From mind to Turing to mind

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Many *numerical problems* can be answered by computing

"What is the area of a circle with radius $4\,\mathrm{m}$?"

Answer: $4^2\pi\,\mathrm{m}^2 = 50.2654824\,\mathrm{m}^2$

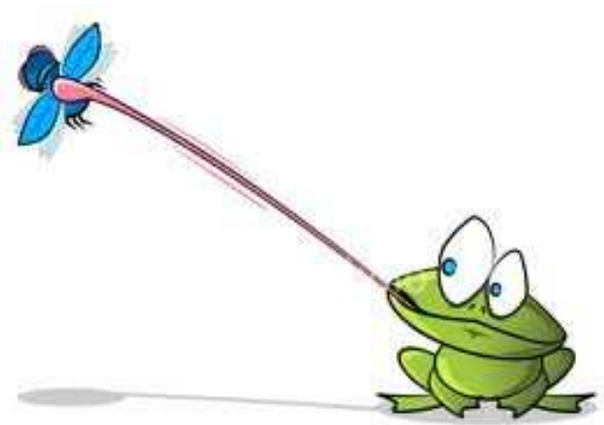
Also many *qualitative problems* may be answered by computing

"Are points $A = (x_1, y_1)$, $B = (x_2, y_2)$ and $C = (x_3, y_3)$ in $\mathbb{R}^2$ collinear

i.e. do they lie on a straight line?"

