

WORDS, GRAPHS, CODE

A unified model

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ENTITIES, SYMBOLS, BINDINGS

Building blocks of symbolic systems

"ATOMIC"

primitive, elementary, assumed, axiomatic, self-evident, self-explained, taken-for-granted...

ENTITIES

Physical objects and concepts



(These are symbols, not entities themselves.)

SYMBOLS

(let's say symbols are just any marks that may mean anything)

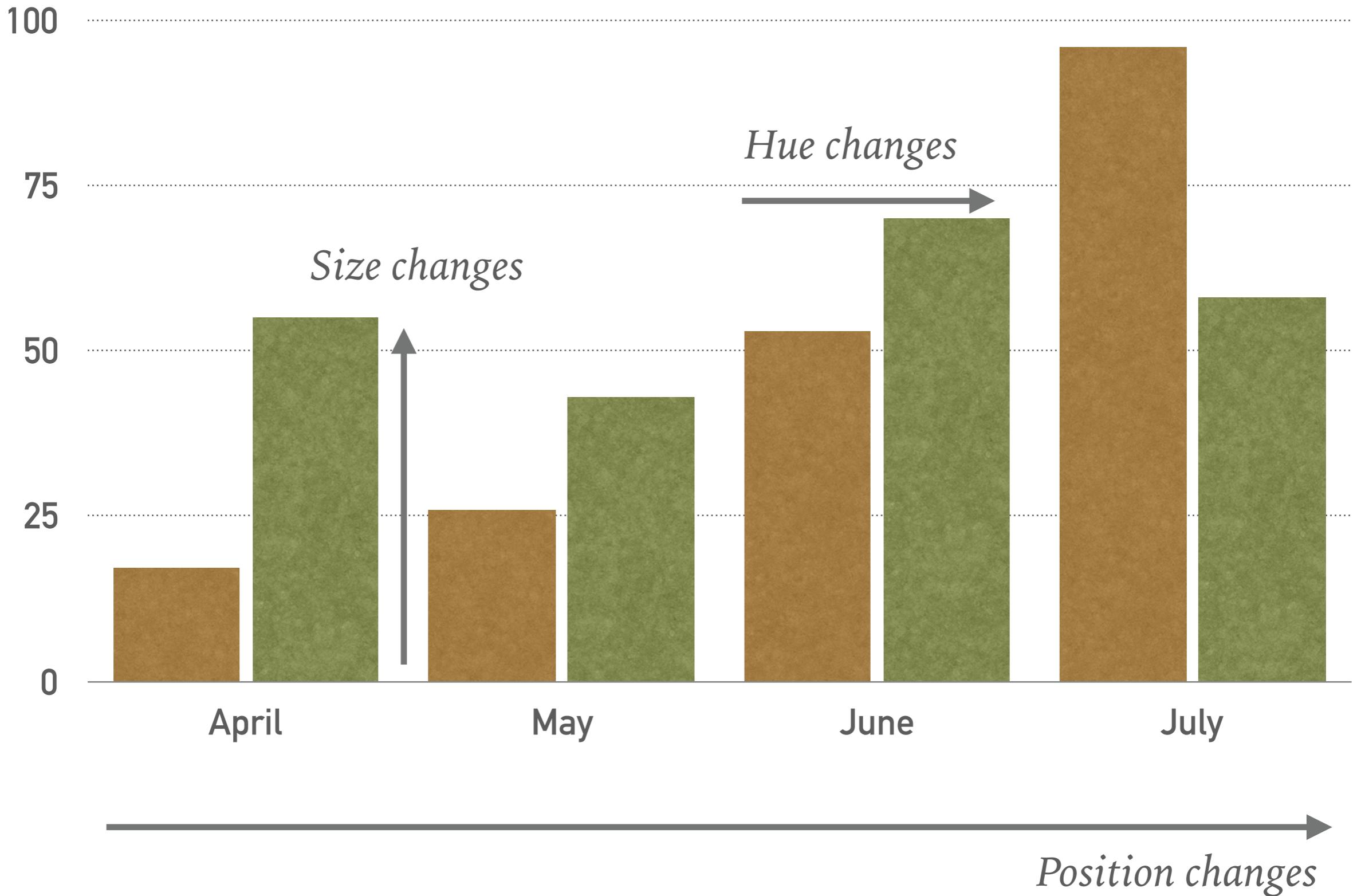
WRITTEN SYMBOLS

- Words
- Punctuations

EXAMPLE OF GRAPHIC SYMBOLS

- Positions
- Sizes
- Shapes
- Colours
- Established symbols
- Words (written symbols)

SYMBOLS IN A GRAPH

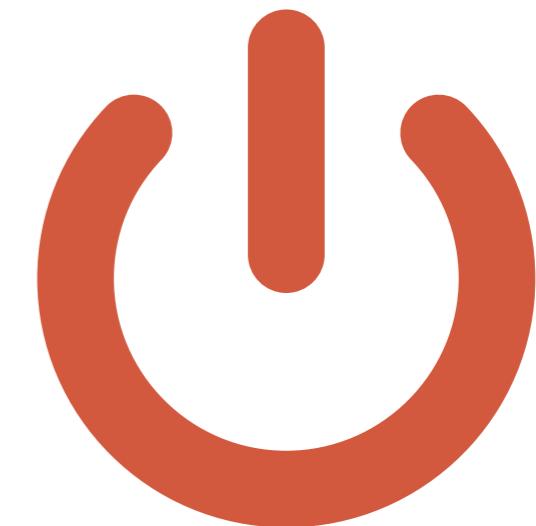
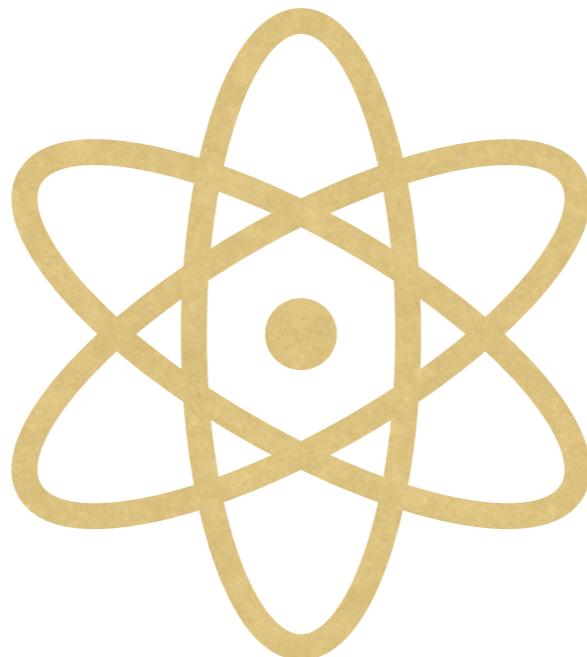
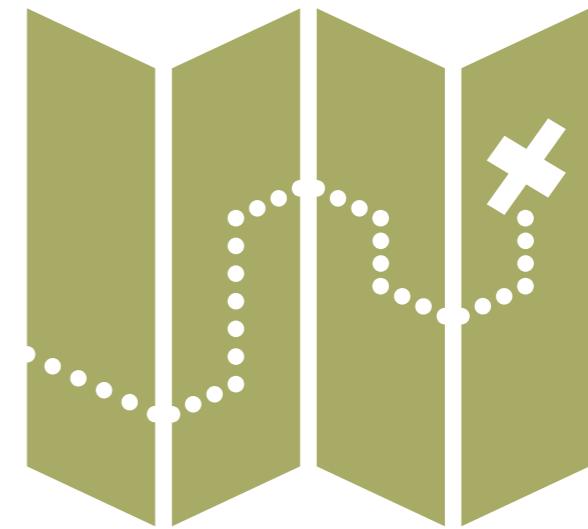


COLOUR MODELS

Colour is not “atomic”: it can be separated into parts

- Biological model
- RGB model
- HSL model

ESTABLISHED SYMBOLS



SYMBOLS IN PROGRAMMINGS

- Variables (for data)
- Functions (for computation)

BINDINGS

Connecting entities with symbols

“apple”

Binding1

“malum”

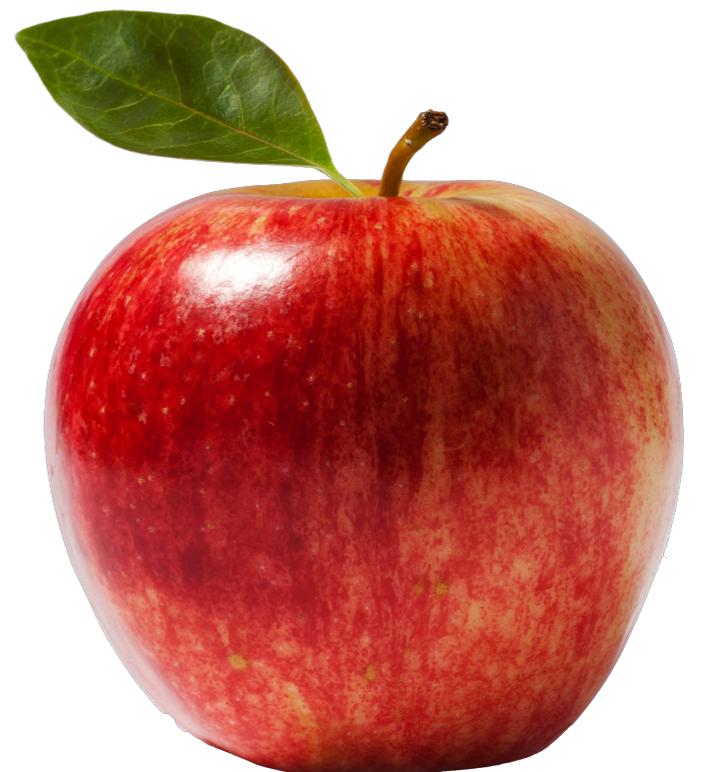
Binding2

“蘋果”

