Consciousness as a Pile of Sand

If you take one grain of sand at a time from a conical pile of sand on a table, when does it become a few grains on the table?

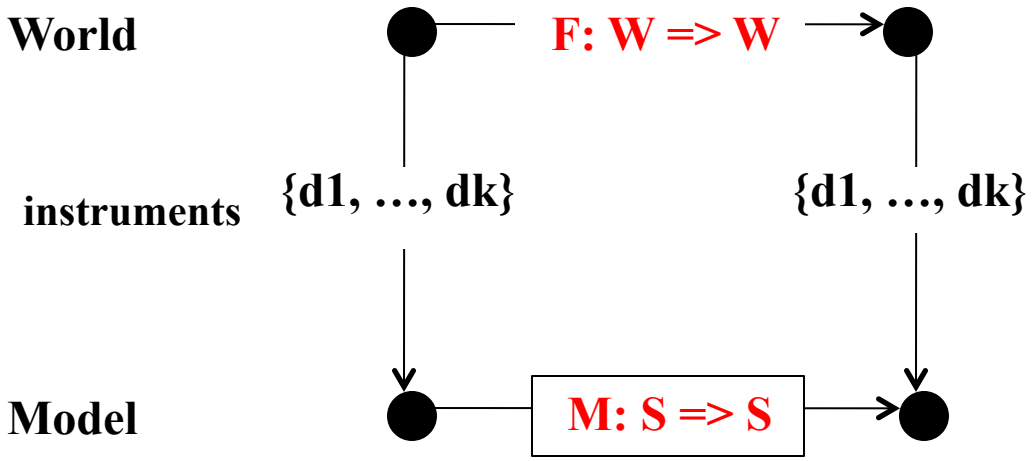
Clearly, a sharp demarcation (say, in terms of number of grains that constitutes a pile) is arbitrary.

Similar considerations apply to important areas in science, such as life (biology), consciousness (psychology), and complex adaptive systems in general.

Models: Reduction and Emergence

The contemplation in natural science of a wider domain than the actual leads to a far better understanding of the actual.

-- A. S. Eddington



Gell-Mann points out that 3 orders of magnitude in the scale of observations (e.g. from molecules to fluid flow) requires new laws. New laws are *constrained* by, but *not determined* by, the laws at lower levels.

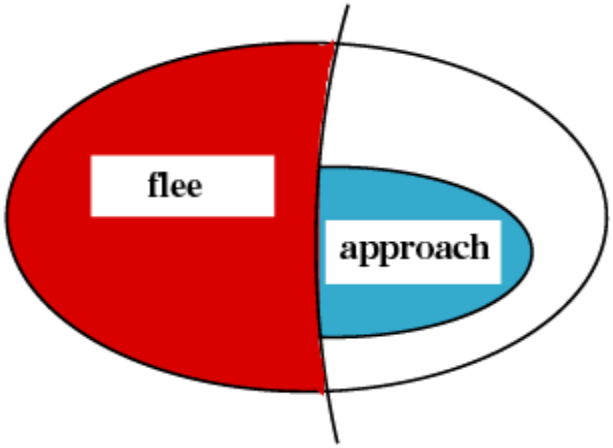
Default Rules

Starting point: Default Rule.
(A rule that is over-general: necessary but not sufficient.)

IF [moving object in vision cone] THEN <flee>

Elaboration: Specialist rule overrides Default.
(Specialist rule requires additional information.)

IF [moving object]&[small]&[winged] THEN <approach>



There is a symbiosis between defaults and specialists.

Progressive Generalization

The # (‘don’t care’) symbol can be used to designate sets of signals.

For example, 1##...# designates all signals that have a 1 prefix.

Instance 1

salient, large, blue ball **0000.1111.0000**

Instance 2

salient, small, red ball **0000.1001.0000**

Generalization of instances 1 and 2 **0000.1##1.0000**

Procedures for Generating Rules

Initially, default rule conditions are formed using just a few bit values drawn from the current environment signal.