Answer: if and only if $(x_1 - x_3)(y_2 - y_3) = (x_2 - x_3)(y_1 - y_3)$

Also in animal life computations are needed: nature has evolved



an electro-chemical computational model

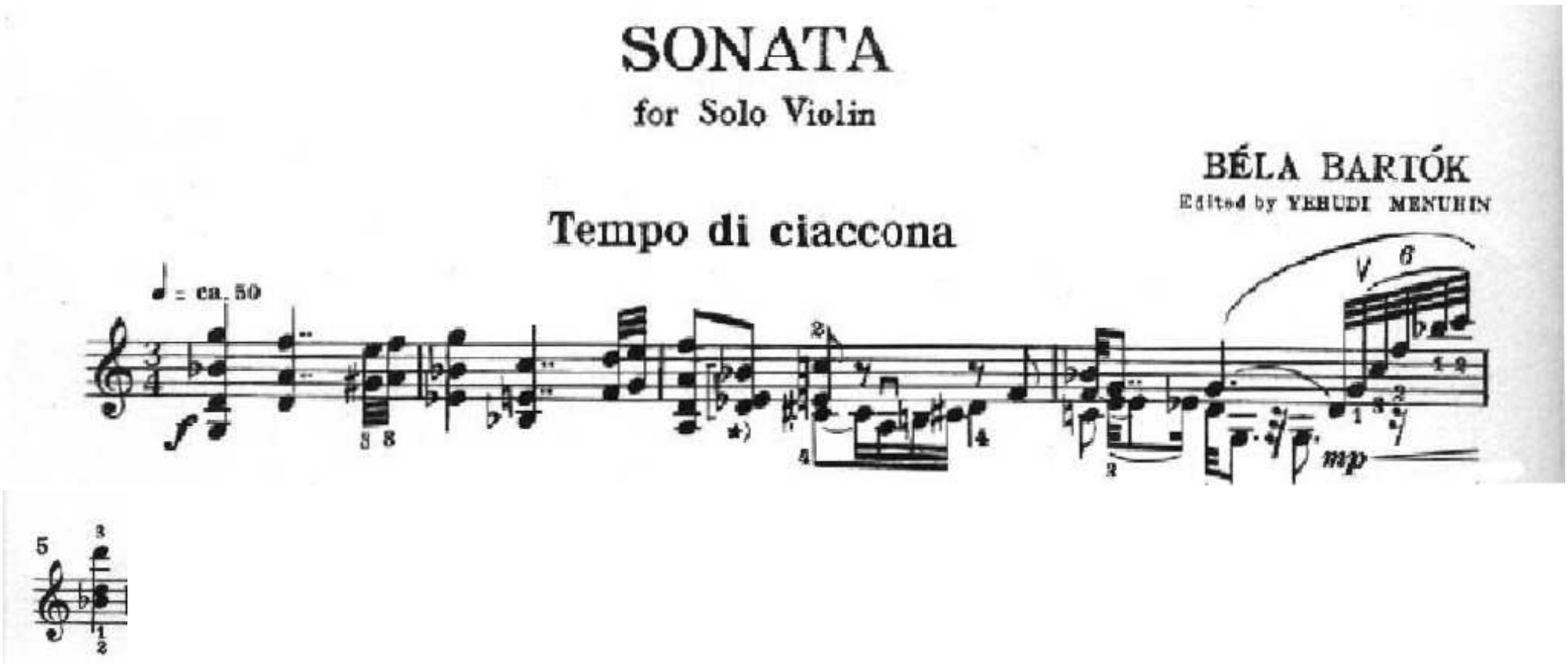
neural net synapse

These are programmed by trial and error
are trained through evolution via genes
run in parallel and are remarkably efficient

In the performing arts computations reach a next higher level

Bartok: Sonata, Ivry Gitlis violin

(needs training via memes, carriers of the evolution of ideas)

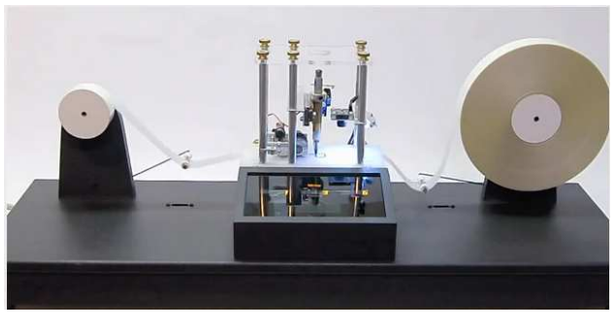


Leibniz: "Can all problems be answered by a computing machine?"

Turing: Impossible for the class of qualitative mathematical problems

but possible for the subclasses of problems: Mathematica, SPSS

How did Turing prove this?



Realization:
Mike Davey

- Gave a well-motivated analysis of computability via *Turing machines* (TM)
  transitions via table; actions: Left, Right, Write
- !! Constructed a *universal Turing machine* U that can simulate any TM
  technological aspect: functionality via *programs*
  $U(p_M, i) = M(i)$
- Formulated about U the *Halting Problem*, unsolvable by any TM

A Turing Machine (TM) is specified by

I a set of symbols
Q a set of states
} finite sets

Quadruples

$$\langle i, q, \{L, R, i'\}, q' \rangle$$

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A a set of actions
} finite sets

T transition rule given as a finite table

where $T : (I \times Q) \to (A \times Q)$ is a partial function

$A = \{L, R\} \cup \{W(i) \mid i \in I\}$

and has a two-sided infinite tape

of cells containing nothing (a blank) or a symbol $i \in I$

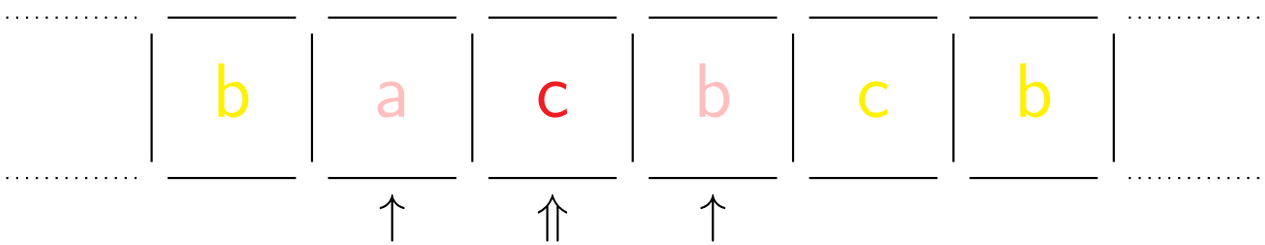
and also has a Read/Write device ('head') placed on one of the cells

