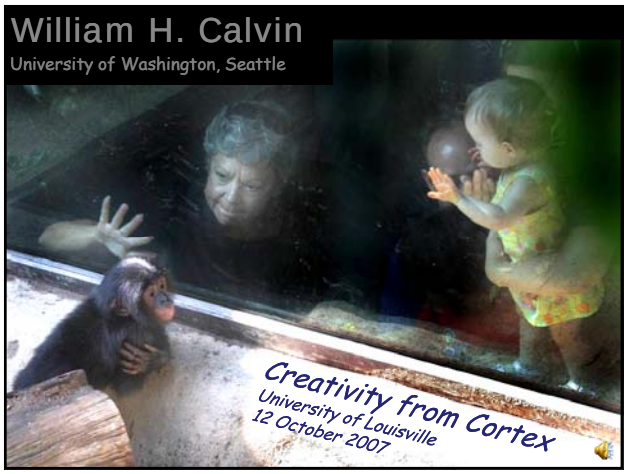
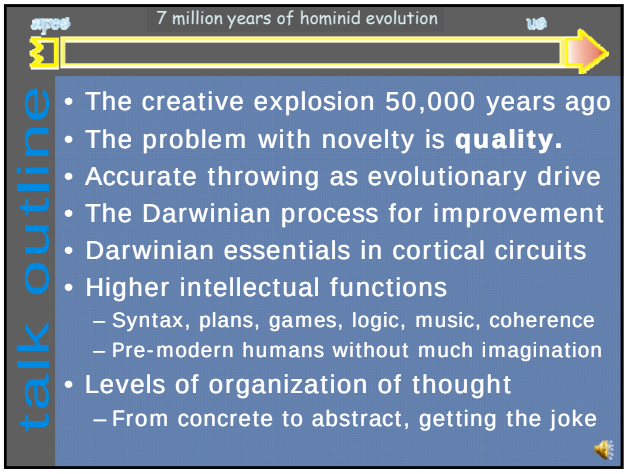
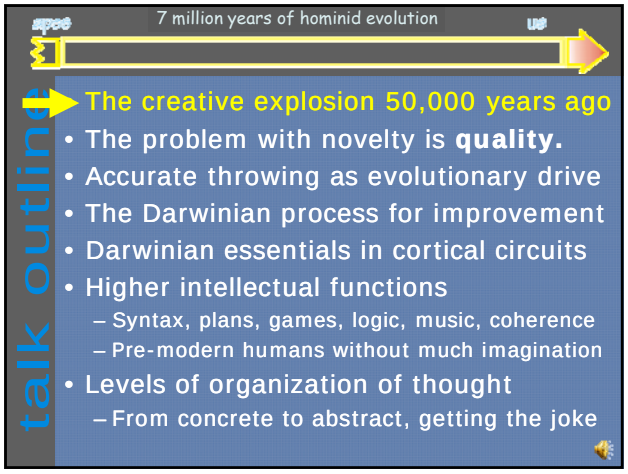


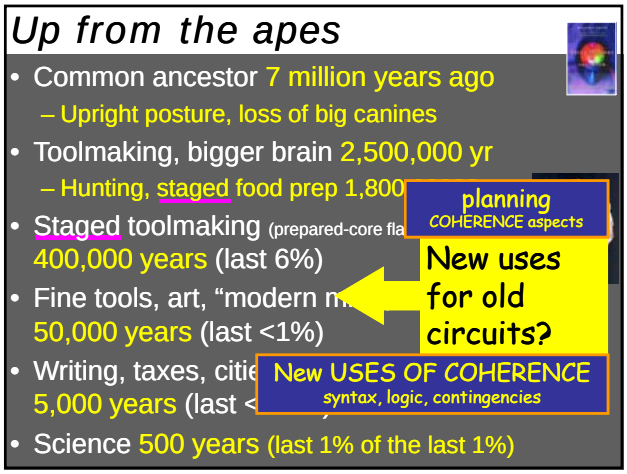
Three books have more depth (and the references)

The thumbnail on a slide will tell you which book has the most on the topic of that slide.

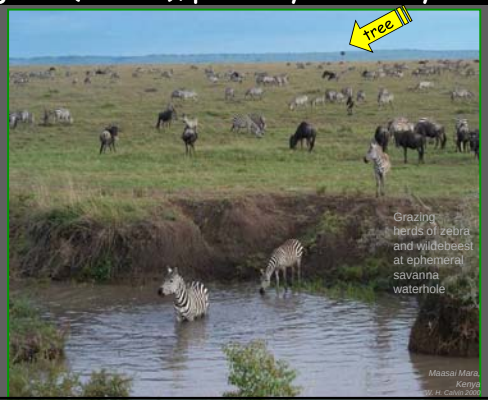
If you want to look something up, try my web site at *WilliamCalvin.com* which has the full text and illustrations of all the books.







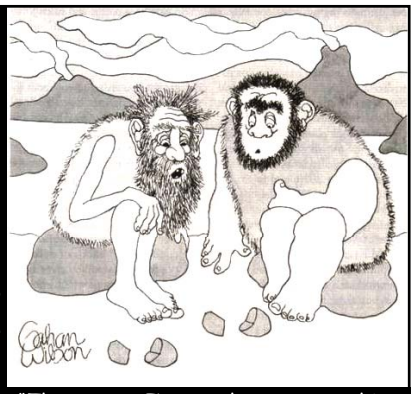
By 1.8 myr, *Homo erectus* was eating a lot of grass ($^{13}C/^{12}C$), probably indirectly via meat.



