What is Computation?

$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v}\cdot\nabla\mathbf{v}\right) = -\nabla p + \nabla\cdot\mathbf{T} + \mathbf{f},$$

$n=7, \delta=20^\circ$

X

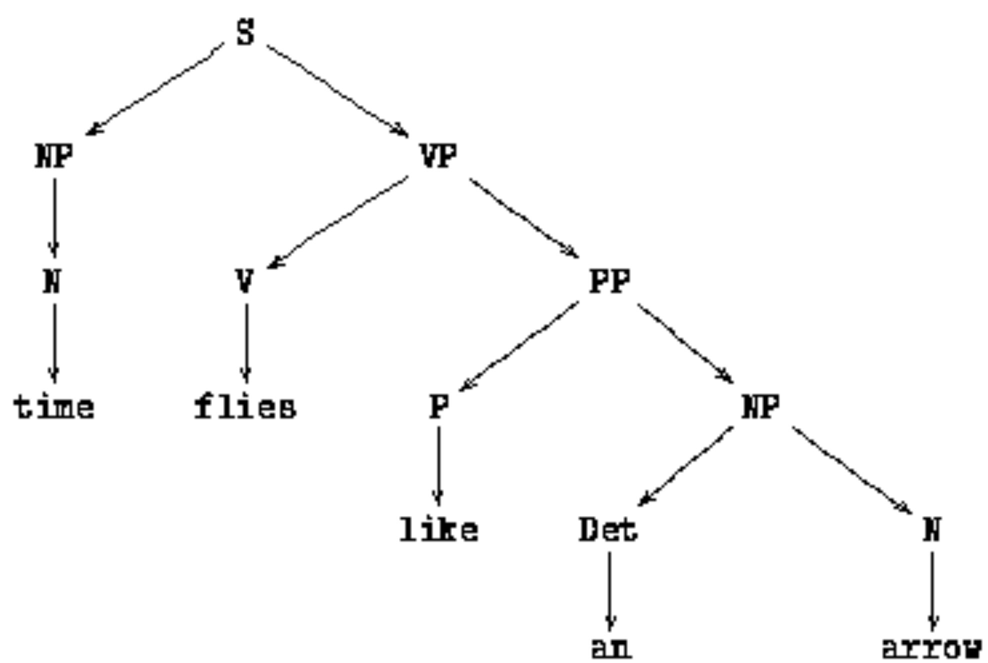
X $\rightarrow$ F[+X]F[-X]+X

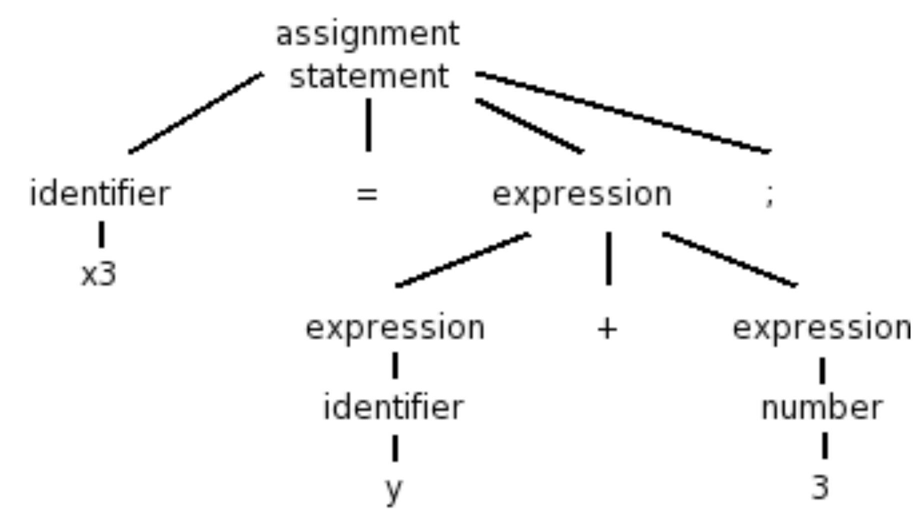
F $\rightarrow$ FF

$$\tau_k \frac{\partial}{\partial t} h_k(\vec{x}, t) = h_k^r - h_k(\vec{x}, t) + \Sigma_{l=e,i} \Psi_{lk}[h_k(\vec{x}, t)] \cdot I_{lk}(\vec{x}, t)$$