For example, signal 011010…0 can be used to form

#1####...#

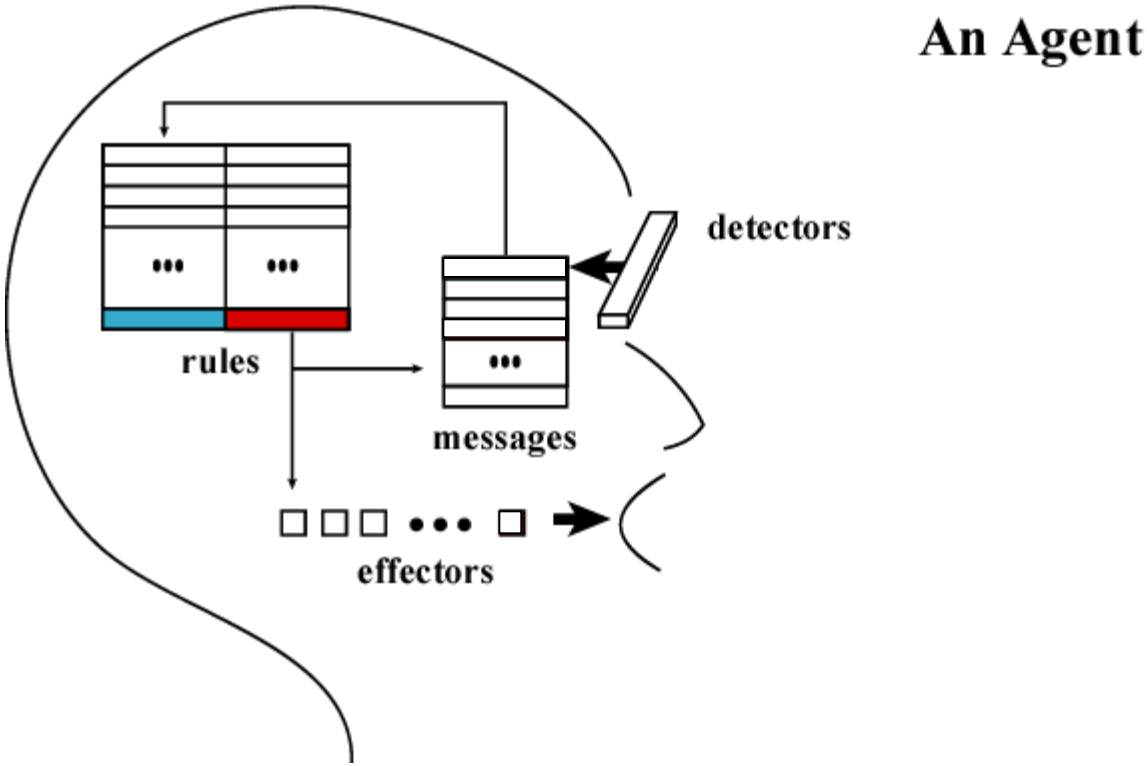
or ###01#...#.

For signals of length L=100, there just L(L+1)/2 = 2450 defaults using 1 or 2 bits => all possible *default rules* can be rapidly tested.

The primary order of learning is both general-to-particular, starting with default conditions,
and particular-to-general, using #'s to generalize from specific signals.

Performance of a Rule-based Agent

PARALELLISM: Many *signals* (e.g. bit-strings) can be present at once, and many signal-processing *rules* <IF (signal present 11000) THEN (send signal 00111)> can be active simultaneously.



Language Acquisition Illustrates the Emergence of Consciousness

1) Acquisition of vocabulary.

Babbling (random action) samples possibilities (diversity) for attaching utterance to situation.\

Some inputs invoke imitation (e.g., 'shared salient object or action', 'Teacher' utterance)

'Meaning' emerges from generalization of conditions associated with the same utterance.

2) Acquisition of specific utterance pairs.

Sequences reduce ambiguity.

3) Generalization of sequences to 'grammatical' rules.

Levels of Consciousness – Level 0
[An approach based on the research of Helena Hong Gao]

'Wired-in' (inherited) cognitive abilities.

Ability to imitate utterances and gestures.

Ability to distinguish between objects and actions.

Awareness of a mutually apprehended salient object or action.

Basic learning procedures (akin to Hebb's learning rule).

IF (any signal) THEN (random effector activity)

Levels of Consciousness – Level 1

Control of motion (as precursor to gesture).

Task: **Bring hand in controlled motion across visual field.**

Mode: **Innate reinforcement for predictable outcomes.**

Anticipation: **Movement according to command.**

IF (hand in vision cone) THEN (<move hand right>)

Levels of Consciousness – Level 2

Utterance for immediate, "wired-in" reward, e.g. 'Teacher's' smile.

Task: **Social interaction.**

Mode: **Imitation of situated utterance.**

Anticipation: **Positive interaction.**

IF (milk bottle present) THEN (<utterance "milk">)

This rule will be strengthened, over other random utterances, because [T-smile] increments sociality reservoir.

Levels of Consciousness – Level 3

Utterance to "move" visible object.