Binding3

“林檎”

Binding4



“NAME”

A name is a symbol bound to an entity

COMPOSITION

Composition groups multiple symbol into an entity, and name the entity with a symbol

EXAMPLES OF SYMBOLIC COMPOSITION

- “**Association football**, more commonly known as football or soccer, is a team sport played between two teams of eleven players with a spherical ball.” (Wikipedia)

```
const average = array => array.reduce(  
  (a, b) => a + b  
) / array.length
```

ALIAS

Binding multiple symbols to one entity

“SYSTEM”

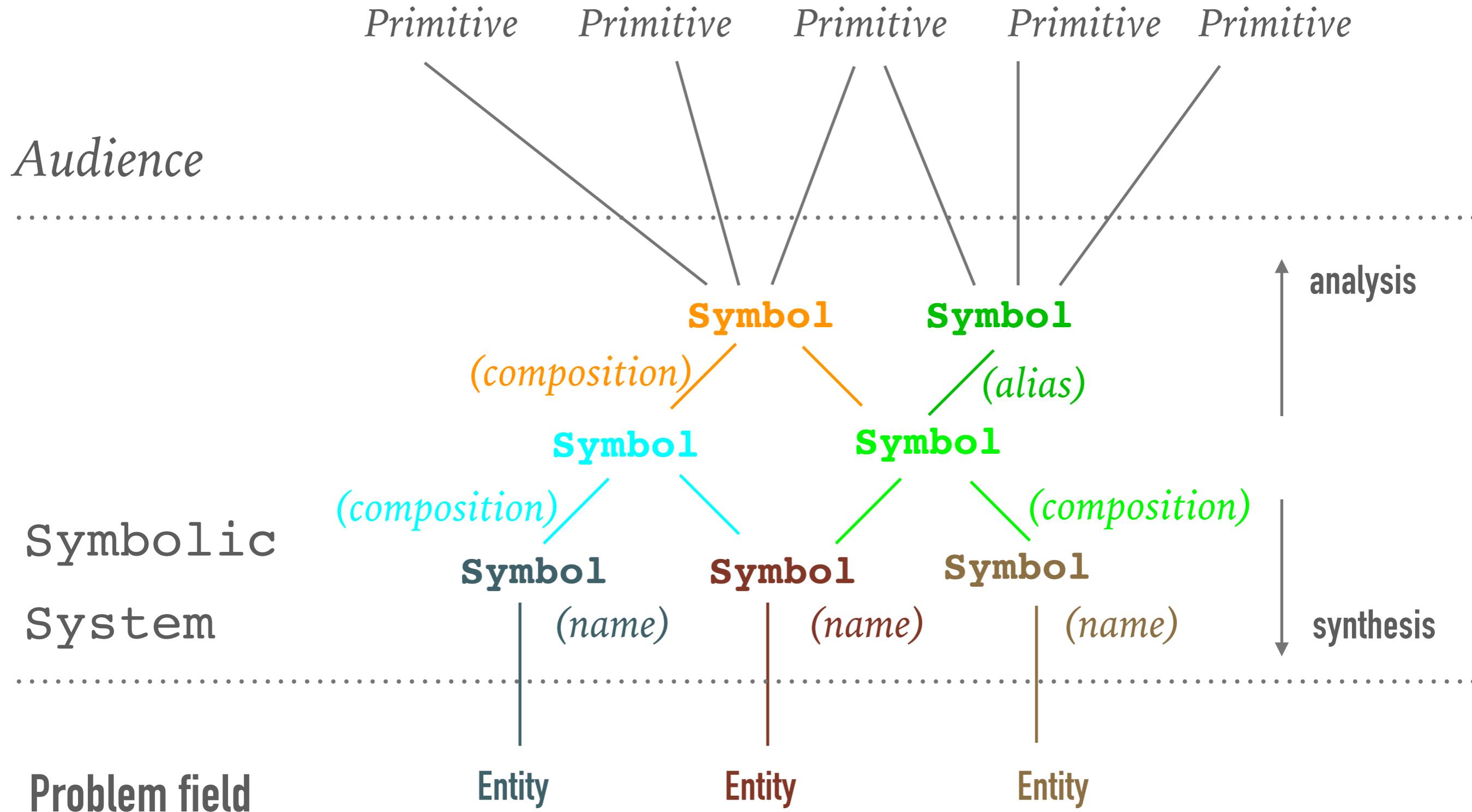
THE IDEA OF “SYSTEMS”

- A system is structured:
 - 1. It has parts;
 - 2. Connections between the parts are significant.
- Systems often interface with other systems: Input/Output
- Systems may contain sub-systems

“SYMBOLIC SYSTEM”

A symbolic system is a system whose parts are symbols

SYMBOLIC ENGINEERING



WHY USE SYMBOLS?

BENEFITS OF SYMBOLS

- Easy to transfer
- Cheap duplication
- Bend physical laws
 - What-ifs
- Arbitrary rules can be set up

SYMBOLIC SYNTHESIS

Composing symbols

CSV: CALCULATING THE AVERAGE AGE

name, age

John, 23

Mary, 44

Justin, 67

Lucy, 32

characters

newline (\n)

comma (,)

row

column

index

cell

data (age)