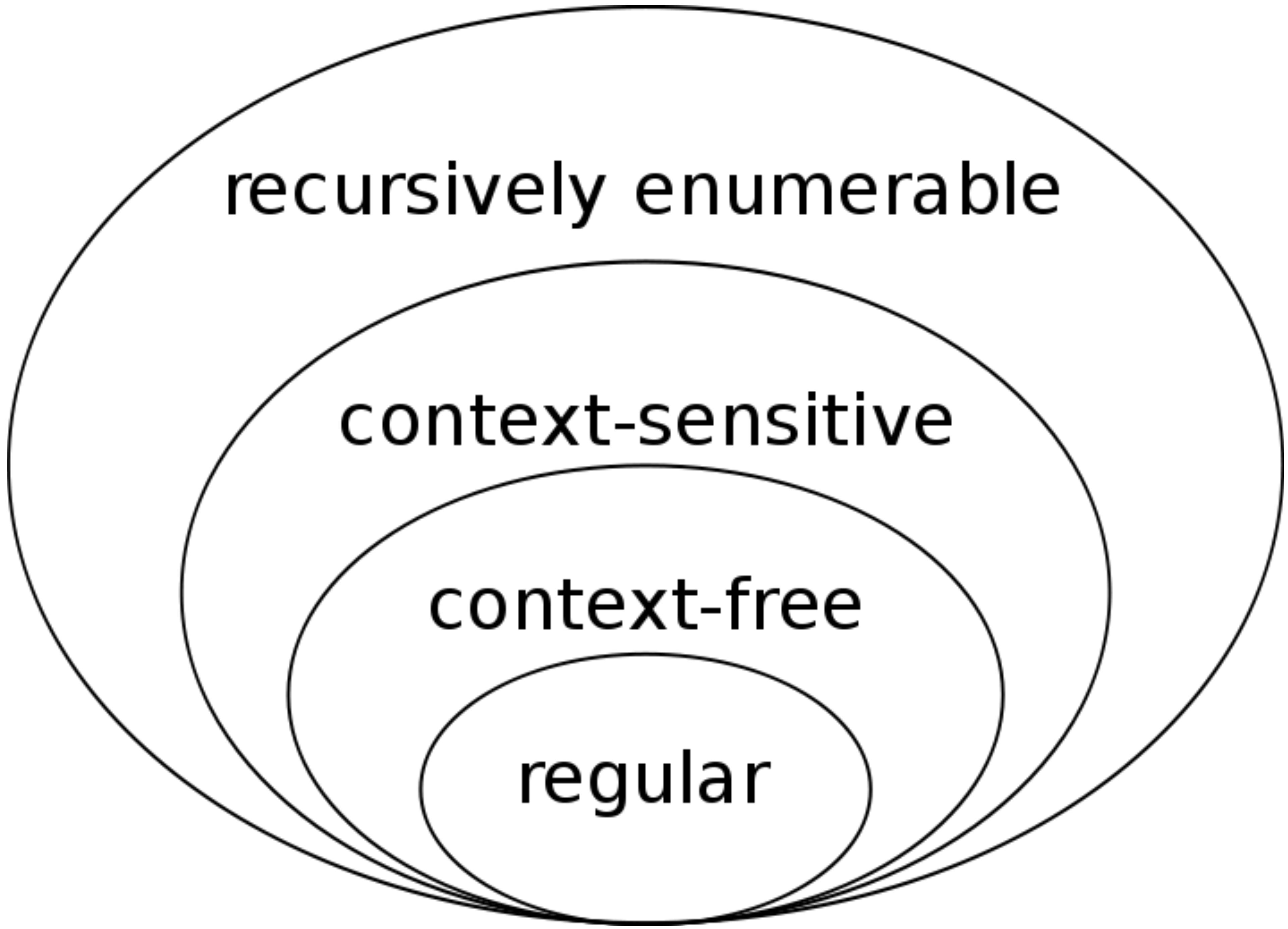
or

"What do I want for lunch?"

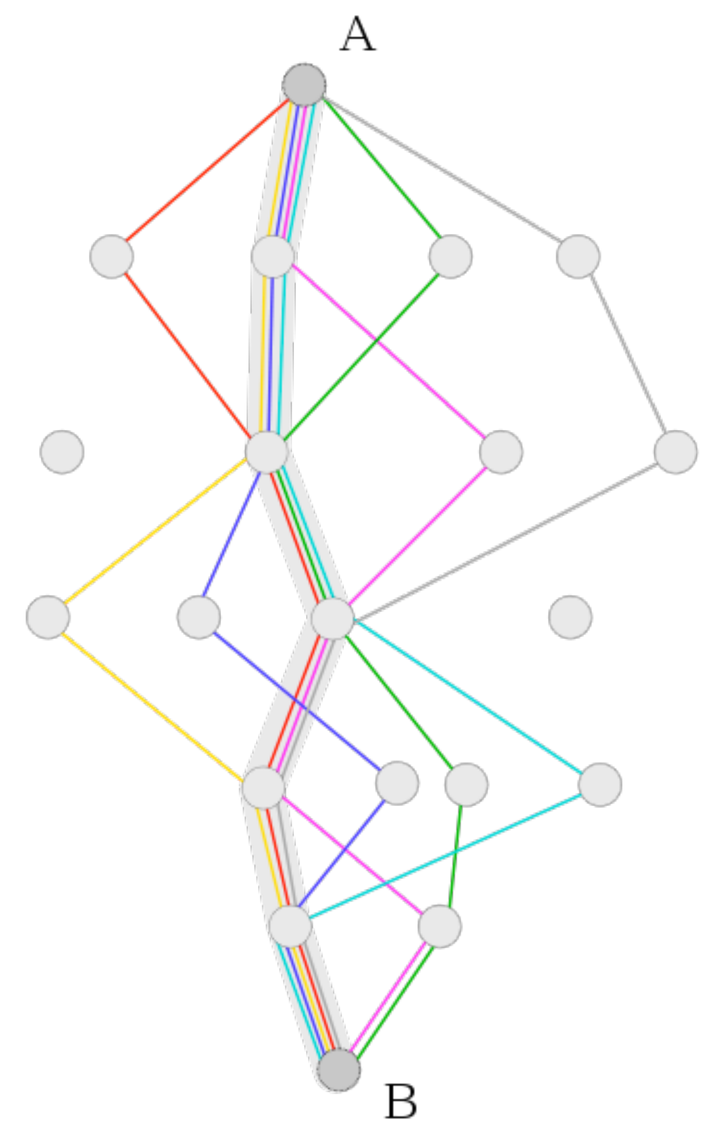




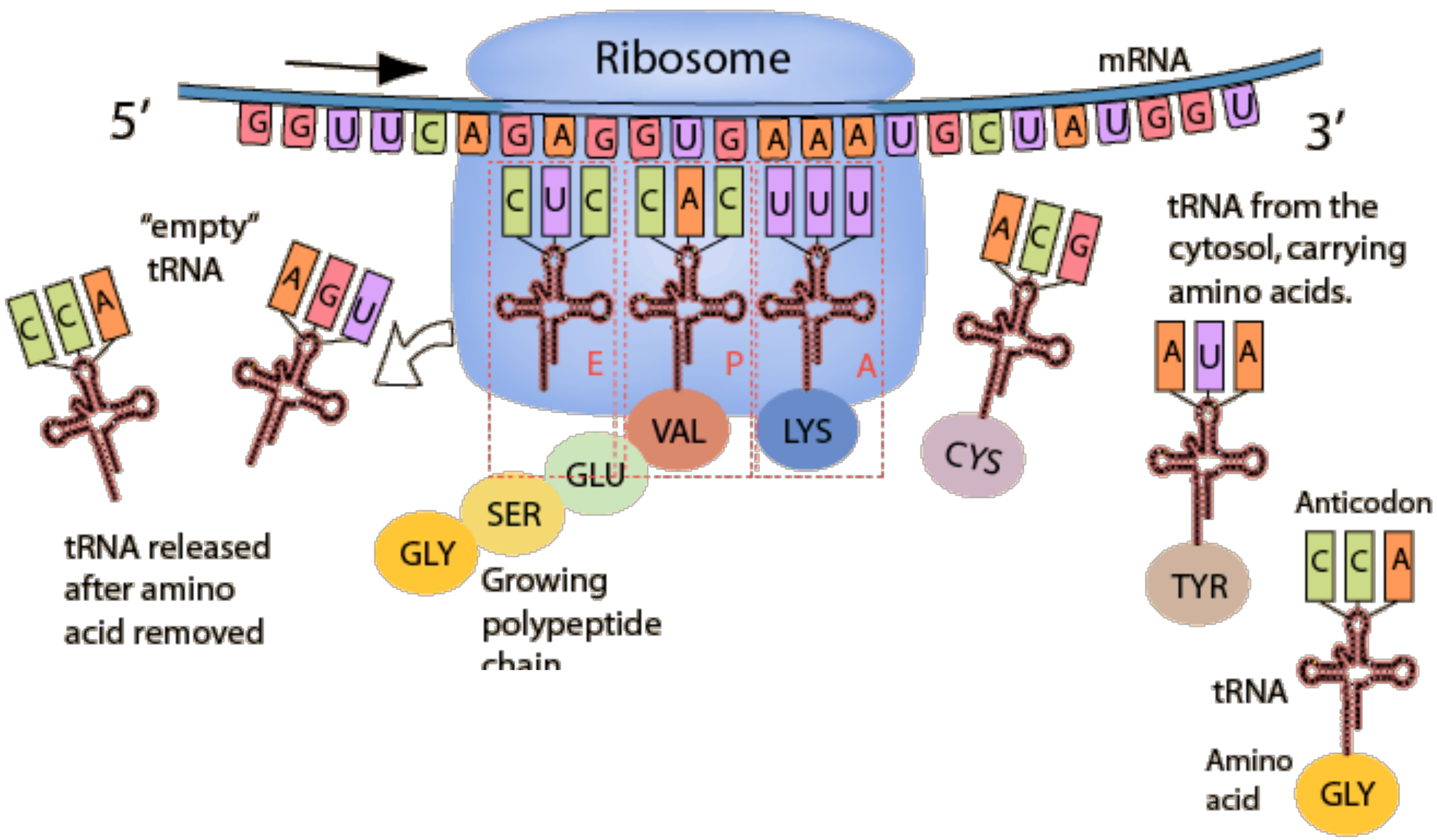
Languages are *all about* computation!



