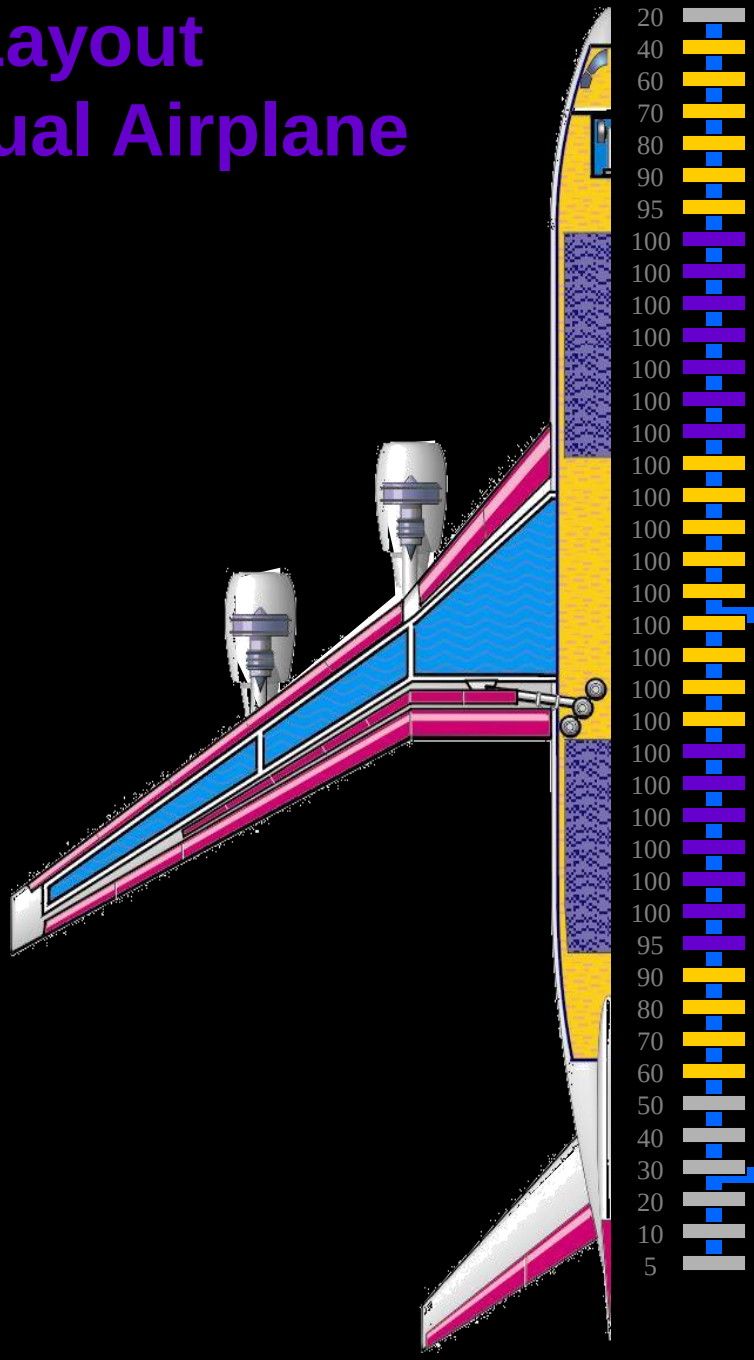


P^3 Theory of Design

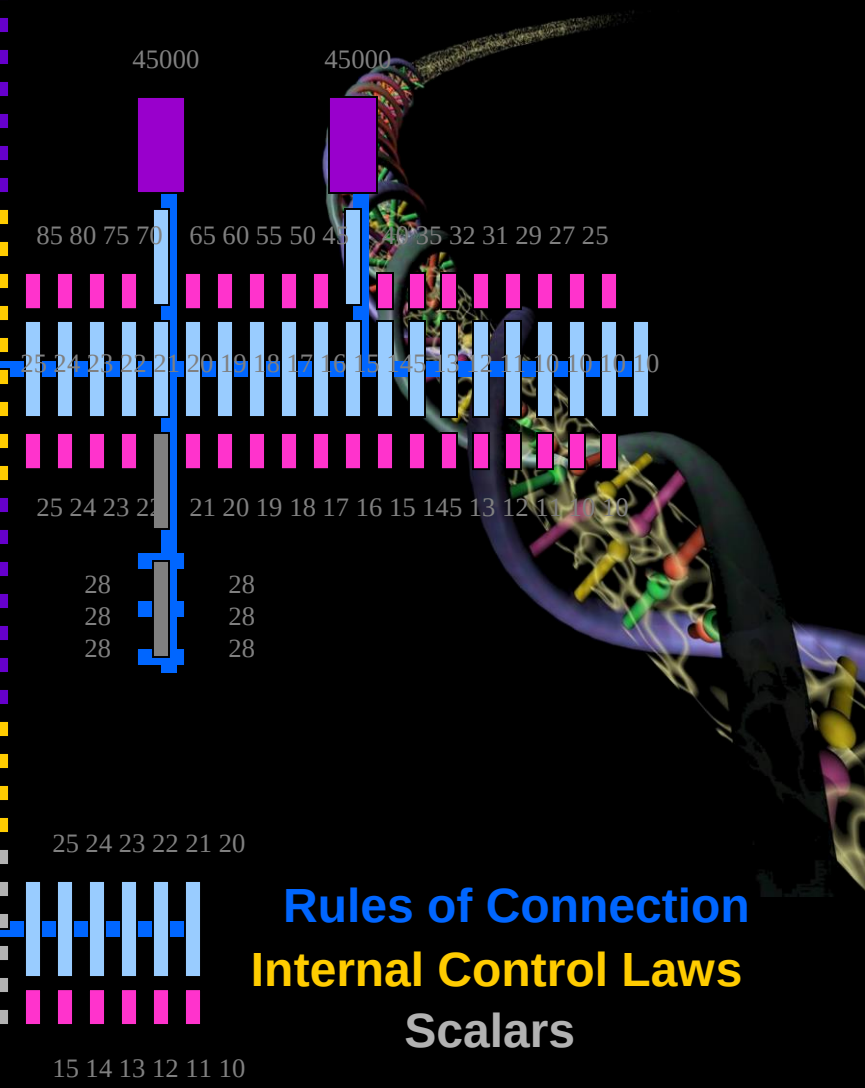
- ***THE GREAT CHALLENGE***
- **Describe an airplane using a sequence of sentences, each consisting of only 3 words;**
  - **Pattern - ROC's**
  - **Proportions - Scalars**
  - **Purpose - ICL's**
- ***This will build an un-sized shell***
  The "machine" that will make the plane
- ***It gets <u>sized</u> by its environment***



Layout of Actual Airplane



Ordinal Model Of Airplane



Rules of Connection

Internal Control Laws

Scalars

P^3 SUMMARY

P^3
Pattern
Proportion
Purpose

Design in nature and industry share many elements.

- Competitive advantage is the engine for advancement.

- Most designs are evolutions of successful predecessors.

-This we understand in modern optimization algorithms.

- However, the root words may not be well understood.

- P^3 may be the appropriate word for the design language.

- ***Pattern*** *- Rules of connection - Where am I?*
- ***Proportion*** *- Scalars - How big am I?*
- ***Purpose*** *- Internal Control Law - What do I do?*

Happy Birthday Tony!!!