adding

summation

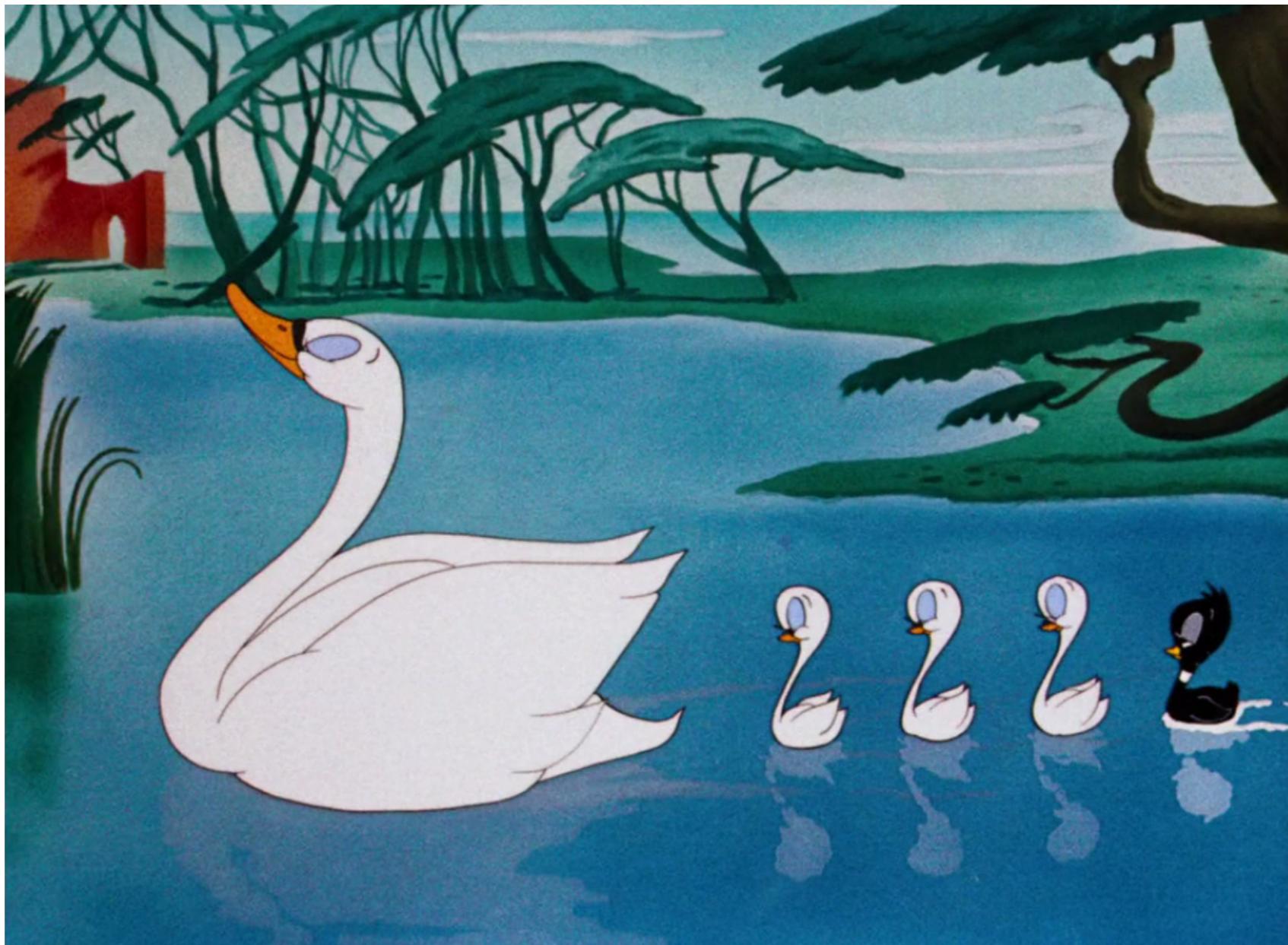
average

GENERAL PROCEDURE OF SYMBOLIC SYNTHESIS

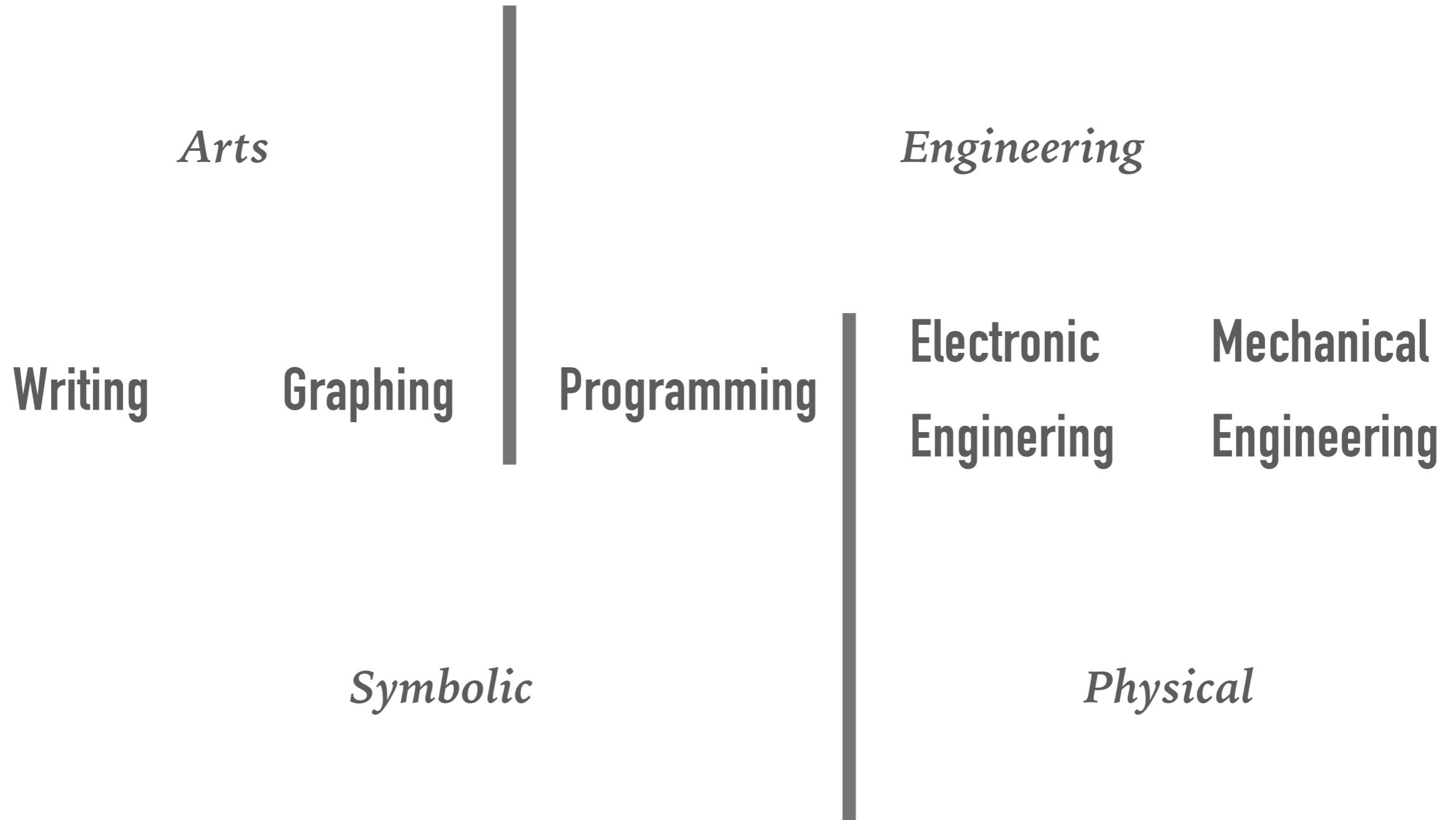
Procedure	Writing	Graphing	Coding
1. What are the primitives?	What does my audience already know?	What visual patterns can my readers already recognise?	What are provided by the standard library and host environment?
2. What are the entities to represent?	What do I want to write about?	What do I want to show?	What do I want to implement?
3. What to optimise for the system?	Brief? Eye-grabbing? Memorable?		Fast? Short? Maintainable?
4. Start with primitives or entities?		Combine primitives, or decompose entities (or names thereof)	
5. What intermediate symbols are the best choices?		Work out the connections	

THE UGLY DUCKLING THEOREM (SATOSI WATANABE, 1969)

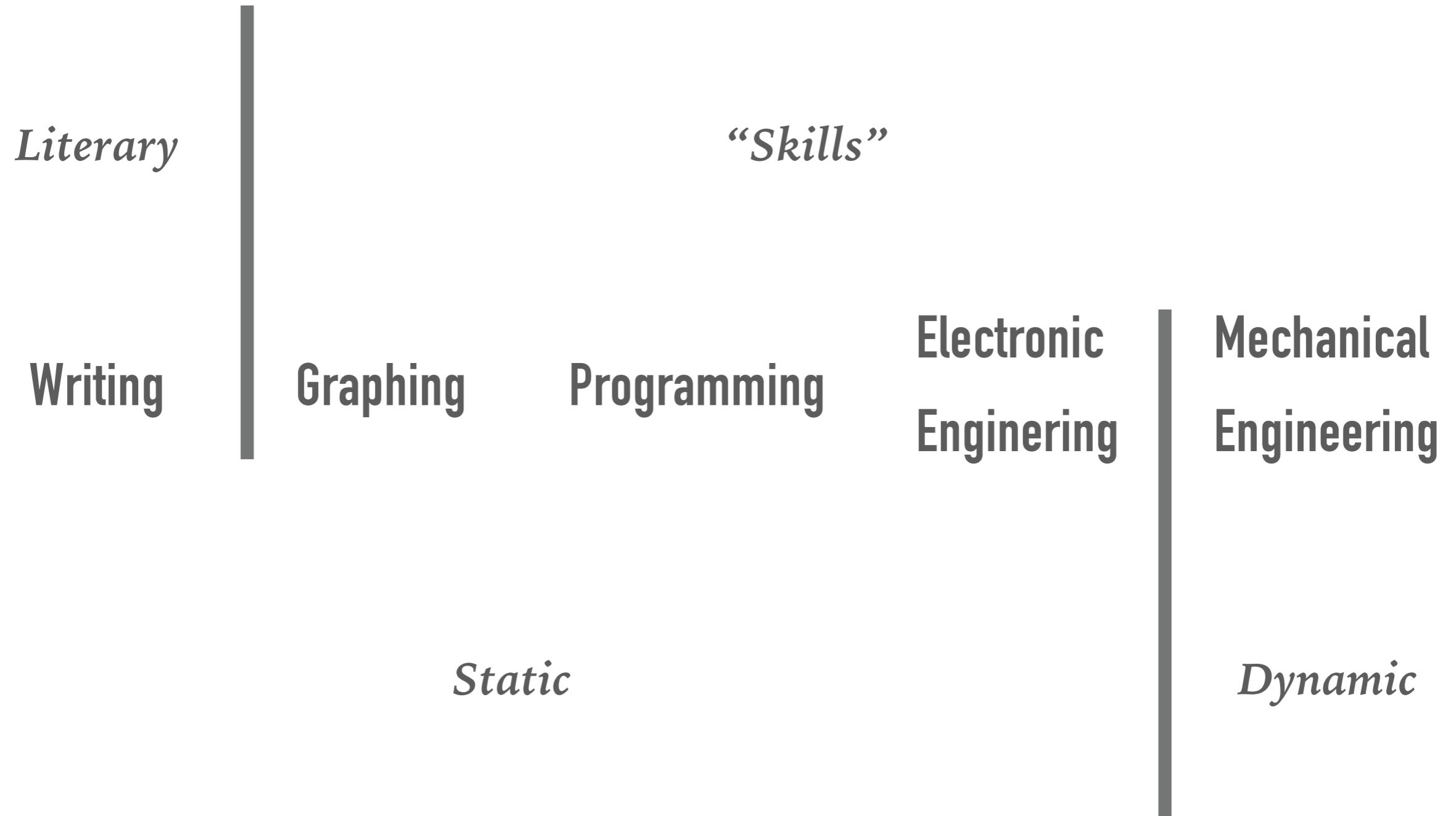
- For complex entities, any grouping is arbitrary and equally valid, unless criteria are in force



WHICH FIELD DOES PROGRAMMING BELONG?