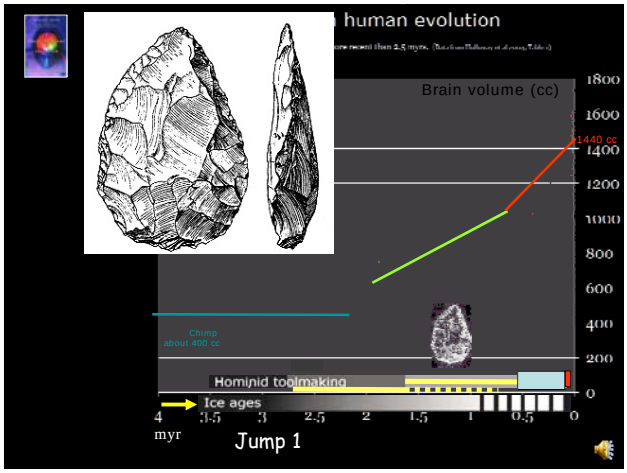
Few trees for refuge, but a lot of meat on the hoof.

Earliest stone tools about 2.7 million years ago were crudely split rocks yielding a sharp edge and a hand grip.

No progress for another million years.

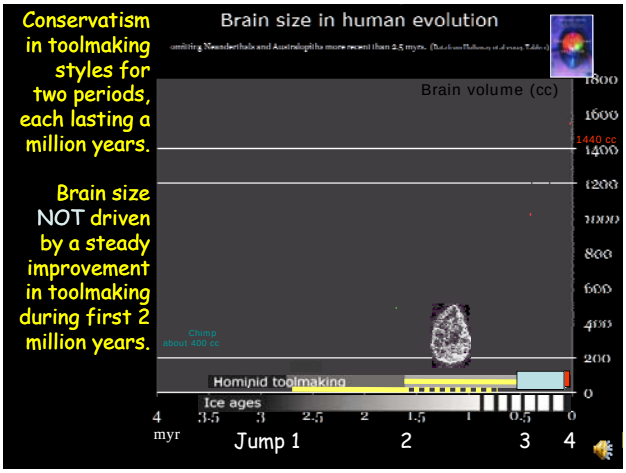


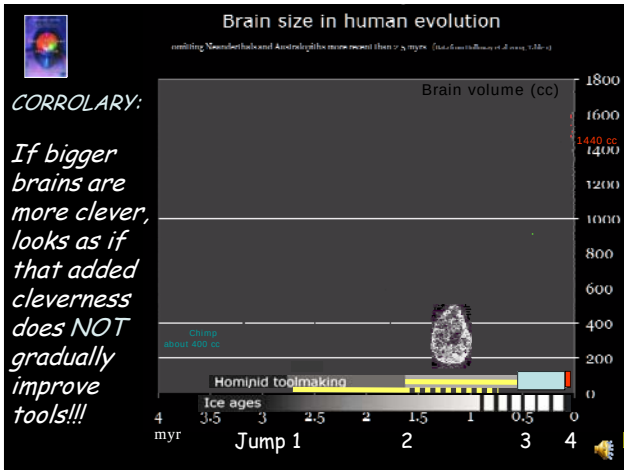
"There—now I've taught you everything I know about splitting rocks."



Conservatism in toolmaking styles for two periods, each lasting a million years.

Brain size NOT driven by a steady improvement in toolmaking during first 2 million years.





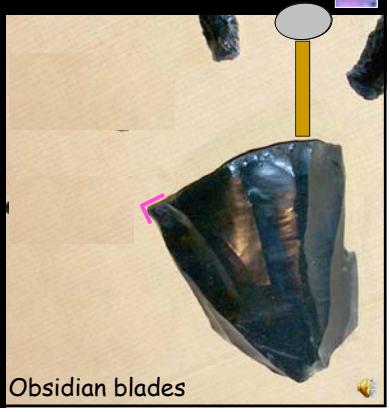
CORROLARY:

If bigger brains are more clever, looks as if that added cleverness does NOT gradually improve tools!!!

Staged Toolmaking

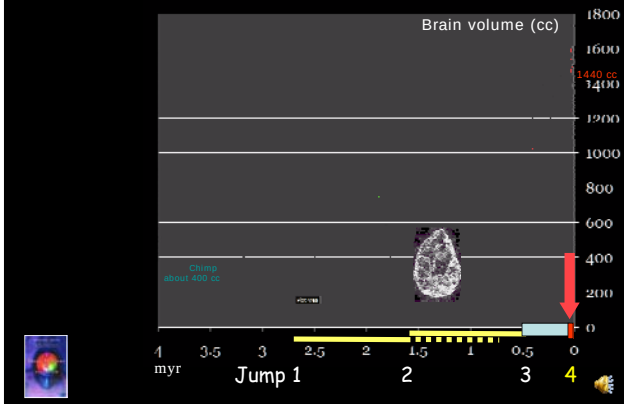
1. Make a flat surface.
2. Use pusher at edge.
3. Strike, shave off blade.

Blades start at about 280,000 years ago in Africa, well established by 120,000 years ago.



Obsidian blades

The Creative Explosion of the last 50,000 years



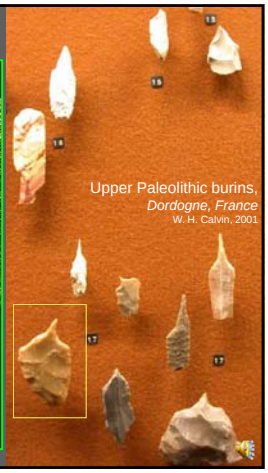
About 80,000 to 90,000 years ago, the Katanda region of Congo has barbed harpoon points carved out of bone (Brooks & Yellin 1988).

Photograph by David Brill in *From Lucy to Language* by Donald Johanson and Blake Edgar (1996).