if $T(i, q) = (a, q')$, then we write $(i, q) \to_T (a, q')$

The discrete action was based on introspection of how we compute

An (*instantaneous*) *configuration*

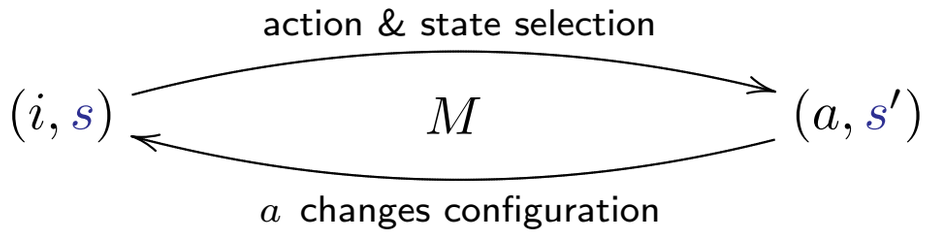
is the information on the entire tape & position of the head
(at a given moment)



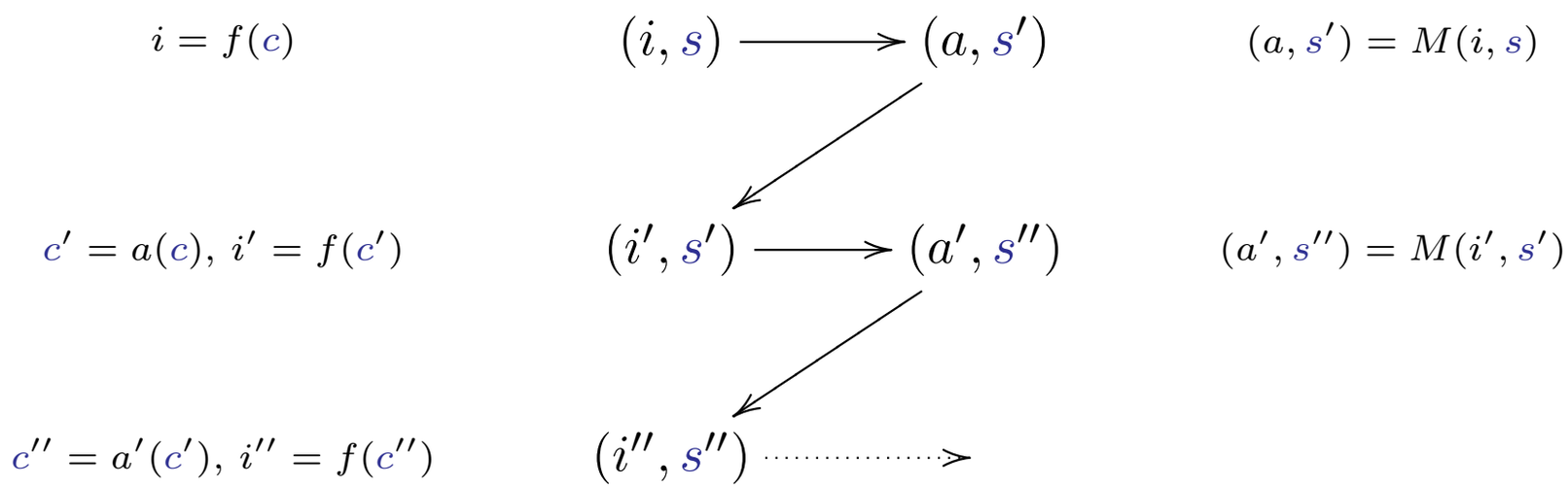
In this example (terminology suggestive for sequel)

⇑		position of read/write head
↑		potential next position of head
red	letter	(conscious)
pink	letters	(pre-conscious)
yellow	letters	(unconscious)