The Chomsky Hierarchy,
equally familiar to linguists and
theoretical computer scientists



$$\tau_{xy} \leftarrow (1-\rho)\tau_{xy} + \sum_k \Delta\tau_{xy}^k \qquad \Delta\tau_{xy}^k = \begin{cases} Q/L_k & \text{if ant } k \text{ uses curve } xy \text{ in its tour} \\ 0 & \text{otherwise} \end{cases}$$



Definition 0.1 A *frameshift machine* is a five-tuple $M = (\Sigma, \Gamma, \tau, E, \delta)$ where

$$
\begin{gathered}
\Sigma \text{ is the finite input alphabet,} \\
\Gamma \text{ is the finite output alphabet,} \\
\tau \in \mathbb{N} \text{ is the frame size,} \\
E \subseteq \Sigma^\tau \text{ is the set of end frames,} \\
\delta \subseteq \Sigma^* \times \Sigma^\tau \times \Sigma^* \times \Gamma \times \mathbb{Z}(\tau - 1), \\
\delta \text{ finite, is the transition relation.}
\end{gathered}
$$

So what?

If we model processes (like translation) as computations...

Proposition 0.1 *Let* $x = ax'b, x \in \Gamma^{+}_{\mathrm{AA}}$ *with* $a, b \in \Gamma$. *Then*

$$(w, \lambda, 1) \vdash^{*}_{M^{\leftarrow}_{\mathrm{GEN}}} (w, ax'b, k),$$
$$(v, \lambda, 1) \vdash^{*}_{M^{\leftarrow}_{\mathrm{GEN}}} (v, ax'b, l),$$

implies $w(2) \cdots w(k+1) = v(2) \cdots v(l+1)$.

... then we can *prove theorems* about them.

Algorithm 1 Determine prefix and dual RNA regular expressions

input: $\alpha = (a_1, b_1) \cdots (a_n, b_n), a_j, b_j \in \Gamma_{AA} \cup \{\lambda, \$\}, M_{duo} = (Q, \hat{\Gamma}_{AA}, F, q_0, \delta)$.

output: i, the longest prefix such that $(a_1, b_1) \cdots (a_i, b_i) \in L_{duo}$,regular expressions $\overline{w}, \overline{v}$ for all possible w, v of minimal length corresponding to $(a_1, b_1) \cdots (a_i, b_i)$ in equations (1), (2), (3), (4) of Proposition 0.3.

$i \leftarrow 1$
inDuo $\Leftarrow$ true //this will be true if the prefix of length i is in L_{duo}
$q \leftarrow 1$ //start state of M_{duo}
while $i \leq n$ and inDuo = true
    $q \leftarrow \delta(q, (a_i, b_i))$
    if q is defined //true if $(a_1, b_1) \cdots (a_i, b_i) \in L_{duo}$
        if $(a_i, b_i) \leftarrow$ (r,e) and ($i = 1$ or $i - 1 \in \{(\underline{s}, \underline{l}), (\underline{l}, \underline{s}), (\underline{h}, \underline{t}), (\underline{c}, \underline{v}), (\underline{y}, \underline{i}), (\underline{a}, \underline{r}),$
            $(\underline{r}, \underline{a}), (\underline{f}, \underline{l}), (\underline{p}, \underline{p}), (\underline{g}, \underline{g})\}$) then $\overline{w}(3(i-1)+1) \leftarrow \{A, \overline{C}\}$.
            //as discussed above.
        else let $\overline{w}(3(i-1)+1)$ be the unique first character of words in $\rho(a_i, b_i)$.
        if $(a_i, b_i) = (\underline{e}, \underline{r})$ and ($i = 1$ or $i - 1 \in \{(\underline{s}, \underline{l}), (\underline{l}, \underline{s}), (\underline{t}, \underline{h}), (\underline{v}, \underline{c}), (\underline{i}, \underline{y}), (\underline{a}, \underline{r}),$
    $(\underline{r}, \underline{a}), (\underline{l}, \underline{f}), (\underline{p}, \underline{p}), (\underline{g}, \underline{g})\}$) then $\overline{v}(3(i-1)+1) \leftarrow \{A, C\}$.
        else let $\overline{v}(3(i-1)+1)$ be the unique first character of words in $\rho(b_i, a_i)$.
        let $\overline{w}(3(i-1)+2)$ and $\overline{w}(3(i-1)+3)$ be unique 2nd, 3rd chars of words in $\rho(a_i, b_i)$.
        let $\overline{v}(3(i-1)+2)$ and $\overline{v}(3(i-1)+3)$ be unique 2nd, 3rd chars of words in $\rho(b_i, a_i)$.
        i++
    else inDuo $\Leftarrow$ false.
let $\overline{w}(3(i-1)+4)$ be the set of all last ribonucleotides of strings in $\rho(a_i, b_i)$.
let $\overline{v}(3(i-1)+4)$ be the set of all last ribonucleotides of strings in $\rho(b_i, a_i)$.
output $i - 1, \overline{w}, \overline{v}$

... and develop new algorithms.