Some bone tools are decorated

Behaviorally-modern *fine* tools

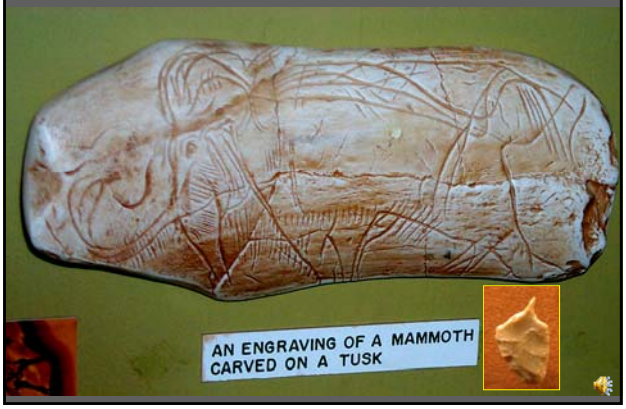
Paleolithic cloth bone-sliver needle
26,000 years old
Enlene, France
David Brill



Upper Paleolithic burins,
Dordogne, France
W. H. Calvin, 2001

Portable Art: *Ivory carving*

(National Museum of Kenya)

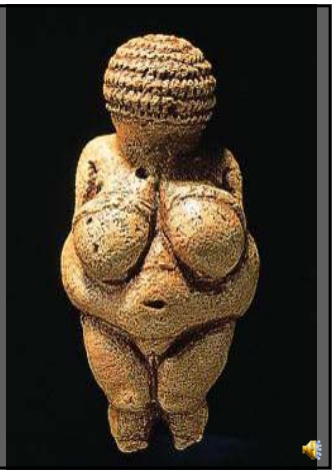


Portable Art:

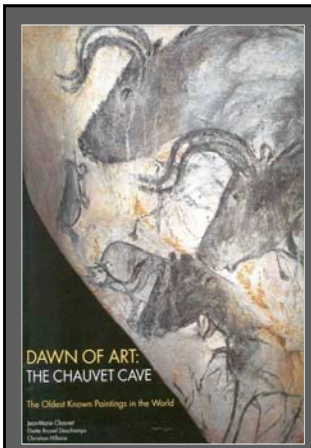
Venus of Willendorf

limestone figure from a site on the Danube

Photograph by David Brill in *From Lucy to Language* by Donald Johanson and Blake Edgar (1996).



Wall Art: *Cave art sites*

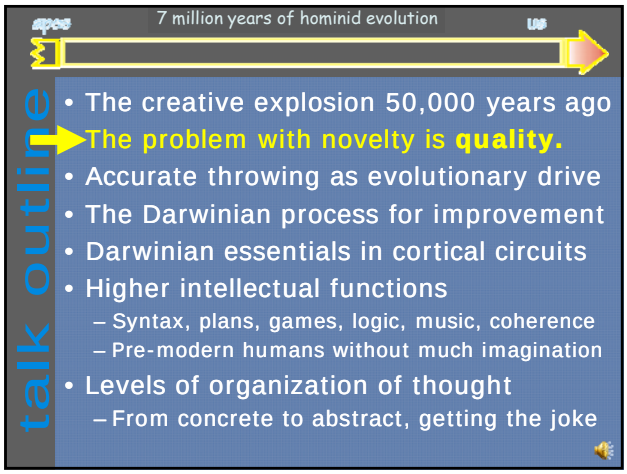


35,000 years old *(earlier in Asia???)*

"Creative intelligence"

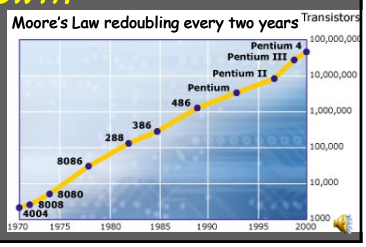
To summarize

- The reason for bigger brains was not general intelligence but something more specific, having a long growth curve.
  - Words and short sentences?
  - Sharing?
  - Throwing accuracy?
- The niche of regularly eating large grazing animals involves all three.



Searching for evolutionary drivers

- There are a hundred important differences between apes and humans but only a few of them have a *long growth curve*, capable of being intensified repeatedly.



Planning behaviors and hunting

- Many aspects of meat-eating cannot be intensified. The long growth curve is for ***throwing.***
- Twice as far, twice as fast, twice as accurate — they're all good for an additional payoff in terms of days per month when your family can eat high-quality food in hard times.

Planning behaviors and hunting

- And no matter how good you are, getting better has an additional payoff.
- Missing the first time is *worse* than not throwing at all.
- ***Dinner runs away.***
- ***They keep their distance next time***
- ***You have to get better and better or find a naïve herd.***

When detailed plans are needed

- No need for a detailed plan for most novel actions.
- "Fumble and find" suffices.
- Blindly picking up an empty coffee cup, and stopping it before it hits your nose, works because the movement is slow enough.

- If it took 1/8 sec, ***there's no time for feedback to correct the "ballistic" movement.*** Now need a ***detailed plan.***

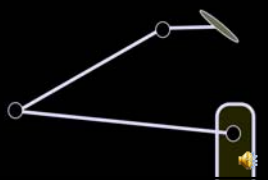
talk outline

7 million years of hominid evolution

- The creative explosion 50,000 years ago
- The problem with novelty is **quality.**
- Accurate throwing as evolutionary driver
- The Darwinian process for improvement
- Darwinian essentials in cortical circuits
- Higher intellectual functions
  - Syntax, plans, games, logic, music, coherence
  - Pre-modern humans without much imagination
- Levels of organization of thought
  - From concrete to abstract, getting the joke

Ballistic movements are too fast

- Throwing a dart takes only 1/8 sec, and our feedback loop is too slow to fix things if you get started a little bit wrong.
- Hammering, clubbing, kicking, spitting



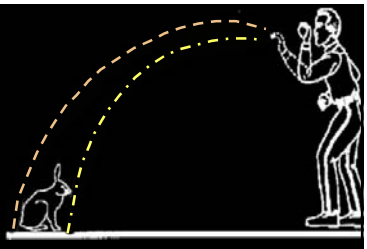
Release early, goes too far

Twice the distance, 8X as difficult.