The two phases of M combine as follows



giving a 'scenario' as follows: c initial configuration, s initial state, f 'focus of'



M *halts* if no more transition is possible. Then *input*: initial c; *output*: final c

A Turing *process* is a run of a TM

A Turing *computation* is a terminating run of a TM

A process is intended to continue forever
(e.g an operating system, an animal, conscious cognition)
A computation is intended to have an output
For a process the input (and possibly output) is represented by a configuration

Turing's Thesis

Every computable process can be captured by a Turing process

and every computable computation by a Turing computation

Turing's Theorem

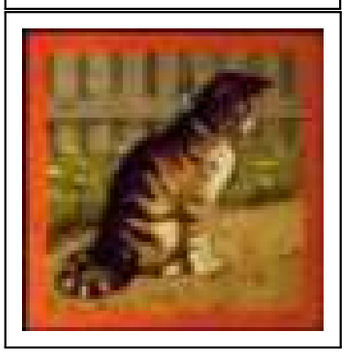
There is a *Universal Turing Machine*, that can simulate all other TMs

by adding as input a *program* simulating an intended machine

directed to an input

i_1

i_2



i_3

directed to an input having a state (higher order concept, 'emotion')

(i_1, s_1) fear

(i_2, s_2) desire

(i_3, s_3) shared joy

(i, s): collaboration between frontal lobe & amygdala [4]

0. Behaviourism: $i \longmapsto a$ input (stimulus) is changed into an action (response)

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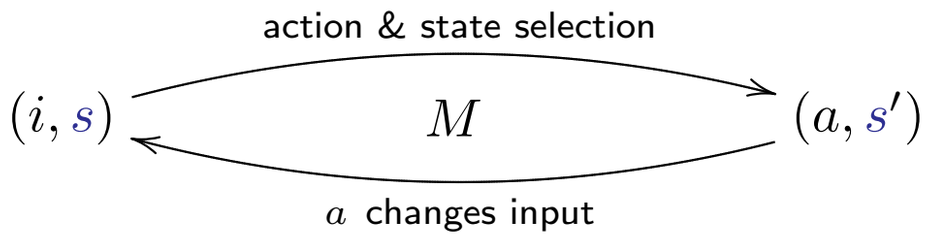
1. Every moment there is a pair (i, s) (in kinetic gass theory $s \in \mathbb{R}^{6.10^{23}}$)
which is changed into a (re)action and a possibly new state (a, s')

$$(i, s) \longmapsto (a, s')$$

2. Then the a (action) changes the scene, resulting in a new input

Together this gives a two-phase process



The transitions are determined via a computation using the brain

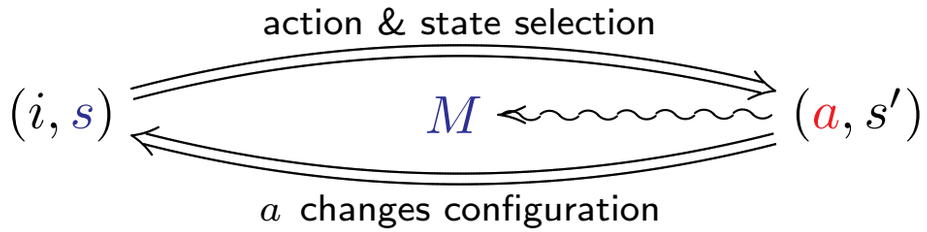
Turing (1912-1954) gave a two-fold analysis of computing (1937, 1950)
equally strong with different efficiencies: via Turing machines & neural nets

From Turing machine to computer to animal to homo sapiens (1,2,3,4 historical order)

3. Turing machine	4. computer	1. animal	2. human
tape	disc, flash	associative	Idem
one bit cell	1GB internal memory	attention	Idem
no I/O	sensors & actuators	senses & motorcontrol	Idem
transition table	via program	via neural net	Idem
states $s_1, \ldots, s_{15}$	10^{10^9} states	survival directed	Idem
universality	Idem	–	mindfulness

Simulating M by U (universality) enables a to act on both

M (really on p_M in the memory)
s (also now in the memory)
} mindfulness (meta-awareness) in humans



A hybrid Turing model of conscious cognition

with notion of attention, preconscious, unconscious

Discreteness

attentional blink
psychological refractory period
short term memory retrieval
thalamo-cortical pulse
wagon-wheel illusion
trained phenomenology

Future research: how do some processes within processes take place?