What is Computer Science?

Every process is a computation.

Computer Scientists study *computation*,
not necessarily *computers*.

"Computer Science is no more about computers than astronomy is about telescopes"

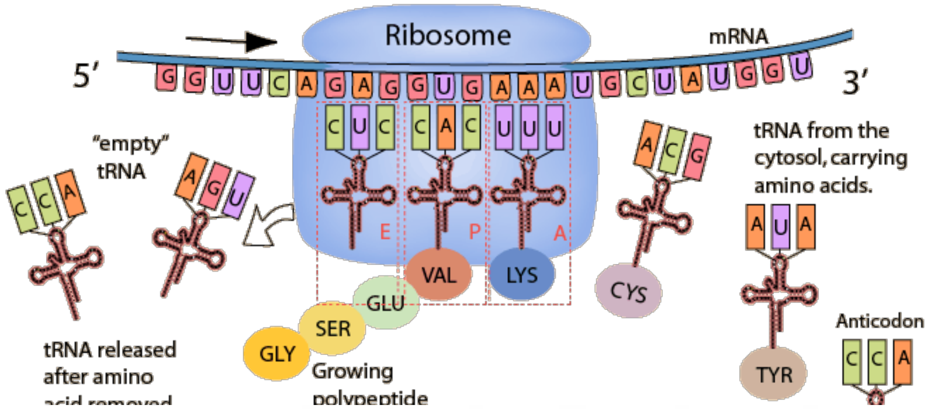
(attribution disputed)

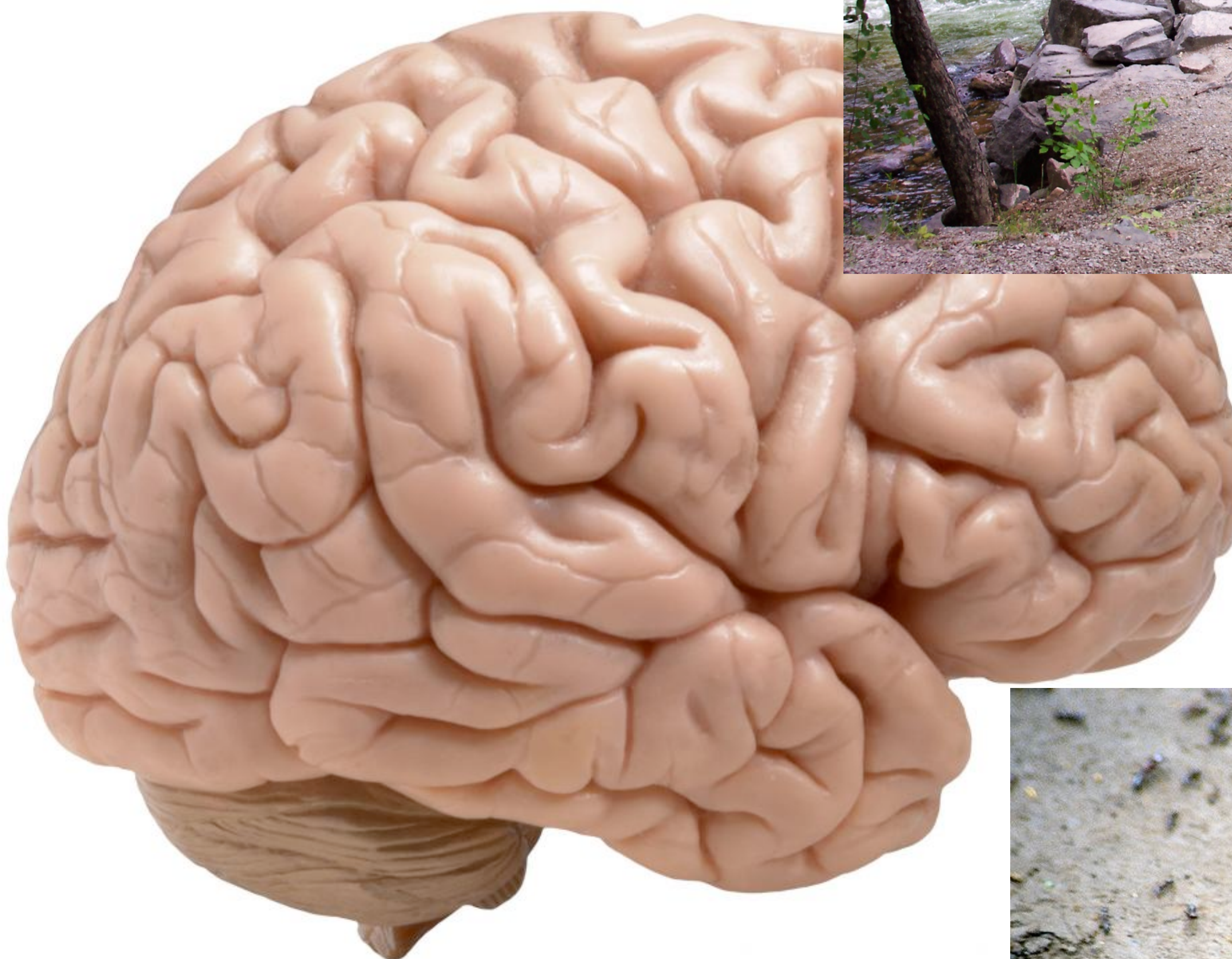
I love that quote, because it’s true for me.