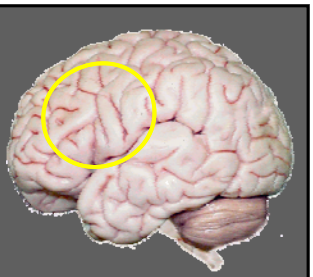
Release late, falls short

- For accurate throwing, you have to plan *every little detail* of the muscle activation sequence in advance as you *Get Set*.

- Set pieces, like free throws.
- But most target distances are novel, so the neural circuitry for *planning* that 1/8th sec action sequence, in excruciatingly fine detail, was likely improved over several million years.

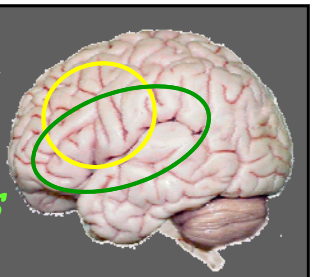


The parts of the frontal lobe involved with planning novel hand and arm movements also work pretty well at planning mouth and face movements.



William H. Calvin, *A Brain for All Seasons*, 2002

- *They also have a lot of overlap with brain regions used during language tasks.*



Multifunctional circuitry?

William H. Calvin, *A Brain for All Seasons*, 2002

7 million years of hominid evolution

talk outline

- The creative explosion 50,000 years ago
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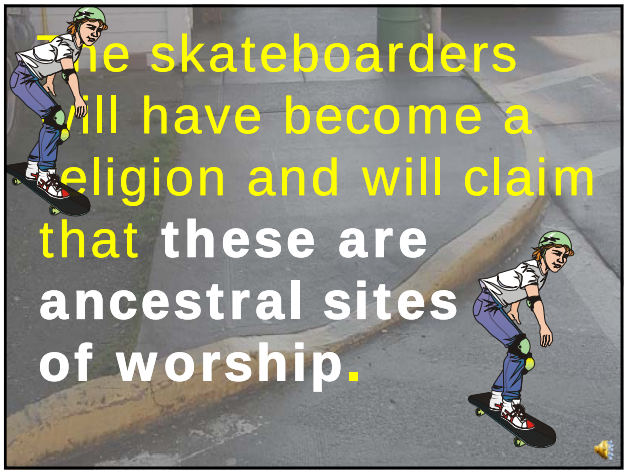
Curb cuts are multifunctional

Curb cuts at airports created suitcase queues.

Secondary suitcase use paid for making curb cuts wider

Soon, robotic wheelchairs and suitcases will climb stairs, making the paid uses *obsolete*.



The skateboarders will have become a religion and will claim that **these are ancestral sites of worship.**

The highest-use fallacy: Soon, the *best use* of the curb cut will suggest that **"Curb cuts were created for skateboards."**

The highest-use fallacy: the current *best use* was what its evolution was all about. "**Big brains are all about intelligence.**"

The brain is very good at secondary uses. So planning ballistic movements like throwing and hammering may have paid for the neural circuitry that has "free" secondary uses,

…"free" secondary uses, like planning a long sentence to speak, or planning a week-long agenda, where you must coordinate the various parts as you "get set."

Novel collections are easy but incoherent

The problem with most novel collections is ***low quality***, as we see in our night-time dreams – people, places, and occasions that simply do not fit together.

Awake, it's an off-line search for ***coherence***, for combinations that "hang together" particularly well.

W. H. Calvin, *A Brief History of the Mind*, Oxford University Press 2004

Things other animals probably don't do

What sort of on-the-fly process does it take to convert such an incoherent mix into a coherent compound, whether it be an on-target movement program or a novel sentence to speak aloud?

W. H. Calvin, *A Brief History of the Mind*, Oxford University Press 2004

Physiology of thought

- The problem is **novelty** (innovation, creativity) and how you **regulate it**.
- Random combinations can be easily produced, but how do you improve the quality until it is good enough to act on?
- *The Darwinian process is the only quality-improvement process we know that can bootstrap itself from rude beginnings to high quality.*

A century ago, **Alfred Russel Wallace** emphasized the combination of

- variation
- selection
- inheritance

Like a three-legged stool, evolution takes all 3 of them to stand up.

When trying to make Wallace's list a little more abstract, I listed six ingredients that seem essential to turn the crank:

1. There's a **pattern** of some sort (a string of DNA bases called a gene is the most familiar such pattern, though a cultural meme – ideas, tunes – may also do nicely).
2. **Copies** can be made of this pattern (indeed the minimal pattern that can be semi-faithfully copied tends to define the pattern of interest).
3. **Variations** occur, typically from copying errors and recombinations.

The first three focus on individuals, but the next three all involve populations:

4. A population of one variant **competes** with a population of another variant for occupation of a space (bluegrass competing against crabgrass for space in my backyard is an example of a copying competition).