Task: **Food acquisition (when food visible).**
Mode: **Conditioning.**
Anticipation: **Food.**

IF (milk bottle visible) THEN < "milk">
'Teacher' moves milk bottle to mouth.
IF (<milk bottle at mouth>) THEN (<consume milk>)

Levels of Consciousness – Level 4

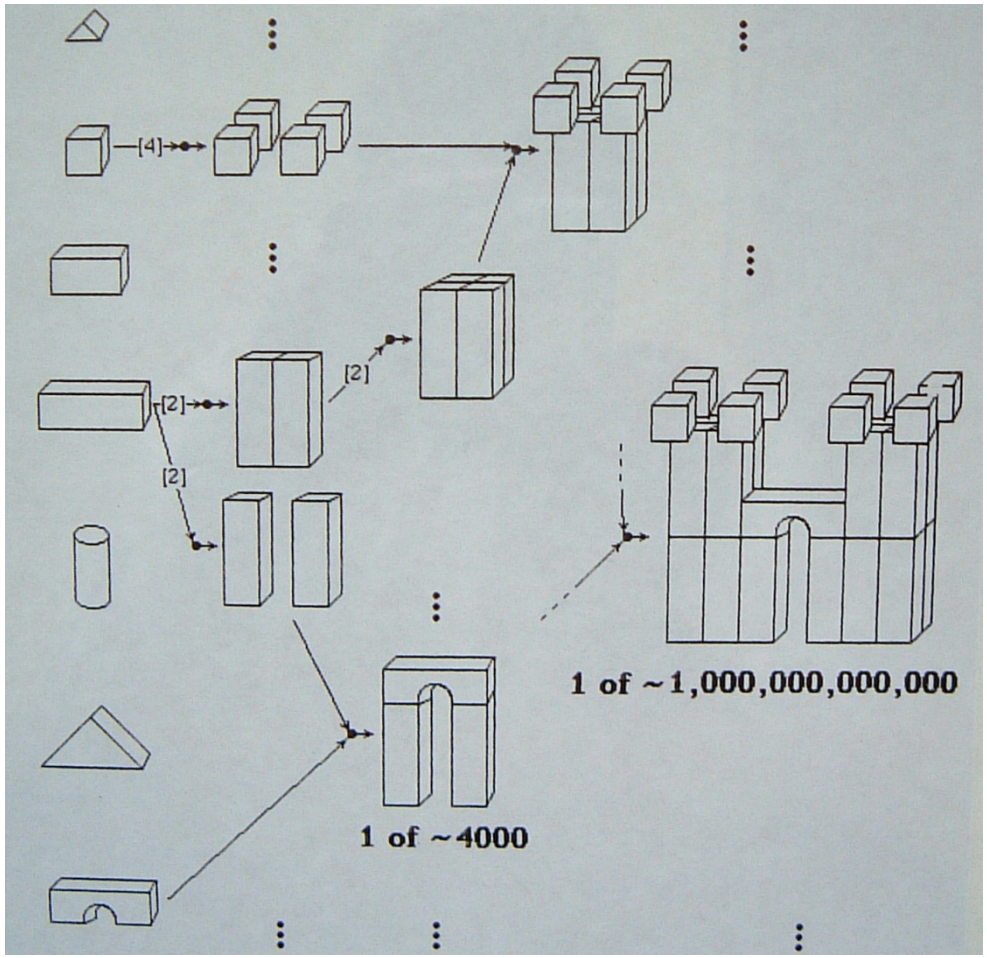
Utterance to cause appearance of object.

Task: Food acquisition (when food not visible).
Mode: Internal model (lookahead) – autonomy required.
Anticipation: Appearance of food (later generalized to arbitrary objects)