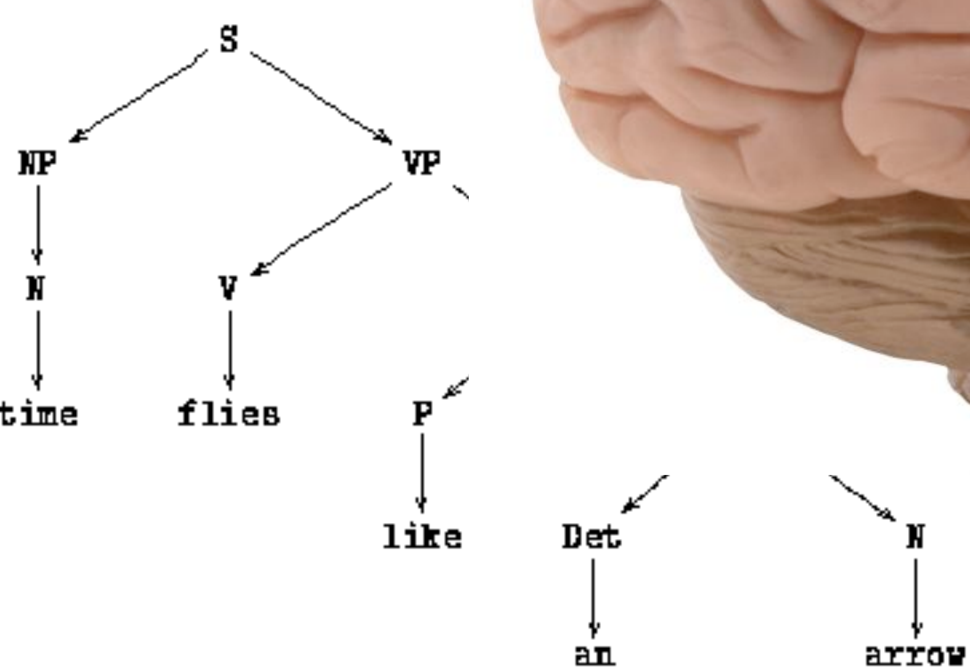
But for all of CS? It’s **complete bullshit.**

Some of us study *computation*, but some of us really do study telescopes.
I mean “computers”.

What is a Computer?

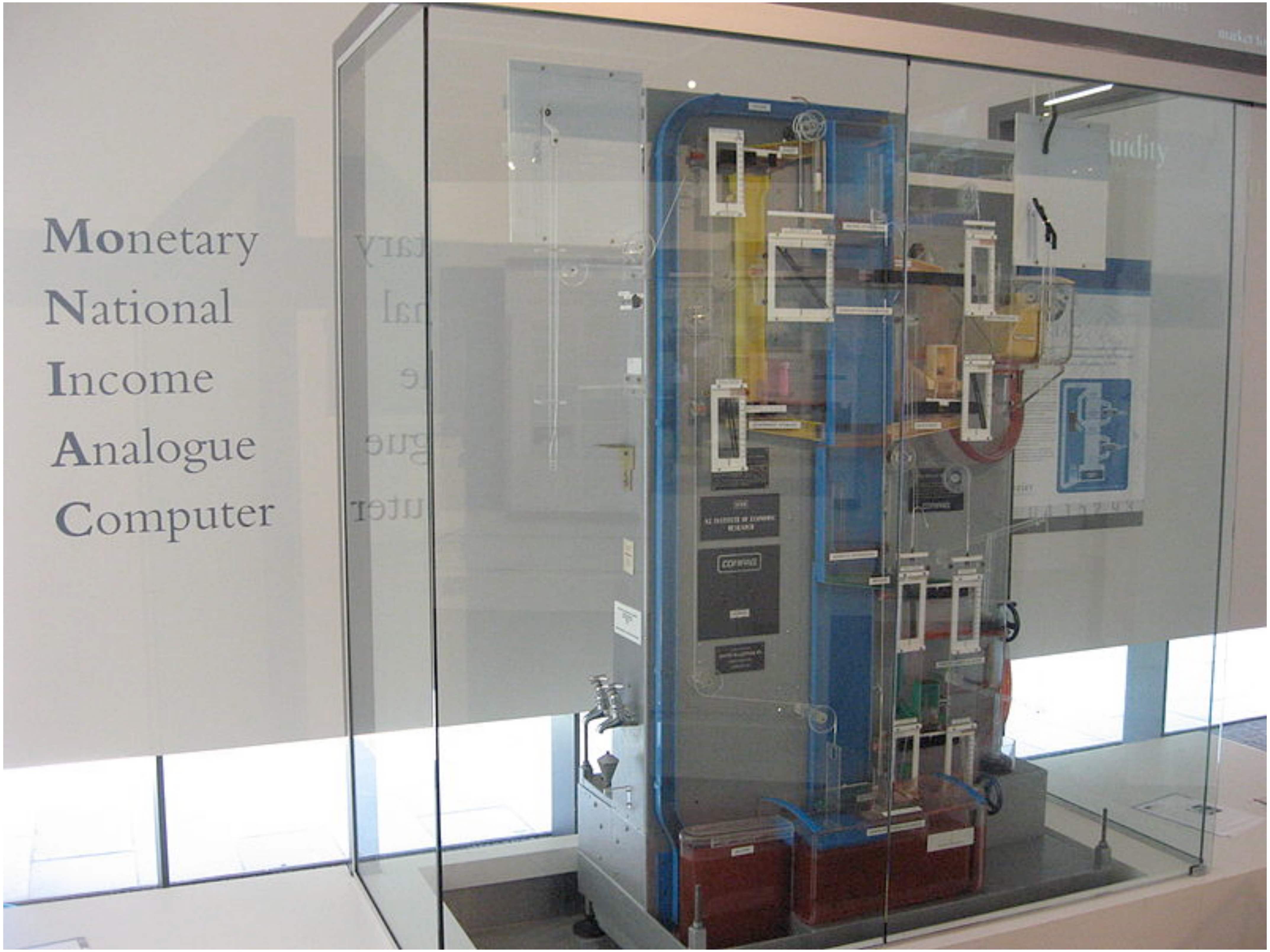

Ribosome
mRNA
5′
3′
"empty" tRNA
tRNA from the cytosol, carrying amino acids.
Anticodon
tRNA released after amino
Growing
E
P
A
VAL
LYS
GLU
SER
GLY
CYS
TYR