The first three focus on individuals, but the next three all involve populations:

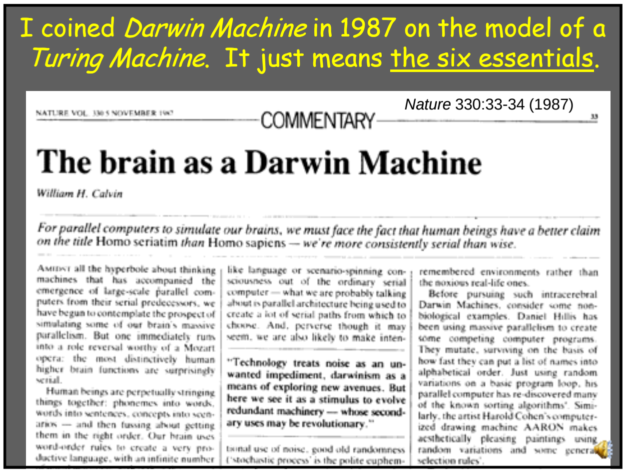
5. There is a **multifaceted environment** that makes one pattern's population able to occupy a higher fraction of the space than the other (for grass, it's how often you water it, trim it, fertilize it, freeze it, and walk on it). This is the "natural selection" aspect for which Darwin named his theory, but it's only one of six essential ingredients.

The last one is **Darwin's inheritance principle**

6. And finally, the **next round of variations are centered on the patterns that proved somewhat more successful** in the prior copying competition. *So variation isn't truly random; the starting place really does matter. And the next generation's starting place can shift a little.*

The six essentials for a Darwinian process

1. There's a pattern.
2. The pattern is copied.
3. Variations occur.
4. Populations of the variant patterns compete for a space.
5. Natural selection makes some patterns do better than others.
6. The next round of variations is centered on the more successful variations of the current generation.



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The brain as a Darwin Machine

William H. Calvin

For parallel computers to simulate our brains, we must face the fact that human beings have a better claim on the title Homo seriatim *than* Homo sapiens *— we're more consistently serial than wise.*

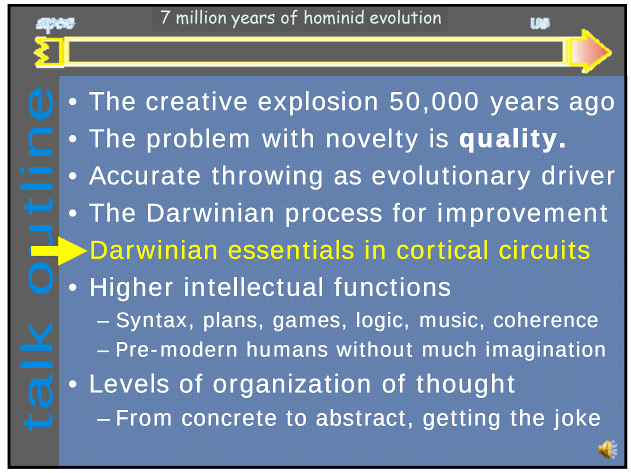
AMIDST all the hyperbole about thinking machines that has accompanied the emergence of large-scale parallel computers from their serial predecessors, we have begun to contemplate the prospect of simulating some of our brain's massive parallelism. But one immediately runs into a role reversal worthy of a Mozart opera: the most distinctively human higher brain functions are surprisingly serial.

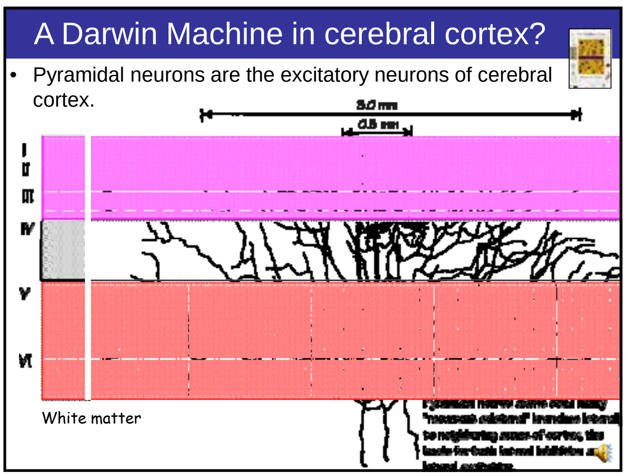
Human beings are perpetually stringing things together: phonemes into words, words into sentences, concepts into scenarios — and then fussing about getting them in the right order. Our brain uses word-order rules to create a very productive language, with an infinite number like language or scenario-spinning consciousness out of the ordinary serial computer — what we are probably talking about is parallel architecture being used to create a lot of serial paths from which to choose. And, perverse though it may seem, we are also likely to make inten-

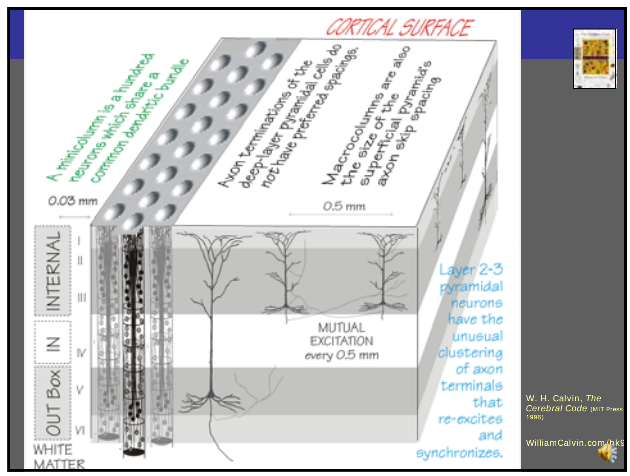
"Technology treats noise as an unwanted impediment, darwinism as a means of exploring new avenues. But here we see it as a stimulus to evolve redundant machinery — whose secondary uses may be revolutionary."