REALLY, ANY GROUPING CAN BE JUSTIFIED

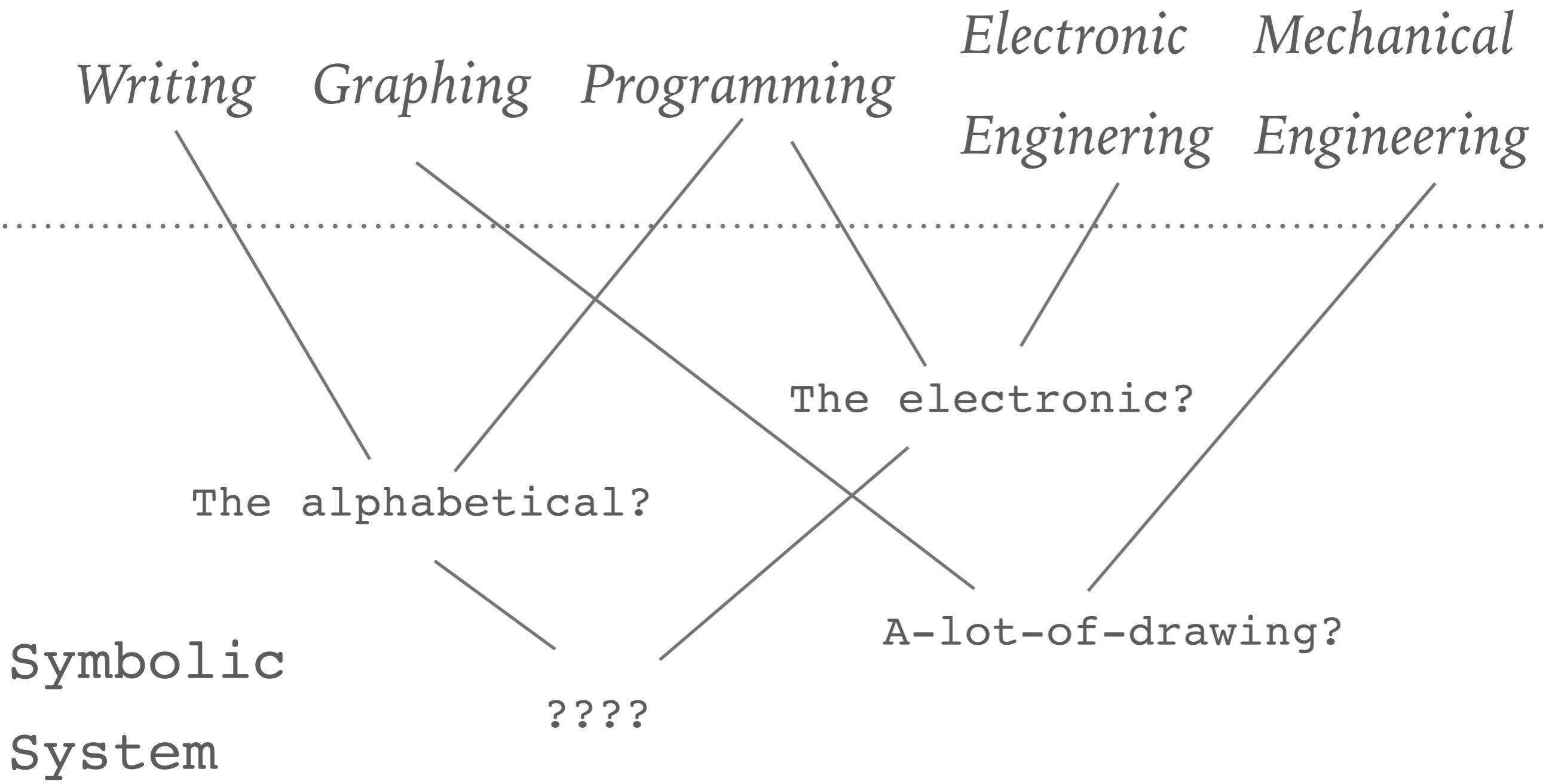


CAVEATS

- Entities need to be “complex”, i.e. feature rich
 - You can't really group (1, 1, 1, 1, 1, 2, 2, 2)
- If some criteria are in force (some groupings are favoured over others), by definition some groupings are superior

ALL SYMBOLIC STRUCTURES ARE POSSIBLE

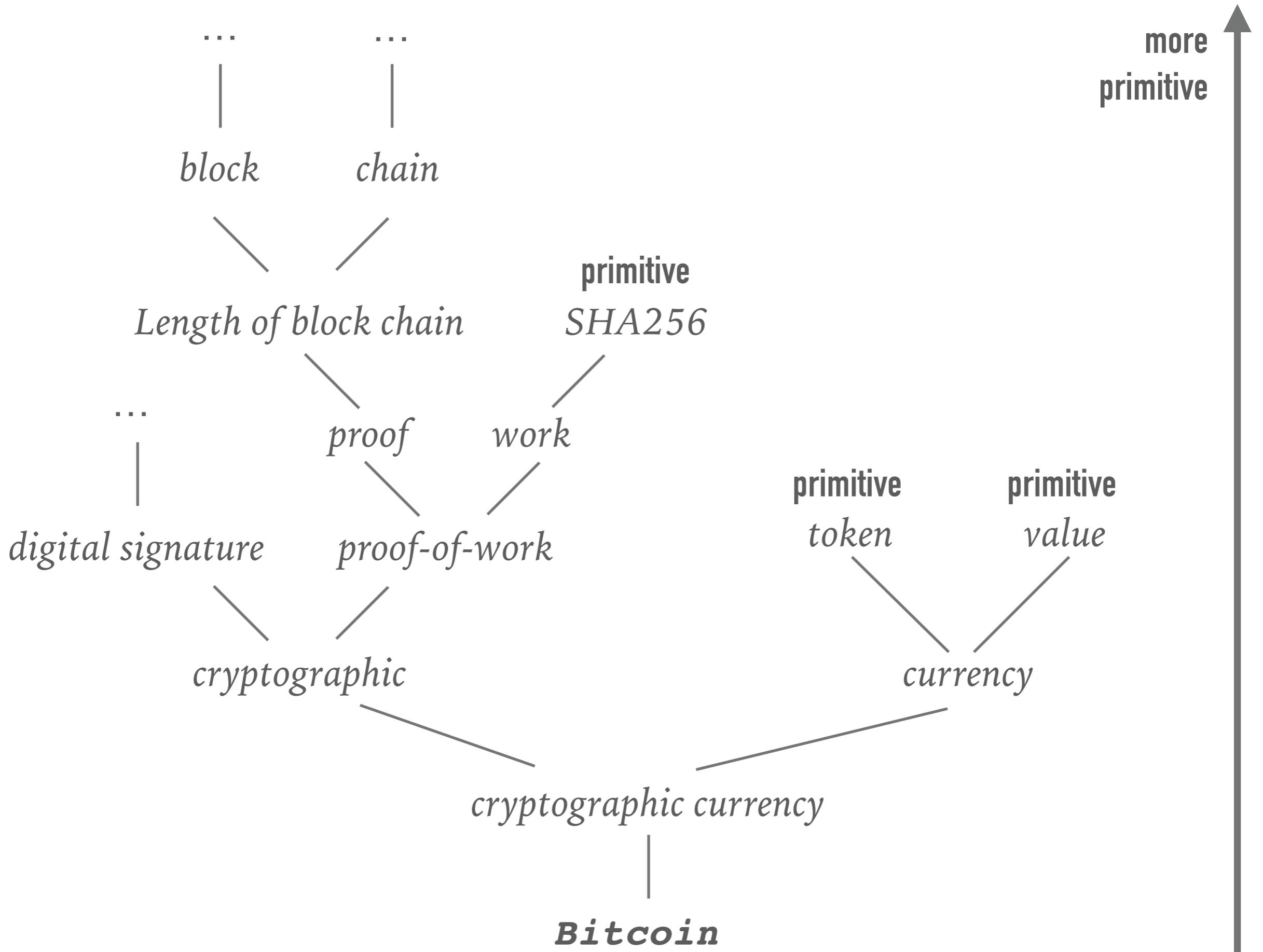
Primitives



SYMBOLIC ANALYSIS

Decomposing symbols

**SO, WHAT EXACTLY IS
BITCOIN?**



GENERAL PROCEDURE OF SYMBOLIC ANALYSIS

Procedure	Writing	Graphing	Coding
1. What is the symbol to investigate?	A term?	A graph?	A function?
2. Is the symbol primitive?	Do I know this symbol already?	Do I know what this graph says?	Do I know what this function do?
3. If not primitive, how is the symbol composed?	How is the symbol defined in terms of others	What's components of this graph?	What functions does this function call?
4. Repeat 2-3 until all symbols are primitives		Keep decomposing symbols	

SYNTHESIS VS. ANALYSIS IS ARBITRARY

**ALL SYSTEMS ARE
EQUAL;
SOME SYSTEMS ARE
MORE EQUAL....**

CRITERIA OF GOOD SYMBOLIC SYSTEMS

- Formal criteria
 - Explicit
 - Bijective
 - Minimal
 - Aesthetic
- Contextual criteria
 - Empirical
 - Scientific
- Consequential criteria
 - Pragmatic
 - Darwinian

The lists are neither exhaustive nor mutually exclusive

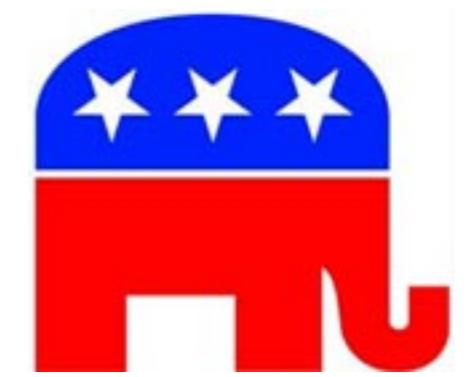
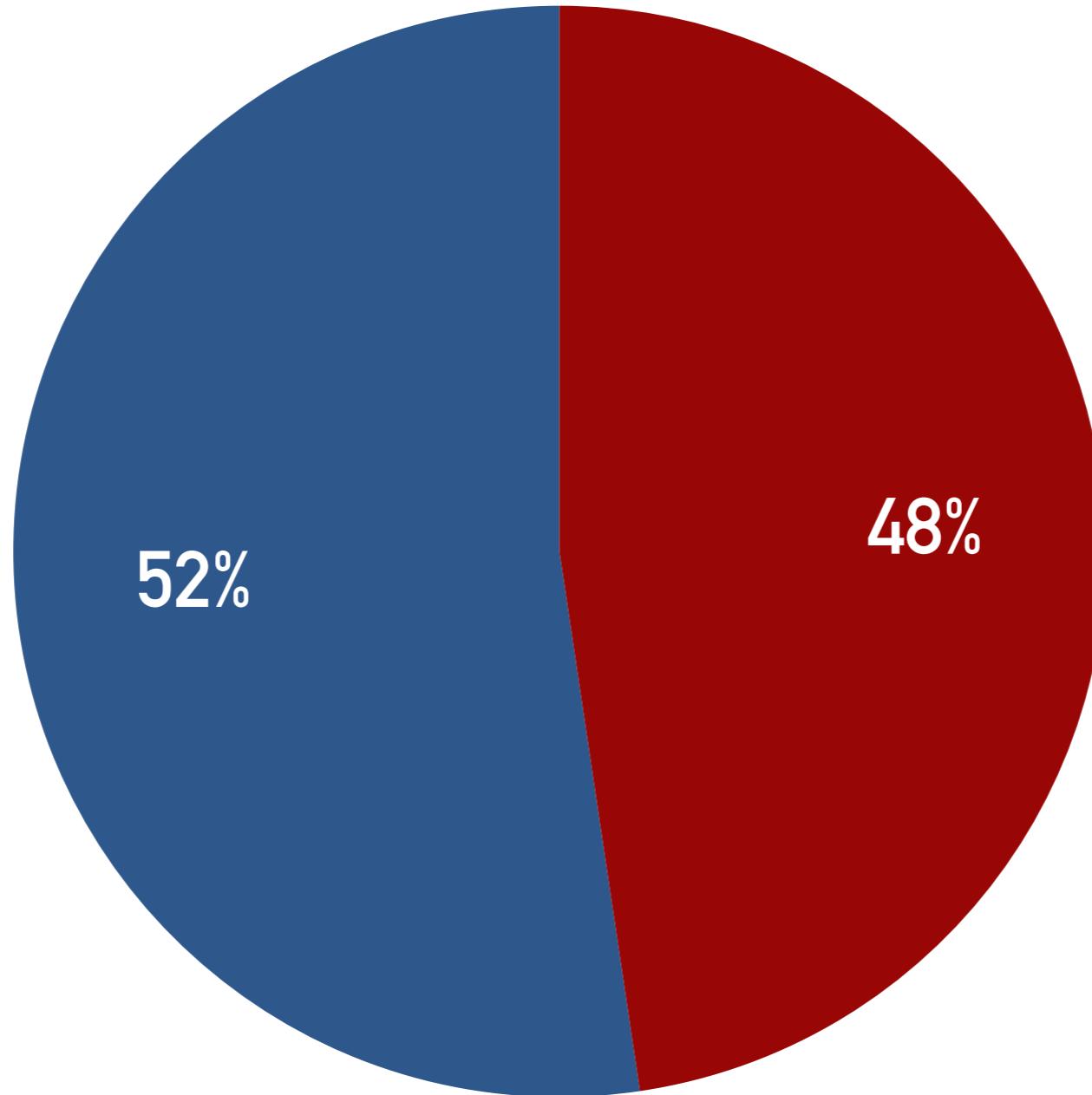
THE EXPLICIT CRITERION