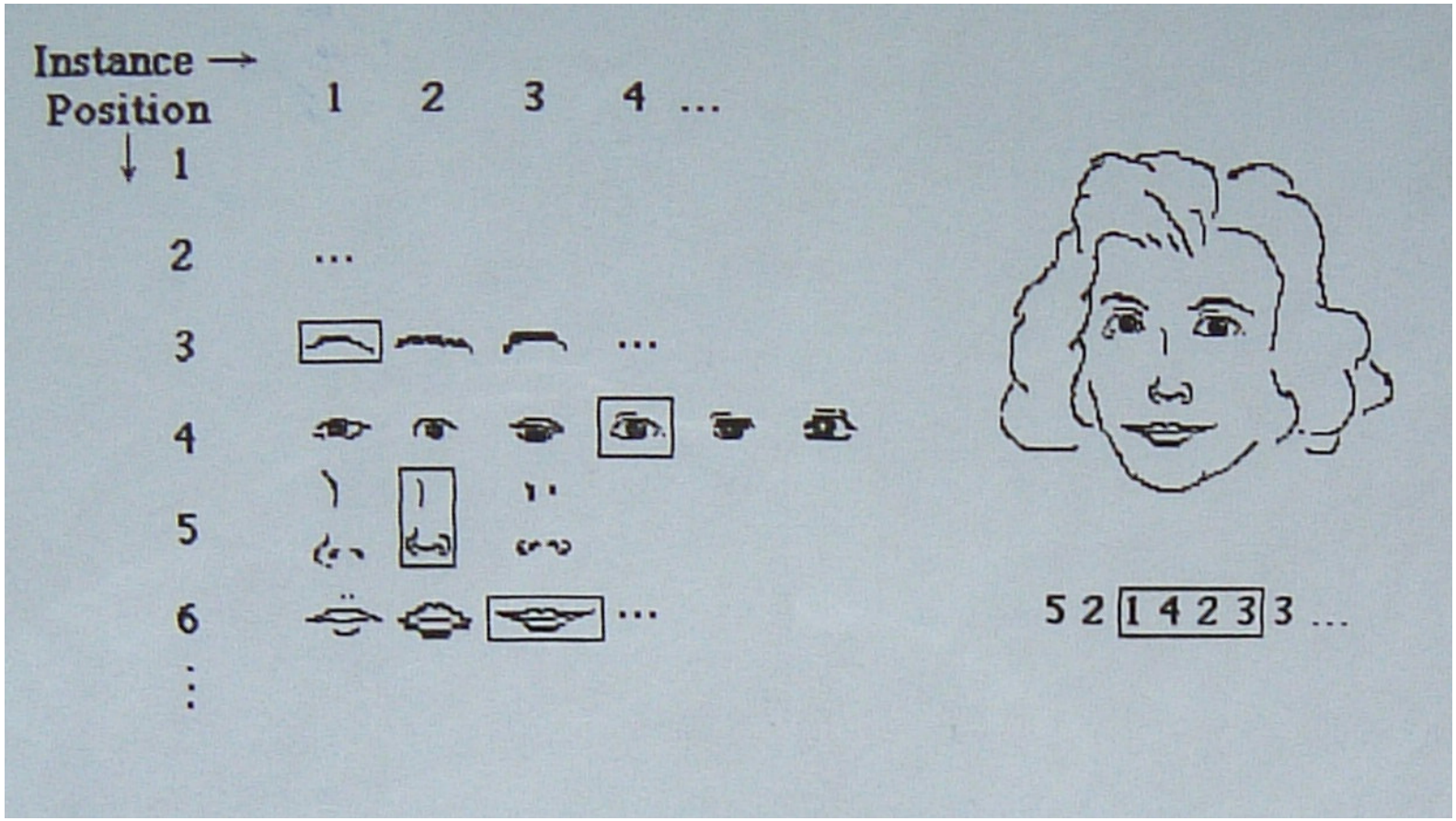
IF ([hungry] & no food visible) THEN <"milk">
'Teacher' acts to fetch milk bottle.
IF (<T acts>) THEN <milk bottle visible>

Acquired from previous levels:
IF (milk bottle visible) THEN < "milk">
'Teacher' moves milk bottle to mouth.
IF (<milk bottle at mouth>) THEN (<consume milk>)