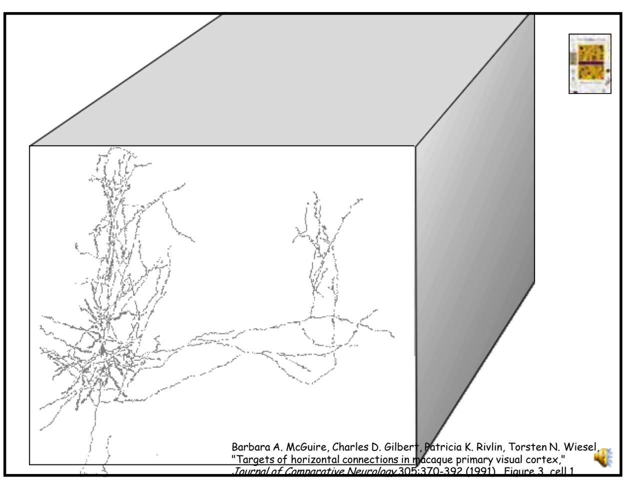
tional use of noise, good old randomness ('stochastic process' is the polite euphem- remembered environments rather than the noxious real-life ones.

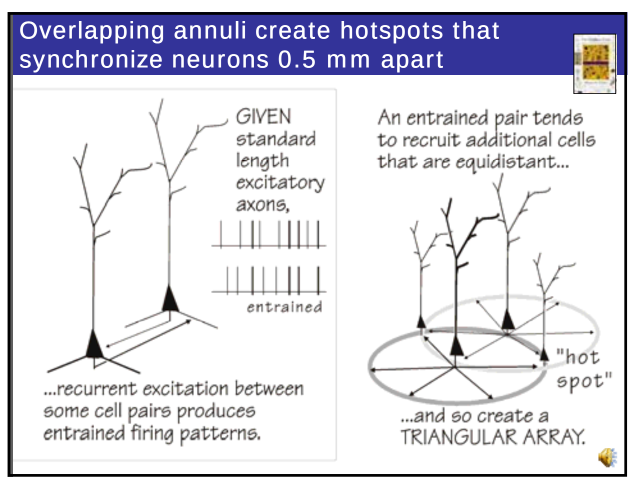
Before pursuing such intracerebral Darwin Machines, consider some non-biological examples. Daniel Hillis has been using massive parallelism to create some competing computer programs. They mutate, surviving on the basis of how fast they can put a list of names into alphabetical order. Just using random variations on a basic program loop, his parallel computer has re-discovered many of the known sorting algorithms'. Similarly, the artist Harold Cohen's computerized drawing machine AARON makes aesthetically pleasing paintings using random variations and some general selection rules'.



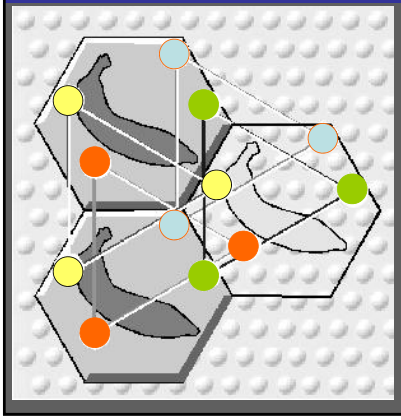








A hexagonal pattern can be cloned



A pair of points 0.5 mm apart create a third.

The largest collection, without redundancy, is confined to a 0.5 mm hexagon.

The six essentials for a Darwinian process

1. There's a pattern.
2. **The pattern is copied.**
3. Variations occur.
4. Populations of the variant patterns compete for a space.
5. Natural selection makes some patterns do better than others.
6. The next round of variations is centered on the more successful variations of the current generation.

The six essentials for a Darwinian process

1. There's a pattern.
2. ***Spatiotemporal patterns* are copied.**
3. Variations occur.
4. Populations of the variant patterns compete for a space.
5. Natural selection makes some patterns do better than others.
6. The next round of variations is centered on the more successful variations of the current generation.

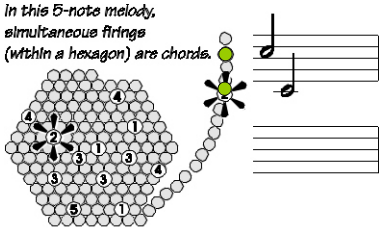
"The brain is waking and with it the mind is returning. It is as if the Milky Way entered upon some cosmic dance. Swiftly the [cortex] becomes an enchanted loom where millions of flashing shuttles weave a dissolving pattern, always a meaningful pattern though never an abiding one; a shifting harmony of subpatterns.... Dissolving pattern after dissolving pattern will, the long day through, without remission melt into and succeed each other...."

Charles Sherrington, *Man on his Nature*, the Gifford Lectures, Edinburgh, 1937-38

- Donald O. Hebb in 1949 postulated a "cell-assembly" to represent a thought.

Extension: Darwinian emphasis on what can be copied shows a minimal cell-assembly and, thereby, an elementary spatio-temporal code.

In this 5-note melody, simultaneous firings (within a hexagon) are chords.



The six essentials for a Darwinian process

1. **There's a pattern.**
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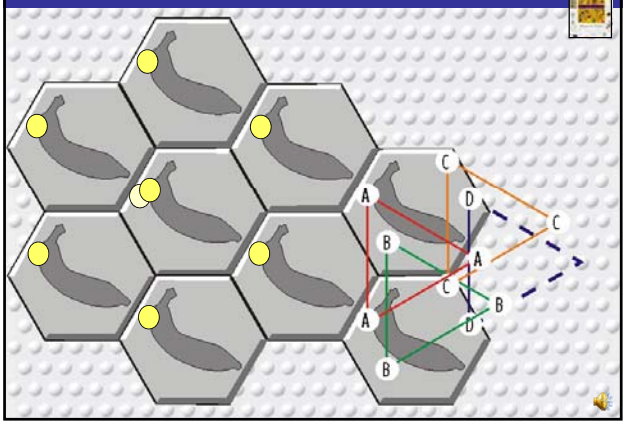
The six essentials for a Darwinian process

- ☑ 1. **There's a pattern** and it's hexagonal.
- ☑ 2. The pattern is copied.
- ☐ 3. Variations occur.
- ☐ 4. Populations of the variant patterns compete for a space.
- ☐ 5. Natural selection makes some patterns do better than others.
- ☐ 6. The next round of variations is centered on the more successful variations of the current generation.