- Primitives, compositions, and new symbols are expressed rather than implied
- Declaration of Independence of the Thirteen Colonies
 - We hold these truths to be *self-evident*, that all men are created equal...
- Explicitness depends on the audience

RESULT OF AN IMAGINARY ELECTION IN US



Democrat



Republican

THIS IS AN INFINITE LOOP IN PYTHON

```
should_continue = true  
while should_continue:  
    do_work()  
    if work_finished():  
        shoud_continue = false
```

THE BIJECTIVE CRITERION

- Each entity has one and only one name
 - Each name refers to one and only one entity
 - No alias or synonyms (e.g. liberty vs. freedom)
 - No unbound names (symbols that don't mean anything)
 - No anonymous entities
-
- Bijective written works could be drys

CENTRAL DOGMA OF VISUAL DESIGN

Similar things should look similar;
Different things should look different.

(or, in Classical Chinese: 同同異異)

WHY DOES THIS LAYOUT LOOK OFF?

*We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator **with certain** unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness.*

—That to secure these rights, Governments are instituted among Men, deriving their just powers from the consent of the governed,

*—That whenever any Form of Government becomes destructive of these ends, it is the Right of the People **to alter or to abolish** it, and to institute new Government, laying its foundation on such principles and organizing its powers in such form, as to them shall seem most likely to effect their Safety and Happiness.*

THE MINIMAL CRITERION

- Use as few symbols as possible to achieve the desired effects
- “Occam’s razor”
- “If it is possible to cut a word out, always cut it out.”

Politics and the English Language, George Orwell

- “Enter late, exit early”

William Goldman

MINIMALISM IS A PROGRAMMING GENRE



JS1k: The JavaScript code golfing competition

[2010 First](#)[2010 Xmas](#)[2011 Oregon Trail](#)[2012 Love](#)[2013 Spring!](#)[2014 Dragons](#)[2015 Hype Train](#)[2016 eleMental](#)[2017 Magic](#)[2018 Coin Mine](#)[About](#)

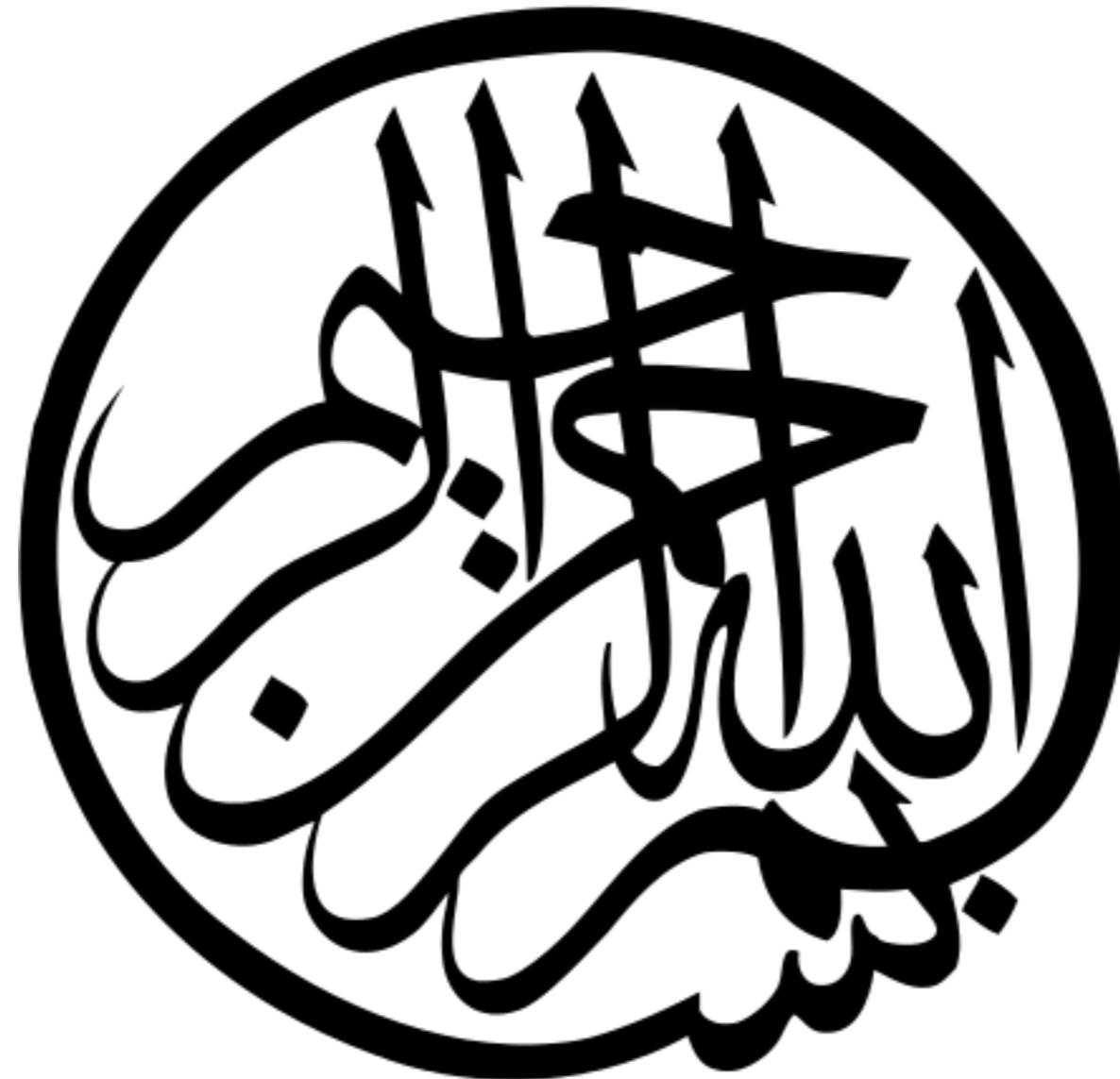
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THE AESTHETIC CRITERION