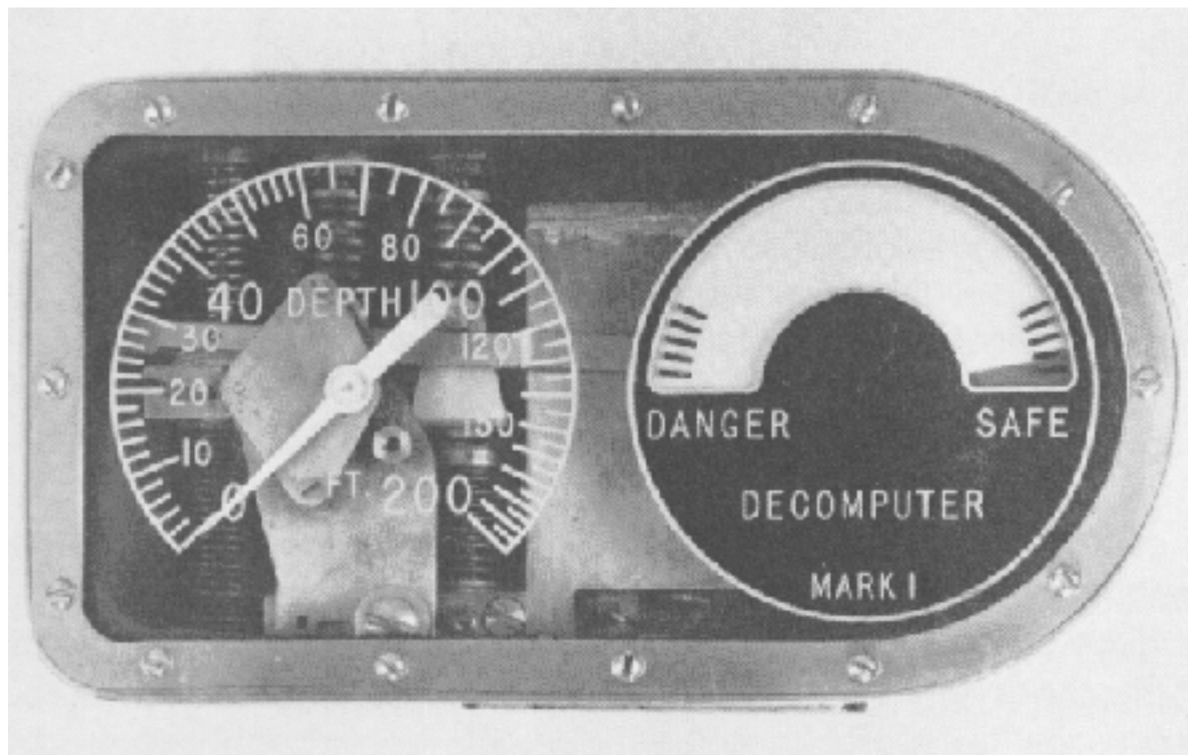



S
NP
VP
N
V
time
flies
P
like
Det
N
an
arrow

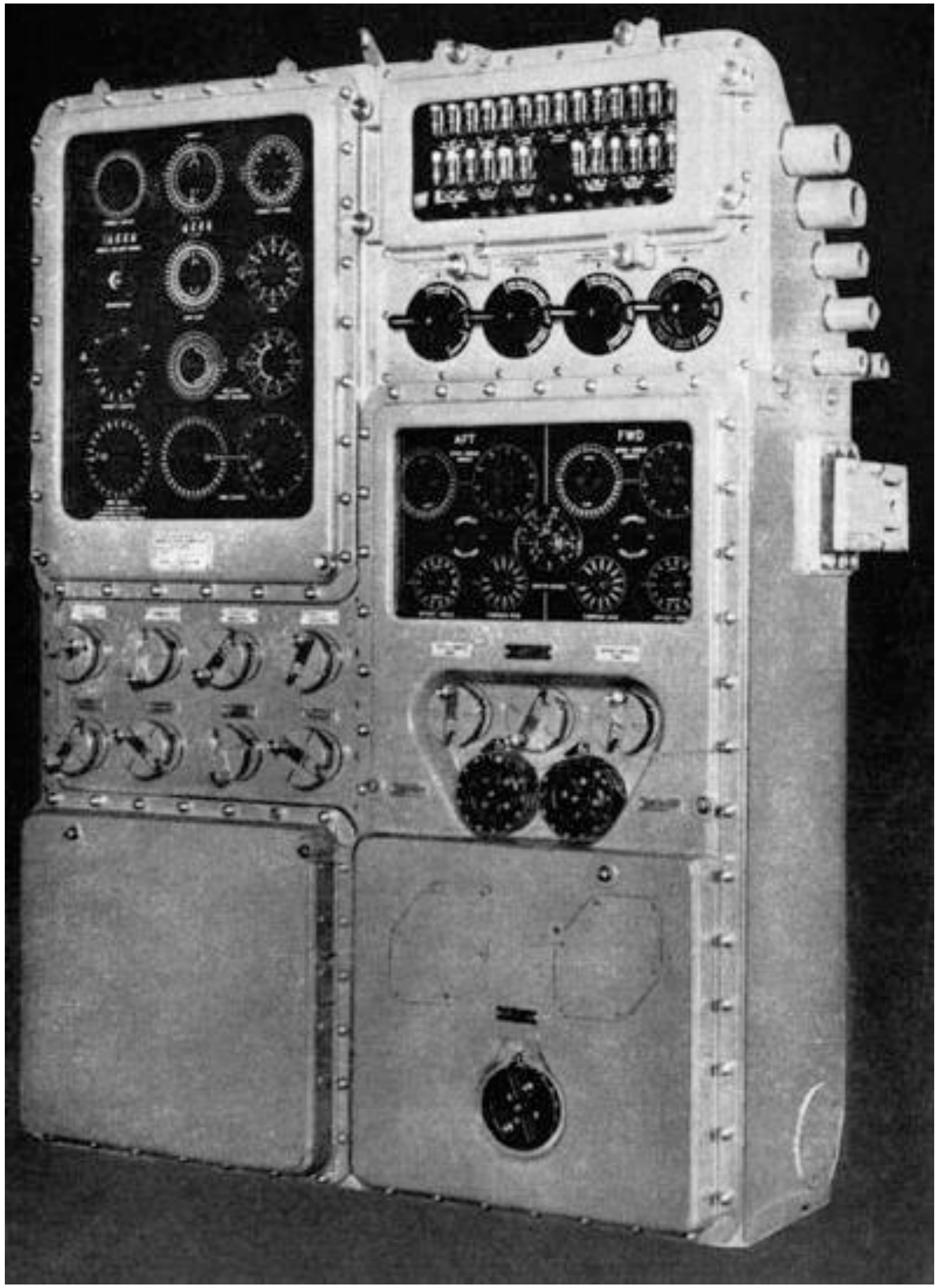
Even if we restrict ourselves to human-made, "artificial" computers, there's more than you might think...