Enforced conformity to a **spatial** consensus



Enforced conformity to a **timing** consensus

THE LAW OF LARGE NUMBERS
(the Hallelujah Chorus Principle)

To reduce timing jitter by half requires four times as many clocks.

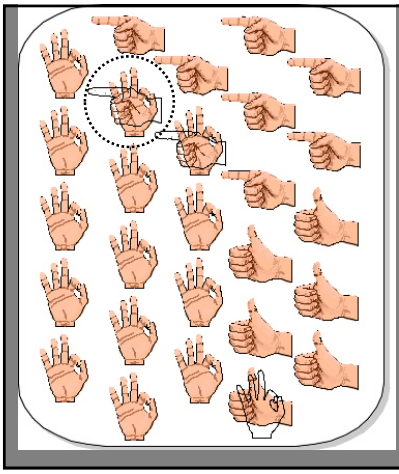
Building a heart in a Petri dish, get ten-fold reduction in timing jitter with 100X as many cells in the myoball. Jitter reduction from extra clocks. It's just the Law of Large Numbers.

Jitter reduction from extra clocks

THE LAW OF LARGE NUMBERS
(the Hallelujah Chorus Principle)

To reduce timing jitter by half requires four times as many clocks.

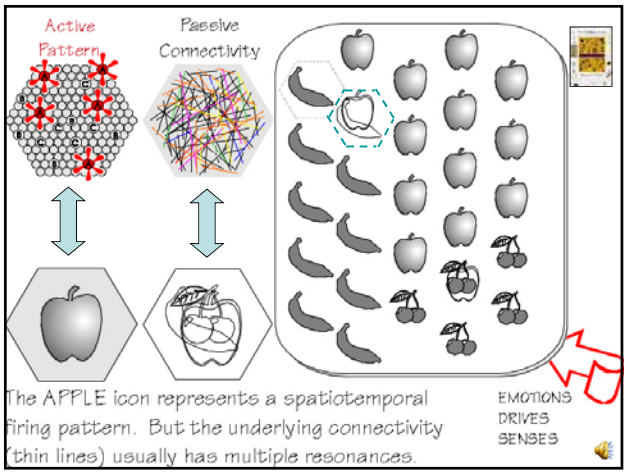
This is what might have been under natural selection during hominid evolution from the bipedal woodland apes, e.g., you need a big chorus to get the jitter out of the timing for the launch sequence.



Competition between possible next moves

The six essentials for a Darwinian process

- ☑ 1. There's a pattern.
- ☑ 2. The pattern is copied.
- ☐ 3. Variations occur.
- ☑ 4. **Populations of the variant patterns compete for a space.**
- ☐ 5. Natural selection makes some patterns do better than others.
- ☐ 6. The next round of variations is centered on the more successful variations of the current generation.

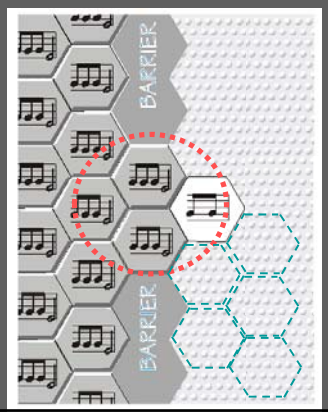


The six essentials for a Darwinian process

- ✓ 1. There's a pattern.
- ✓ 2. The pattern is copied.
- ☐ 3. Variations occur.
- ✓ 4. Populations of the variant patterns compete for a space.
- ✓ **5. Natural selection makes some patterns do better than others.**
- ☐ 6. The next round of variations is centered on the more successful variations of the current generation.

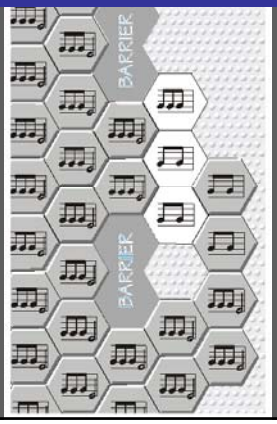
Escaping conformity at a gap

Inexcitable strips ("barriers") allow copying errors to go uncorrected.



Escaping conformity at a gap

Can now clone a new territory and then compete with parent pattern.



The six essentials for a Darwinian process

- ✓ 1. There's a pattern.
- ✓ 2. The pattern is copied.
- ✓ **3. Variations occur.**
- ✓ 4. Populations of the variant patterns compete for a space.
- ✓ 5. Natural selection makes some patterns do better than others.
- ☐ 6. The next round of variations is centered on the more successful variations of the current generation.

A hexagonal inheritance principle

The ***more successful*** hexagonal patterns occupy more area, and thus
- have more perimeter, and
- thus more opportunities to generate variants that escape conformity and have room to themselves make clones.

The six essentials for a Darwinian process

1. There's a pattern.
2. The pattern is copied.
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5. Natural selection makes some patterns do better than others.
6. **The next round of variations is centered on the more successful variations of the current generation.**

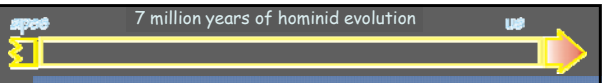
Can see parallels to speedups too.

How regulated?

How regulated?