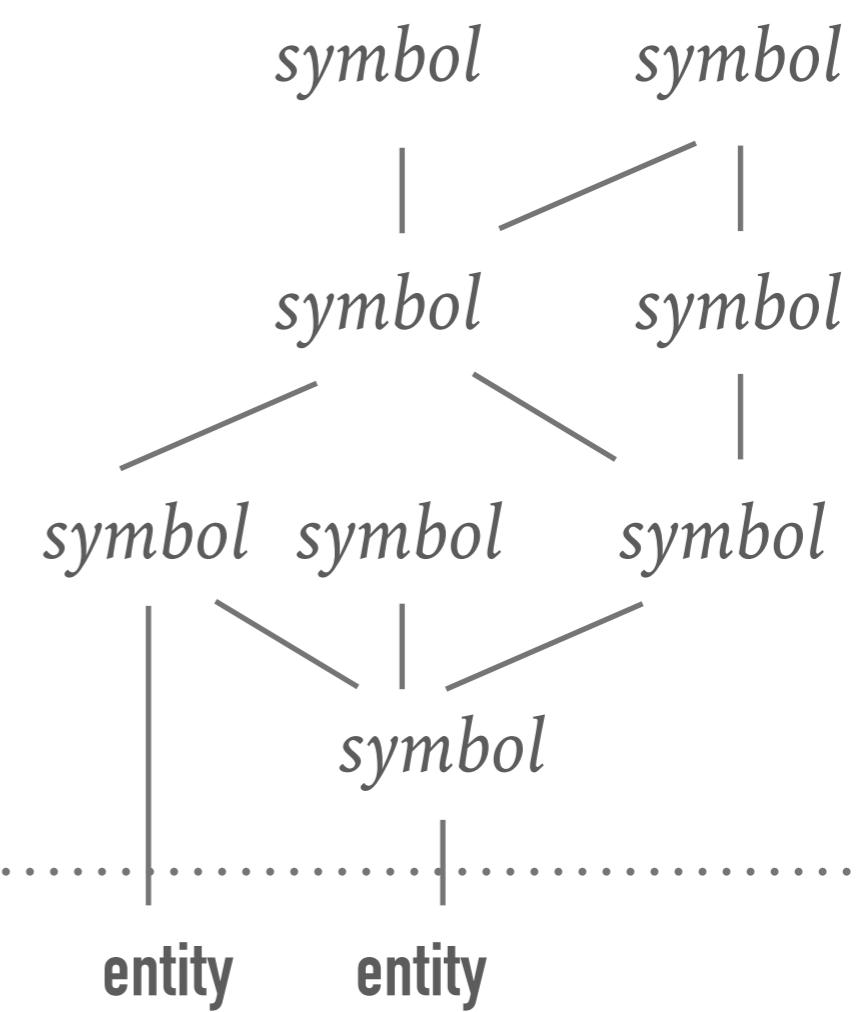
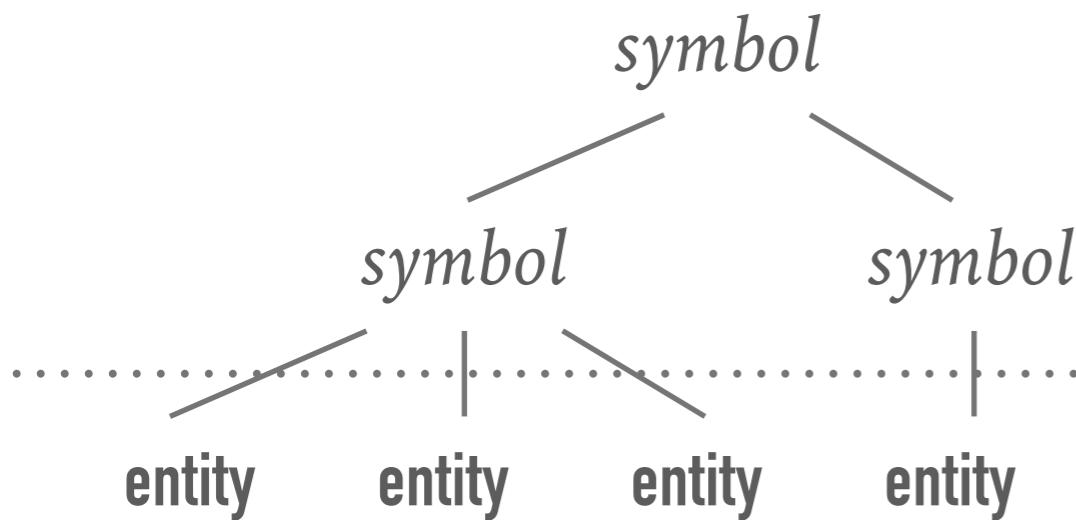
- “It simply looks good”
- Emotional / personal / not-explicit-at-all



THE EMPIRICAL CRITERION

- How strongly the system relates to observable things

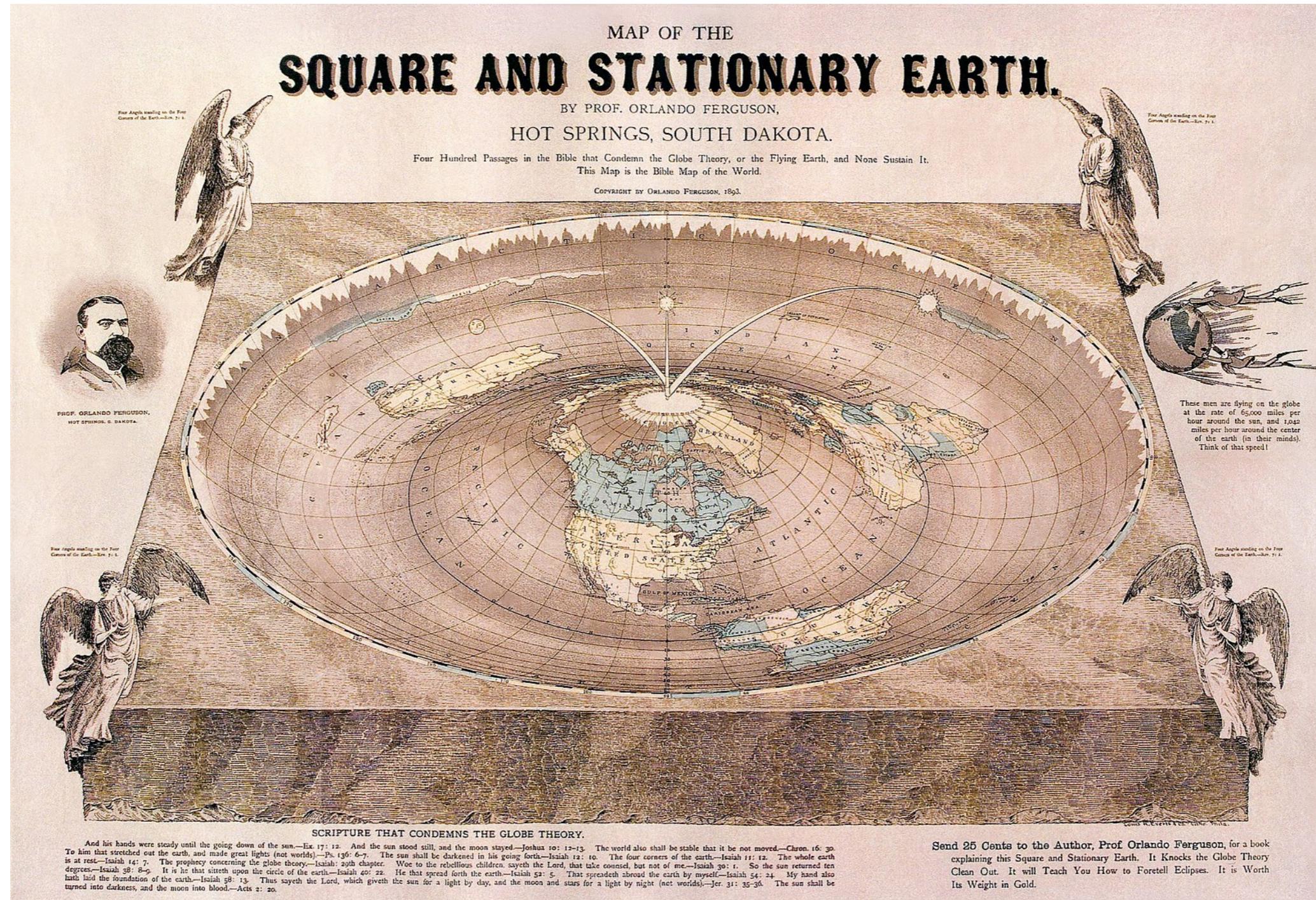
Symbolic realm



Physical realm

SCIENTIFIC CRITERION

- A scientific symbolic systems makes verifiable predictions



THE PRAGMATIC CRITERION

- The system is somehow “useful” or “helpful”
- Not necessarily the most explicit
 - Laws vs public understanding of the law
- Not necessarily the minimal
 - “A monad is just a monoid in the category of endofunctors, what's the problem?”
- Not necessarily the most “correct”
 - Aristotelian / Newtonian / Einsteinian mechanics
- Remember the ugly duckling theorem

A DARWINIAN SYMBOLIC SYSTEM

- A Darwinian Symbolic system is one that is designed to survive and be reproduced (by humans or machines)
- Religions/ideologies (esp. the proselytising ones)
- New reports
- Virus (biological and computer)

MATHS

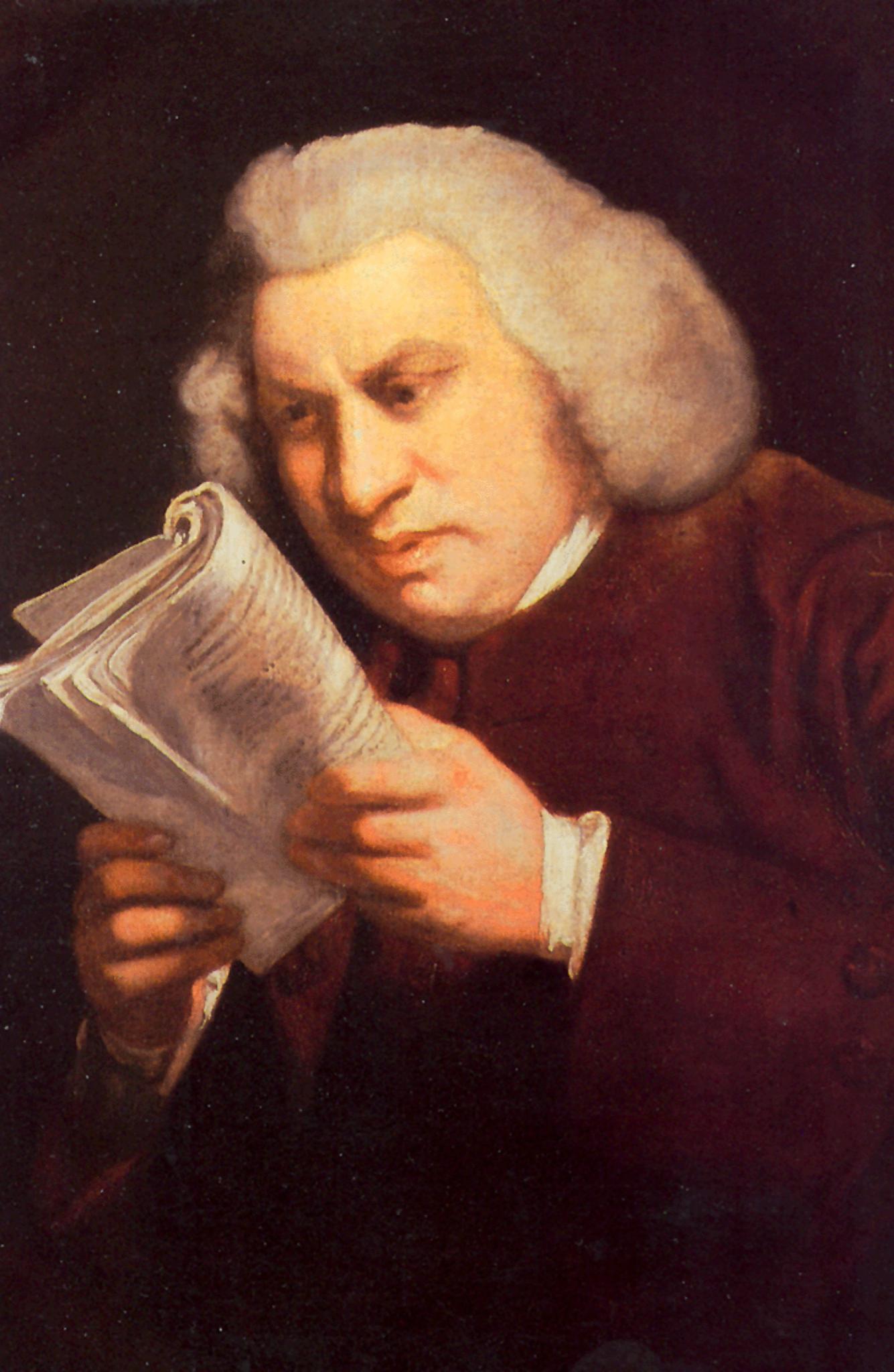
WORDS, GRAPHS, CODE

A symbolic model

**MATHEMATICAL
NOTATION
IS CONFUSING**



“A CAMEL IS A HORSE DESIGNED BY A COMMITTEE”



MATHEMATICAL NOTATION WAS
DESIGNED
BY A COMMITTEE...