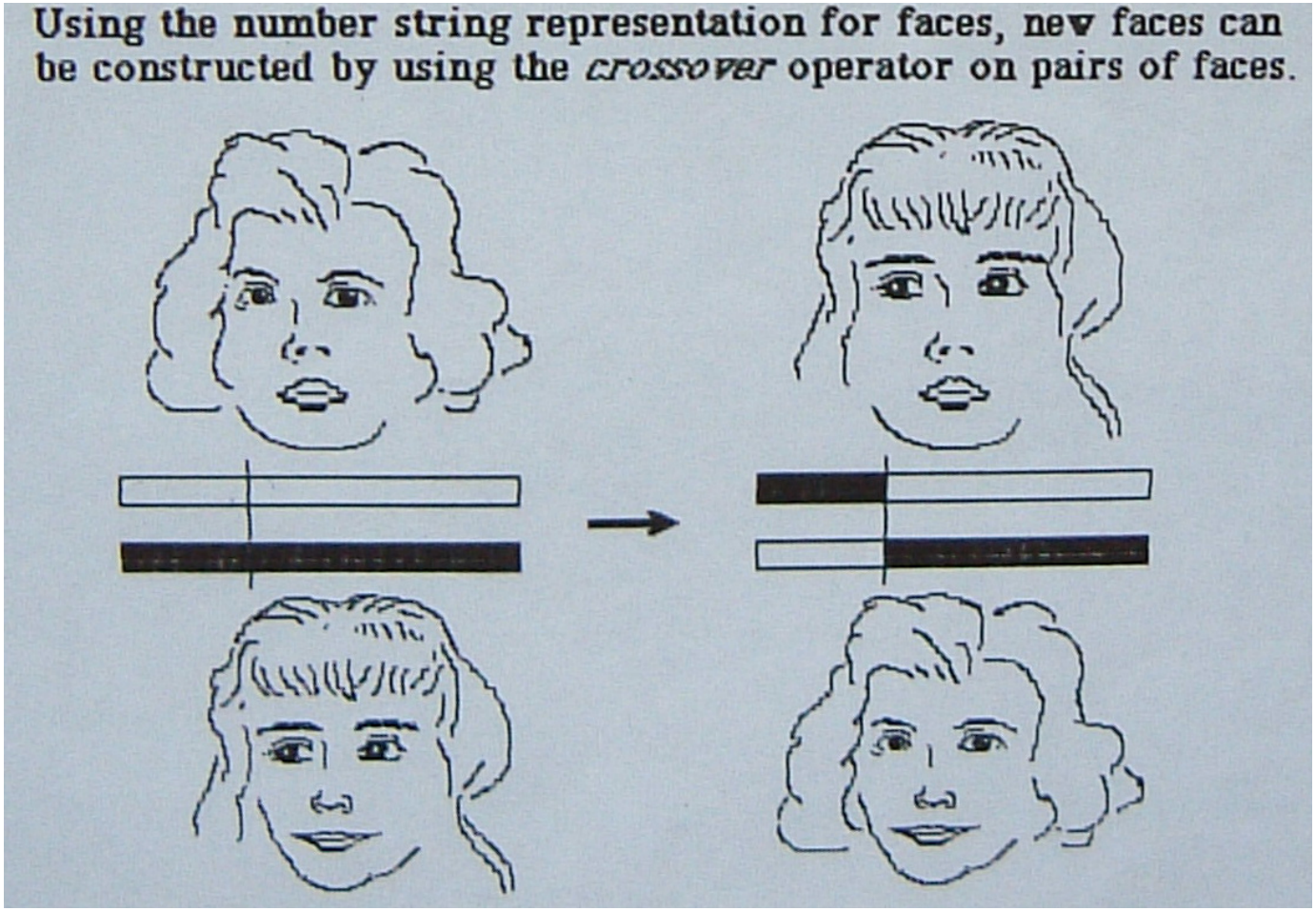
Building Blocks and Emergence



Building Blocks for a Face

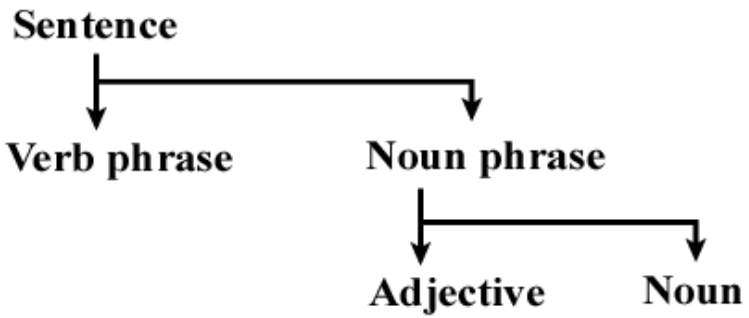


Innovation by Recombination



Vocabulary as Building Blocks

A grammar makes possible the combinatoric use of vocabulary.



'fetch (to me)
'take' (from me)
'go' (to)
'look' (at)

60 meaningful triples can be constructed from the 12 utterances shown.

The number of meaningful triples increases exponentially with vocabulary size: If there are 20 utterances in each category, 8000 meaningful triples can be constructed.

Two Emergent Phenomena
Closely Related to Consciousness

Autonomy (e.g. the internal models used in planning and lookahead) requires recurrence (e.g. networks with many loops a la Hebb).

Input modulates but does not determine ongoing activity.

Pattern recognition by *saccades*: Human pattern recognition proceeds by a series of highly localized 'snapshots' that reveal no detail about the overall scene.

That is, pattern recognition in humans does not use a a pixel-by-pixel raster scan.

These snapshots are directed and integrated by input from higher levels in the CNS.