"The Emperor's New Mind": computers, minds, mathematics and physics

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Consciousness and computing

> *. . . it resembles nothing so much as a bowl of cold porridge.* Alan Turing

A human brain has roughly 10^{11} neurons firing about a thousand times per second—that is 10^{14} switchings per second.

But where is the mind? consciousness?

A modern computer is made of millions of transistors and cruising easily at a GHz—a total of 10^{15} switchings per second, or more. Surely 'artificial intelligence' will soon surpass human.

Roger Penrose's thesis is that human intelligence is far more subtle than 'artificial intelligence' in computers.

Overview

1. There are things which are not computable—not simply that we do not have the computer power available—there are tasks which *cannot* be computable by any physical machine.
2. The mysteries of quantum physics, correct to unbelievable precision, leave scope for uncomputable tasks.
3. There are structures within living cells which may achieve the task of amplifying quantum effects to our human scale.

The truth ..... is likely to be stranger still.

We know truths which are not computable!

> *There are more things in heaven and earth, Horatio, than can be dreamt of in your computer.*
> paraphrasing Hamlet, Shakespeare

List all computer programs: C_1, C_2, C_3, C_4, ...

Express any possible input to such programs as one number n.

Some programs $C_q(n)$:

- will stop (successfully); gcd
- will never stop (unsuccessful); odd$= \sum^n$even
- may or may not stop depending upon n. $m \neq \sum^n$squares

We know truths which are not computable!

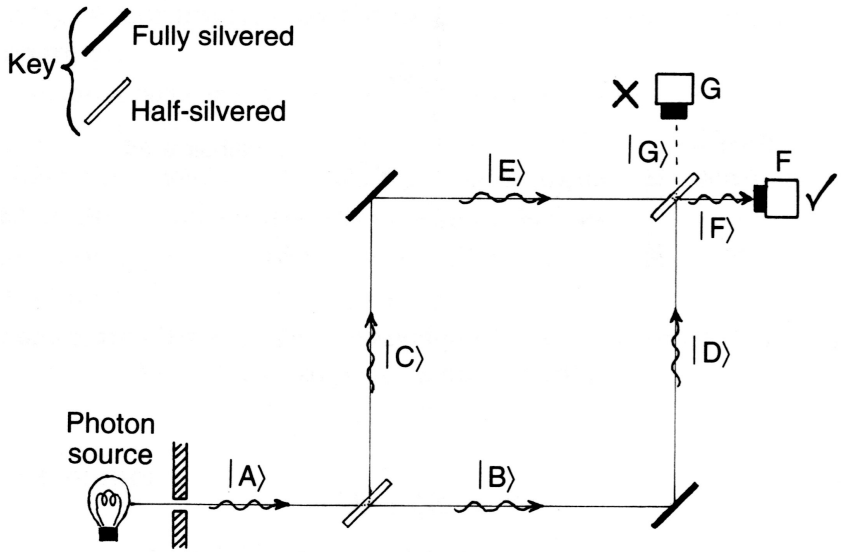
Program A encapsulates *all computational procedures* that examine programs and data $C_q(n)$ to 'prove' whether they stop or not.

1. If A stops when applied to $C_q(n)$, then $C_q(n)$ does not stop.
2. If A stops when applied to $C_n(n)$, then $C_n(n)$ does not stop.
3. But "A applied to $C_n(n)$" is computational, so must appear for some k as $C_k(n)$ in the list of programs.
4. Put $n = k$ in 2.: if $C_k(k)$ stops, then $C_k(k)$ does not stop.
5. *We now know* that $C_k(k)$ cannot stop.
6. By 3., $C_k(k)$ is "A applied to $C_k(k)$":

   $\Rightarrow$ 5. we know A applied to $C_k(k)$ does not stop;

   $\Rightarrow$ A cannot determine whether $C_k(k)$ stops or not.

Quantum theory superbly describes physical reality



Computable quantum evolution $\mathcal{U}$ says

- $|A\rangle \mapsto |B\rangle + i\,|C\rangle$
- $|B\rangle \mapsto i\,|D\rangle$ and $|C\rangle \mapsto i\,|E\rangle$, so $|B\rangle + i\,|C\rangle \mapsto i\,|D\rangle - |E\rangle$
- $|D\rangle \mapsto i\,|F\rangle + |G\rangle$ and $|E\rangle \mapsto |F\rangle + i\,|G\rangle$, so $i\,|D\rangle - |E\rangle \mapsto -|F\rangle + i\,|G\rangle - |F\rangle - i\,|G\rangle = -2\,|F\rangle \equiv |F\rangle$

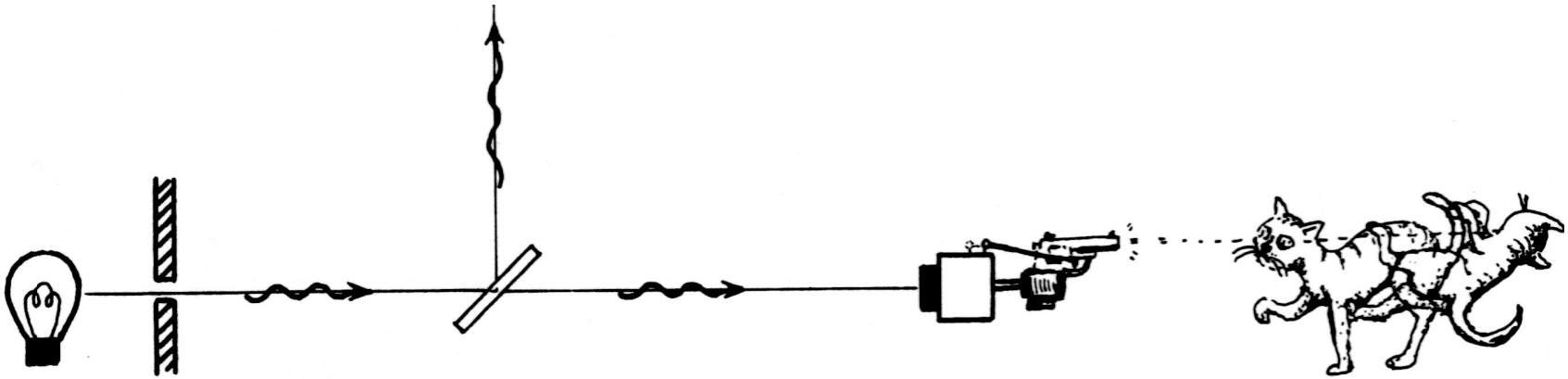
so $\mathcal{U}$ says only F detects any photons!