.....

LIVING CENTURIES
AWAY,
WHO DON'T KNOW
EACH OTHER,
WHO WERE DESIGNING
FOR THEMSELVES

INCONSISTENT (NOT BIJECTIVE, NOR EXPLICIT)

- $abc(d + f)$ is $a \times b \times c \times (d + f)$
- $\sin(d + f)$ is “sine” function applied to $(d + f)$
- $x dx$ is $x \times$ “differential of x ”, but πd is $\pi \times d$

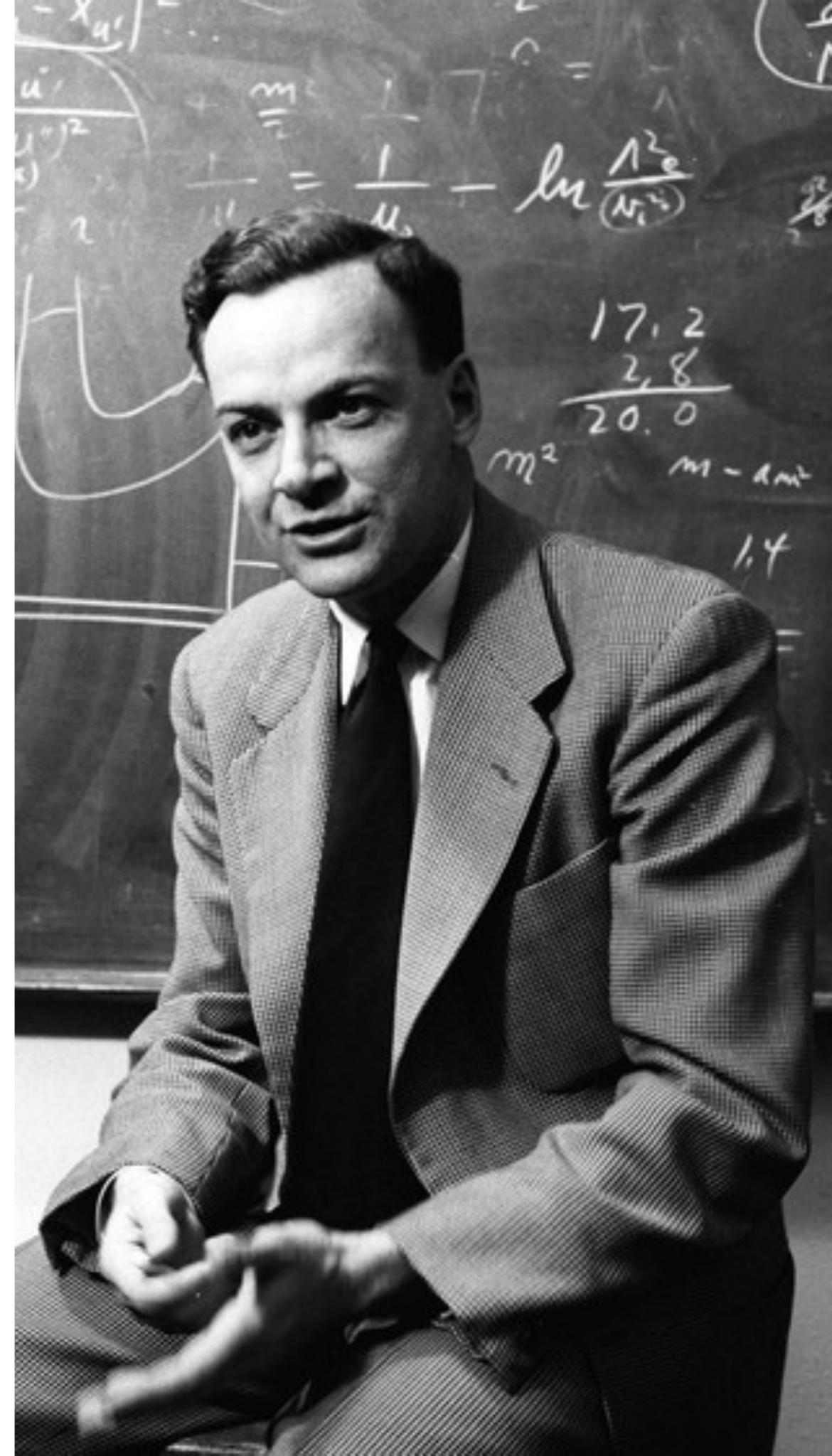
- $\sin^2(x)$ is $[\sin(x)]^2$
- $\sin^{-1}(x)$ is $\arcsin(x)$
 - (or vice versa?)

WHAT TO DO WITH THE SYMBOLIC HAZARD IN MATHEMATICS?

- The Feymann approach
- The von Neumann approach

TO ME, "SIN F"
LOOKED LIKE S
TIMES I TIMES N
TIMES F! SO I
INVENTED ANOTHER
SYMBOL....

Richard Feynman



FEYMAN'S SYMBOLS (ARTIST'S IMPRESSION)

$$\overline{\gamma\theta} = \cos(\theta)$$

$$\overline{0\theta} = \sin(\theta)$$

$$\overline{\tau\theta} = \tan(\theta)$$

$$\overline{\theta\gamma} = \cos^{-1}(\theta)$$

$$\overline{\theta\tau} = \tan^{-1}(\theta)$$

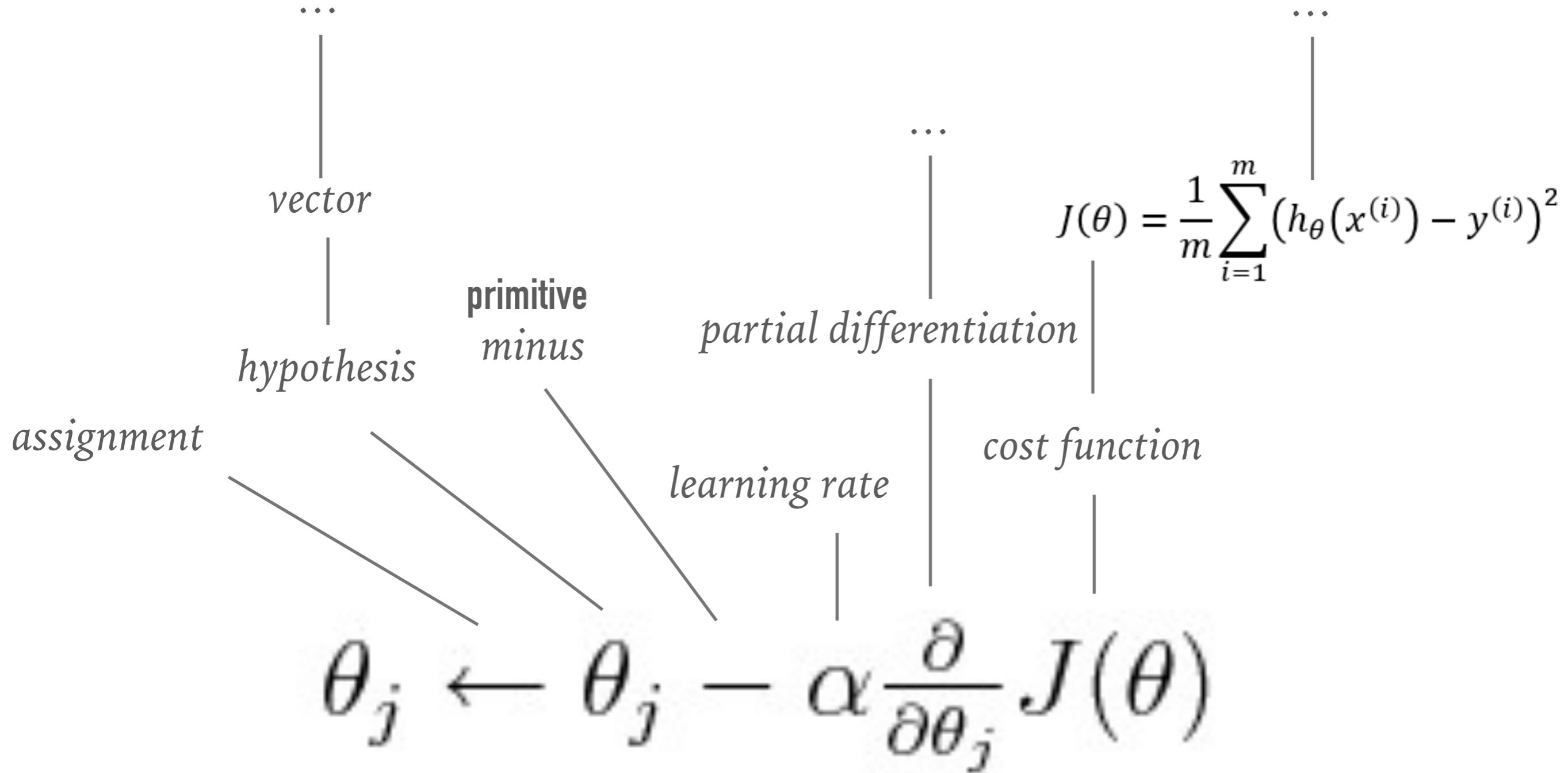
$$\overline{\theta 0} = \sin^{-1}(\theta)$$