Forms of consciousness

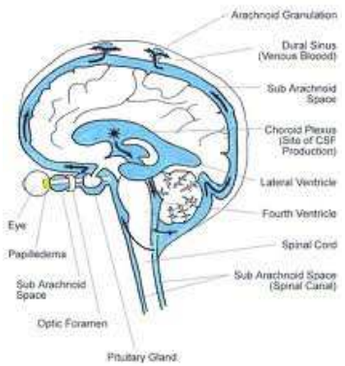
core-conscious
pre-conscious
un-conscious ('subliminal processing')

Operational definitions given in [3]

States

Mathematical necessity

Life science



Overcoming biological noise efficiently [9]

Crucial role for states (including emotions) (i, s)

Need for state-change and state-preservation:

many neuropeptides (~ 100)

volume transmission (CSF [1,5], oxytocin [7], β-endorphin [8])

Also on another level (Colleague molecular biology)

"Model also applies to molecular mechanisms:

discreteness and states (switching on/off genes)

'conscious' (produced proteins for direct use)

'pre-conscious' (prepared proteins for later use)

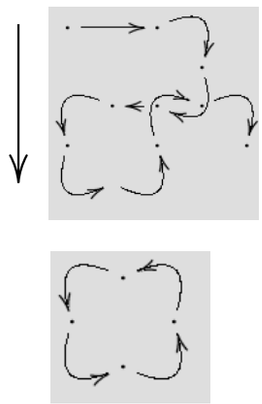
'unconsciou' (potential proteins dormant in genome)"

Molecular biology (Drew Berry)

Mental balance — Fundamental instability of mind → existential fear or 'addiction'

`aversion, desire` — Craving for symptomatic stabilization (with side-effects!)

`mindfulness` — Decreasing frequency of addictive states by



`dynamical system view`

- sensory restriction
- mental restriction: attention on present input
  using mindfulness taking distance from (i, s)
- insight in our vicious circles: deautomatization

The pumping lemma is not valid for Turing machine's

In the meditative state one becomes more like a finite automaton

then the pumping lemma applies

and one can deautomatize vicious circles

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[3] Dehaene, Changeux, Naccache, Sackur, Sergent. Conscious, preconscious, and subliminal processing: a testable taxonomy. *Trends in Cognitive Sciences*, 10(5), 2006, 204-211.

[4] Salzman, Fusi. Emotion, Cognition, and Mental State Representation in Amygdala and Prefrontal Cortex. *Annu. Rev. Neurosci.* 2010(33), 173-202.

[5] Veening, Barendregt. The regulation of brain states by neuroactive substances distributed via the cerebrospinal fluid. A review. *Cerebrospinal Fluid Research*. 7(1), 2010.

[6] Turing. Lecture to the London Mathematical Society (20 February 1947). In: Carpenter, B. E., Doran, R. W. (Eds.), A. M. Turings ACE report of 1946 and other papers. MIT Press, Cambridge, Mass., 1986. .

[7] Veening, de Jong, Barendregt. Oxytocin messages via the cerebrospinal fluid: behavioral effects; a review. *Physiology & Behavior*, 101(2), 2010, 193-210.

[8] Veening, Gerrits, Barendregt β-Endorphin: Effects by volume transmission via the cerebrospinal fluid; a review. Submitted.

[9] Zylberberg, Dehaene, Roelfsema, Sigman. The human Turing machine: a neural framework for mental programs. *Trends in Cognitive Sciences*, 2011, 15(7), 293-300.