Observation Quantum measurement $\mathcal{R}$ asserts a complex state $f\,|F\rangle + g\,|G\rangle$ will be *observed* in these states with probability ratio $|f|^2 : |g|^2$.

Where does the weirdness lie?

Quantum evolution $\mathcal{U}$ is a superb *computable* theory.

However, the measurement $\mathcal{R}$ that connects the quantum level to the classical is *not* understood.

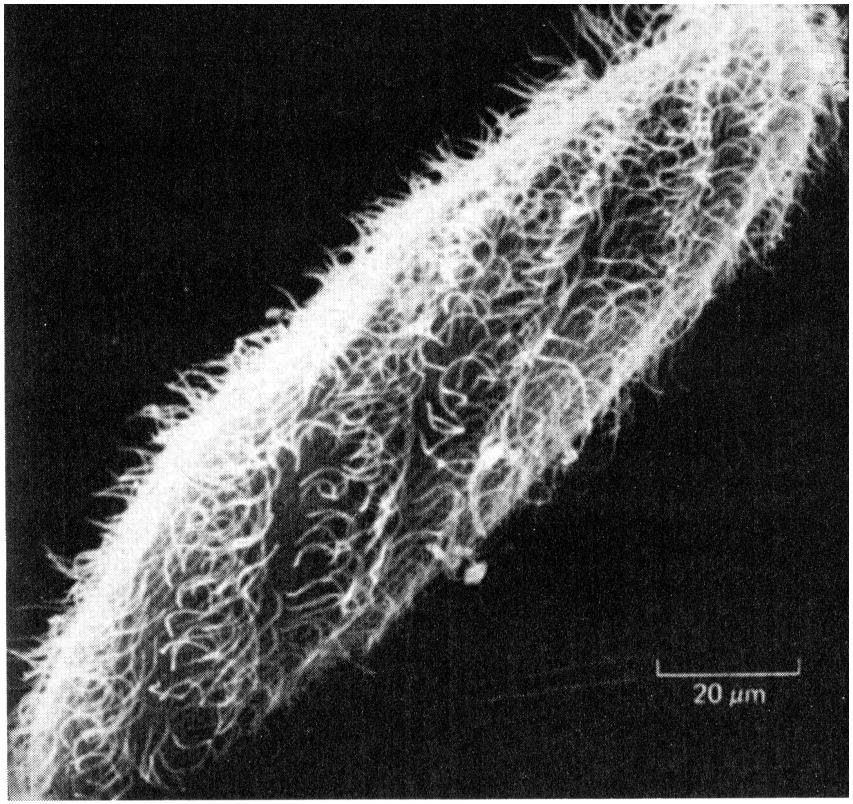


$\mathcal{U}$ $\mathcal{R}$

Conjecture: $\mathcal{R}$ is not computable. The only definite thing we know about $\mathcal{R}$ is the squared modulus rule for probabilities.

Perhaps the brain uses quantum processing to 'understand'.

There must be a complicated control system somewhere



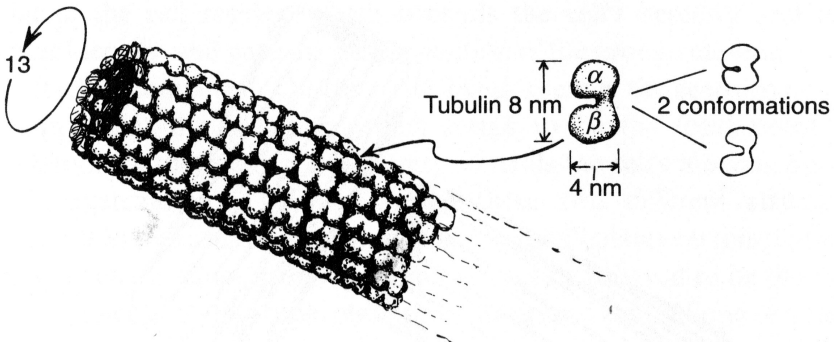
Paramecium is a single cell organism about 40 μm in diameter:

- it swims in the direction of bacterial food;
- and retreats from danger;
- negotiates obstructions by swimming around them;
- and may even *learn* from past experiences.

Rather amazing for a single cell animal!

Where could consciousness lie?

The same anaesthetics that cause us to lose consciousness, have a very similar effect on paramecium!



The *cytoskeleton* not only provides an internal scaffolding for the paramecium, it also:

- contain the control system;
- transports molecules from one place to another.

Microtubules make up the cytoskeleton . . . . . and could compute.

Perhaps microtubules utilise non-computational, quantum measurement $\mathcal{R}$.

Conclusion

- Human understanding is qualitatively different from routine computation.
- Theory linking the quantum level to the macroscopic classical level is deficient.
- That physicists are largely ignorant of such a link is no argument that nature has not used it.

Reading

- Penrose, *Shadows of the mind*.
- Lindley, *Where does the weirdness lie?*