CECIAS
SEPTENTRIO
CIRCIVS
CHORVS

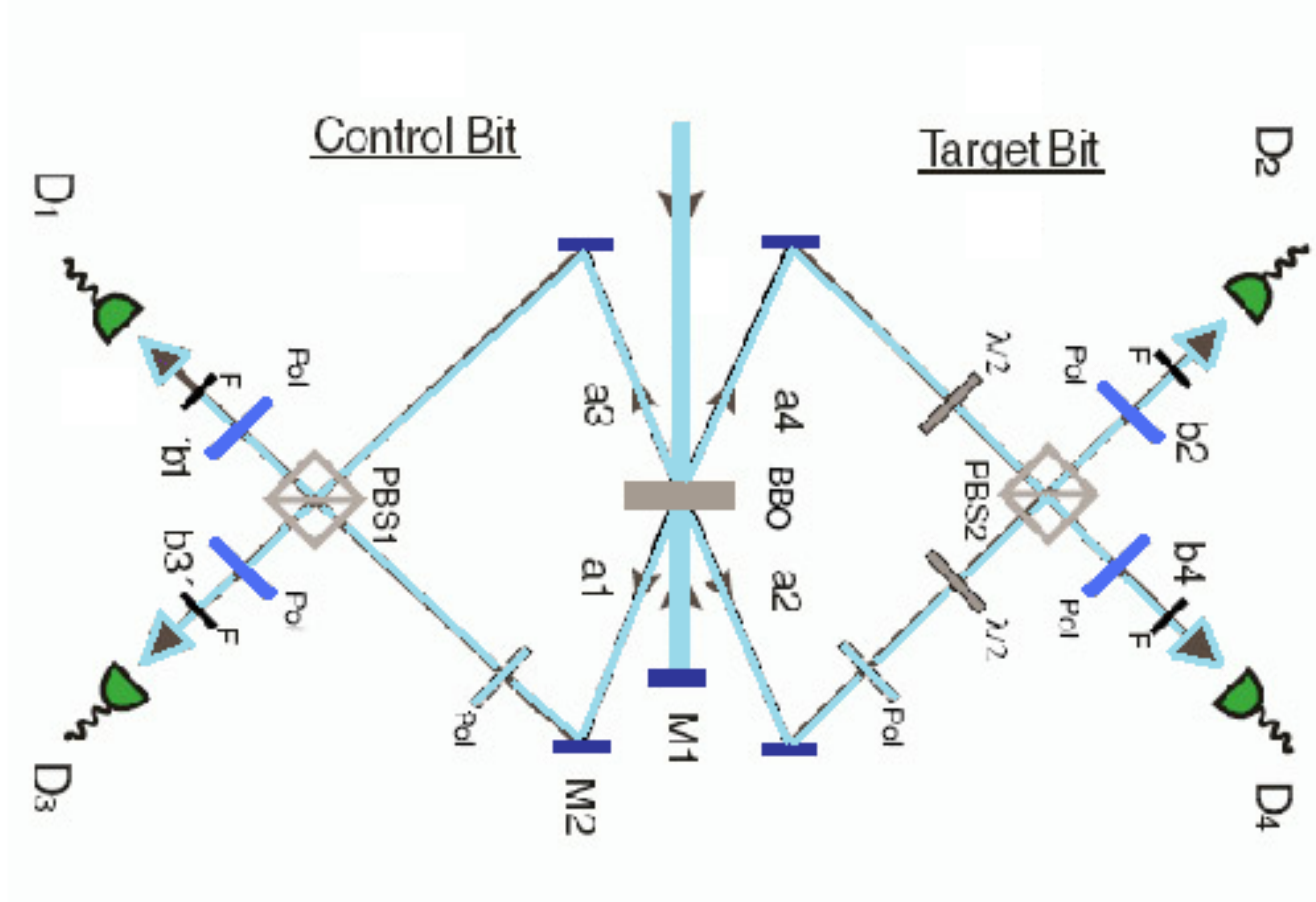

Monetary
National
Income
Analogue
Computer



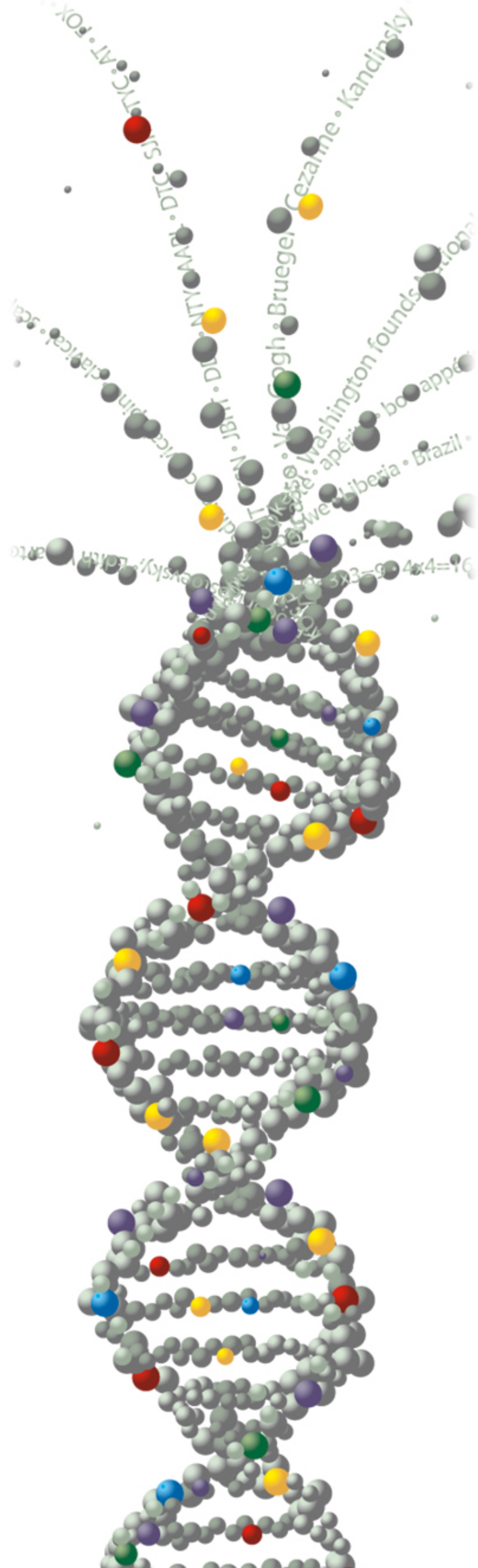
DEPTH
FT
DANGER
SAFE
DECOMPUTER
MARK I

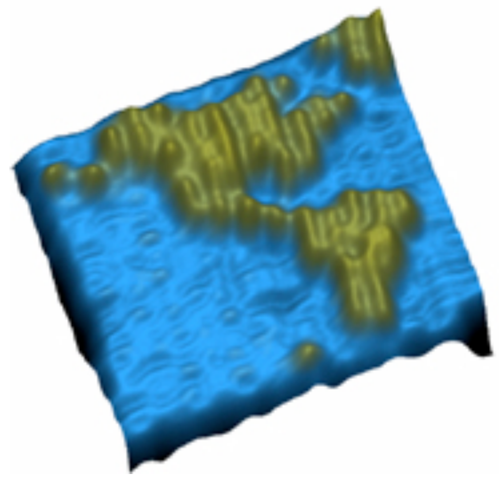

AFT
FWD

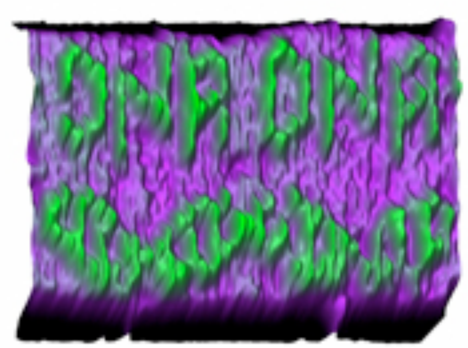

EC-1 Educational Electronic
Analog Computer

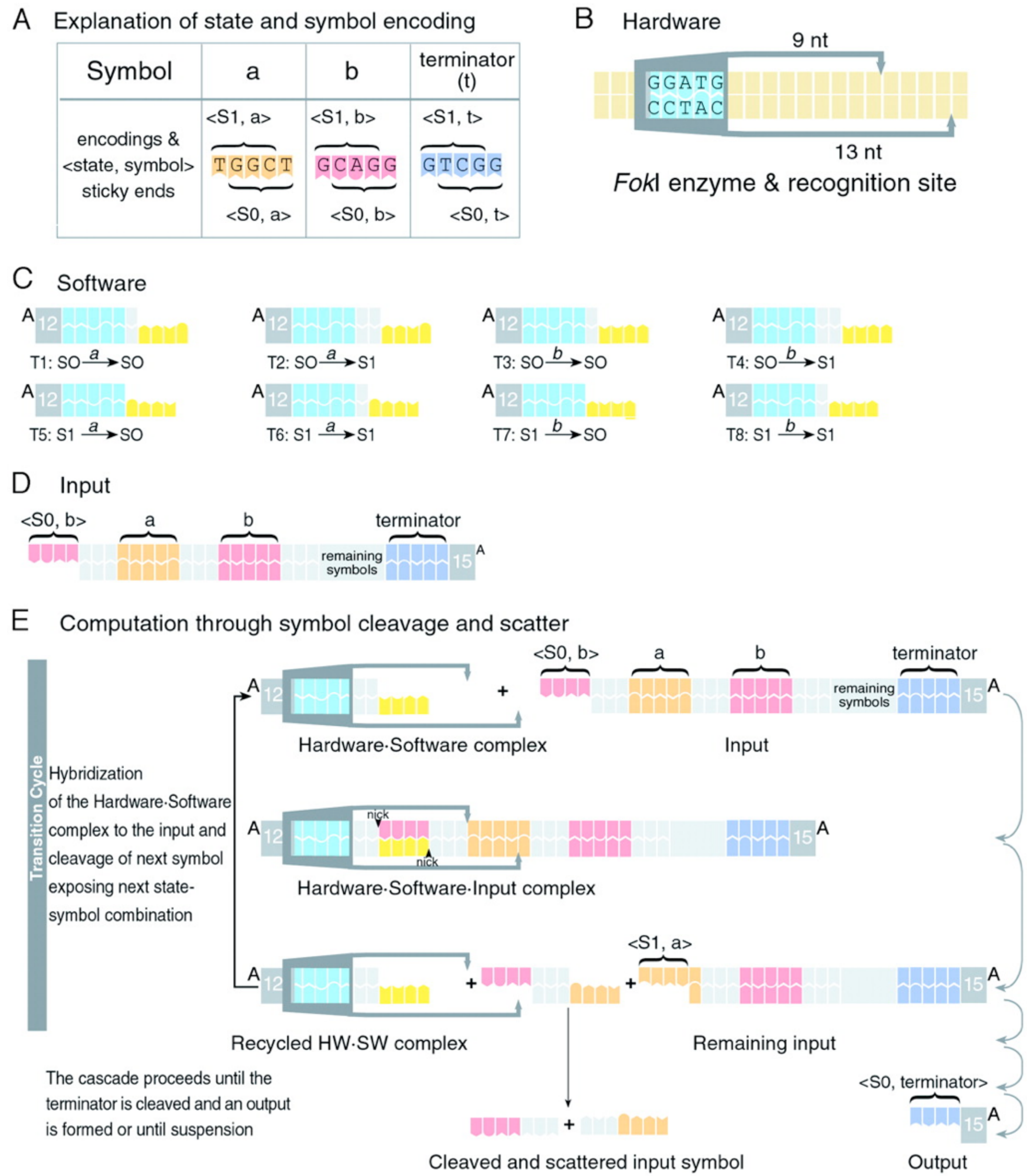


$$a\,|000\rangle + b\,|001\rangle + c\,|010\rangle + d\,|011\rangle + e\,|100\rangle + f\,|101\rangle + g\,|110\rangle + h\,|111\rangle$$








A Explanation of state and symbol encoding
Symbol
a
b
terminator (t)
encodings & <state, symbol> sticky ends
<S1, a>
TGGCT
<S0, a>
<S1, b>
GCAGG
<S0, b>
<S1, t>
GTCGG
<S0, t>
B Hardware
9 nt
GGATG
CCTAC
13 nt
FokI enzyme & recognition site
C Software
T1: S0 a→ S0
T2: S0 a→ S1
T3: S0 b→ S0
T4: S0 b→ S1
T5: S1 a→ S0
T6: S1 a→ S1
T7: S1 b→ S0
T8: S1 b→ S1
D Input
<S0, b>
a
b
remaining symbols
terminator
15
E Computation through symbol cleavage and scatter
Transition Cycle
Hybridization of the Hardware-Software complex to the input and cleavage of next symbol exposing next state-symbol combination
Hardware·Software complex
Input
nick
Hardware·Software·Input complex
Recycled HW·SW complex
<S1, a>
Remaining input
The cascade proceeds until the terminator is cleaved and an output is formed or until suspension
<S0, terminator>
Cleaved and scattered input symbol
Output