**“IN MATHEMATICS
YOU DON’T
UNDERSTAND
THINGS. YOU
JUST GET USED
TO THEM”**

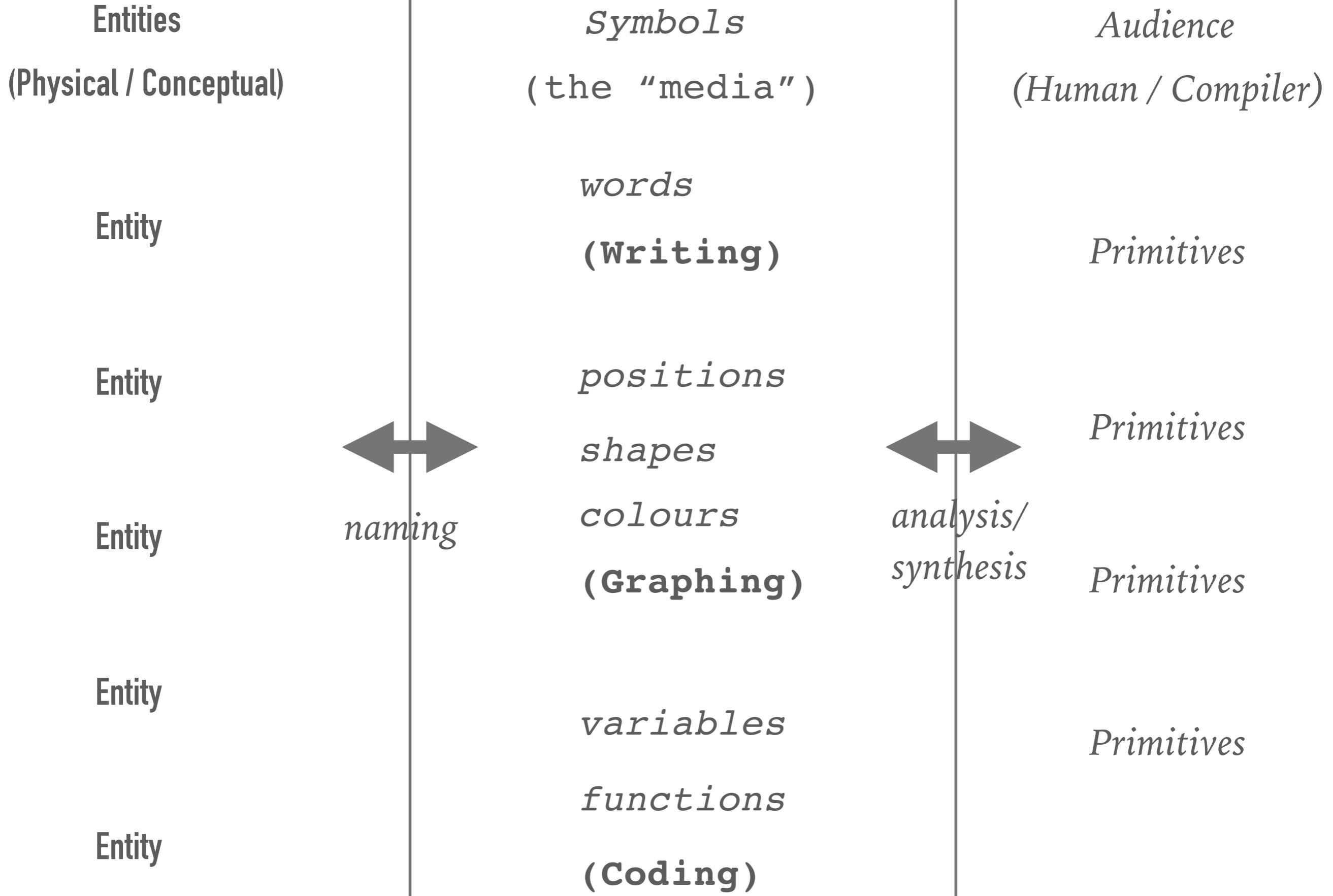
John von Neumann



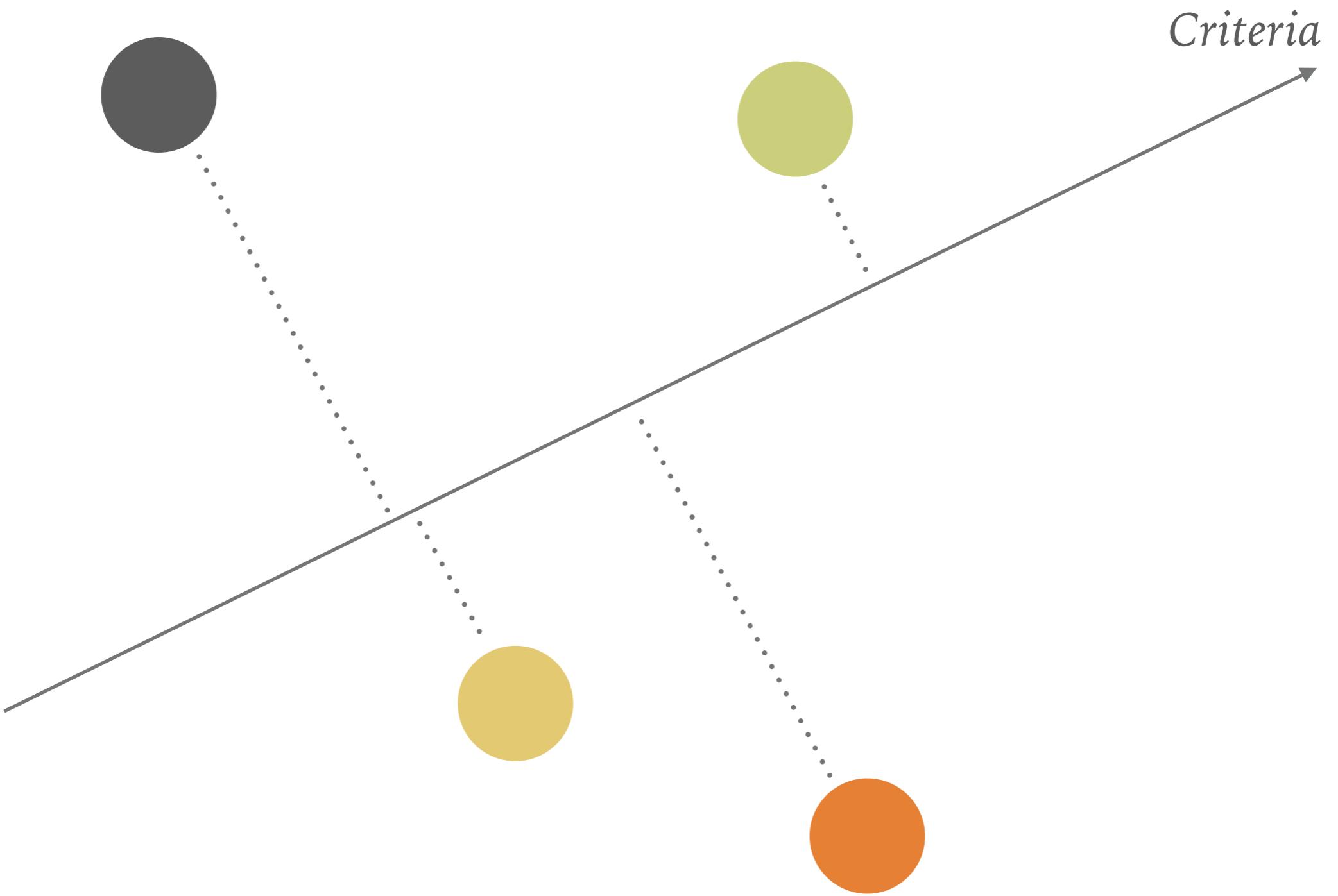
EXPANDING YOUR MATHEMATICAL PRIMITIVES...



SUMMING UP



ALL WAYS TO SYMBOLISE ARE EQUAL



REFERENCES

FURTHER READING

- Growing a Language, Guy Steele
- Structure and Interpretation of Computer Programs, Harold Abelson & Gerald Jay Sussman
- The Shortest History of European, John Hirst
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- World-Systems Analysis, Immanuel Wallerstein
- Thinking and Deciding, Jonathan Baron

IMAGE SOURCES

- Von Neuman: <https://www.nytimes.com/2012/05/06/books/review/turings-cathedral-by-george-dyson.html>
- Physical apple: <http://pngimg.com/download/12405>
- Imaginary Apple: https://commons.wikimedia.org/wiki/File:Apple_logo_black.svg
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- Samuel Johnson by Joshua Reynolds: https://en.wikipedia.org/wiki/File:Samuel_Johnson_by_Joshua_Reynolds_2.png
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- Donkey and elephant: <https://www.infoplease.com/history-and-government/elections/democratic-donkey-and-republican-elephant>
- Bismillah: <https://en.wikipedia.org/wiki/File:Bismillah.svg>
- Flat map: https://en.wikipedia.org/wiki/File:Orlando-Ferguson-flat-earth-map_edit.jpg



MAY THE SYMBOLS BE WITH YOU

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