- The big problem in cortex is all of those reciprocal excitatory synapses
  - Runaway excitation looks possible
  - Seizures indeed common in humans
- Inhibition needs to
  - Dampen generally
  - Provide barriers, erase workspaces
- Spotlights on workspaces
- All seem likely to involve thalmocorticals
  - The Darwinian action might be cortical but keeping workspaces segregated is subcortical.

talk outline

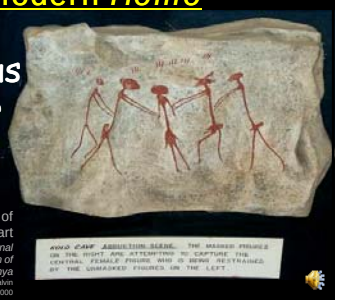


- The creative explosion 50,000 years ago
- The problem with novelty is **quality.**
- Accurate throwing as evolutionary driver
- The Darwinian process for improvement
- Darwinian essentials in cortical circuits
- Higher intellectual functions
  - Syntax, plans, games, logic, music, coherence
  - Pre-modern humans without much imagination
- Levels of organization of thought
  - From concrete to abstract, getting the joke

There is no step more uplifting, more momentous in the history of mind design, than the invention of language. When *Homo sapiens* became the beneficiary of this invention, the species stepped into a slingshot that has launched it far beyond all other earthly species in the power to look ahead and reflect.

– Daniel C. Dennett, *Kinds of Minds*, 1996

For the last 50 years, anthropologists have emphasized the step up from anatomically-modern *Homo sapiens* to behaviorally-modern *Homo sapiens sapiens*. There are various formulations for this big step up:



replica of cave art
National Museum of Kenya
W. H. Calvin 2000

- Imitation
- Symbolic stuff
- "Consciousness"
- Language
- Planning
- Creativity
- Add to all the qualifier, "*with structure.*"

Mimicry as a Behaviorally-modern Candidate

- Much mimicry is seen in birds, orangutans
  - so it isn't that difficult to do, even with a bird-sized brain.
- But, even if easy, there is *limited* mimicry in our closest relatives.
  - De Waal notes limp copied by young chimps
  - Tomasello's experiment with young chimps *failing to mimic gestures* even when there is intense observation and motivation.
  - Train high-ranking female on using probe. *Then* other chimps will copy the technique. Prestige!

Mimicry as a Behaviorally-modern Candidate

- Yet lots of unconscious social mimicry in modern humans.
- "Mirroring, echoing, matching"
- Will synchronize breathing, mimic postures and intonation, even with strangers.
- Use to quickly establish rapport. (How to motivate bigger tips.)

Protolanguage could be older

- Hundreds of words
- But only the two-word sentences of two-year-olds.
- Cannot express complicated thoughts without long sentences, but need structure to keep parts from blending together like a summer drink.

Big step up from protolanguage

- Long sentences need the big step up to *syntax*
- what kids do in their third year after speaking in short sentences.

Higher Intellectual Functions are *structured*

- *Nested syntax.*
- *Contingent plans.*
- *Games* with arbitrary rules. Logic.
- *Music* that goes beyond rhythm and melody to use multiple voices, as in part singing.
- *Coherence-finding*, as when we discover hidden patterns amidst seeming chaos.
  - "Eureka" in jigsaw, crossword puzzles.

Higher Intellectual Functions are *structured*

- *Complex thought,* as in figurative speech, narrative frameworks, and parables that map one story onto another.
- Indeed, they are *all examples of structured thought*, all separate humans from the great apes.
- Now, *imagine us without this….*

Mental life before "The Mind's Big Bang"

- The premodern mind likely had thought, in Freud's sense of "*trial action*."
- But without ***structuring*** plus off-line ***quality improvement***, you can't create novel sentences *of any length or complexity* – and you likely cannot think such thoughts, either.

Cartoons assume silent speech, but…

- *Do chimpanzees have complex thought?*
- if they did, we'd see them *doing things to their advantage*, even if they didn't talk about it.

Cartoons assume silent speech, but…

- They already gang up on lone neighbors, five-on-one *mayhem* that is usually fatal.
- If they could plan a little, they'd advance to staged *raids* in the middle of the night.

Cartoons assume silent speech, but…

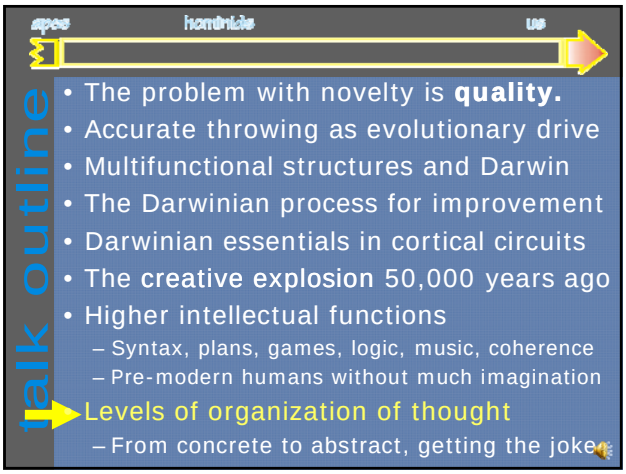
- With more planning, they'd stockpile materials and practice maneuvers, advancing to *warfare.*

Cartoons assume silent speech, but…

- Chimps would be the terror of Africa — but they're not, even though they are easily aggressive enough for war.

Cartoons assume silent speech, but...

- They probably lack *complex thought*, as did the bipedal woodland apes of our ancestry.
- *True of pre-moderns as well?*



A Seattle Coffee Joke

As we advance beyond the one-word level of language after the morning cup of coffee, we begin talking about relationships ("This is bigger than that").

With a second cup, we can advance another level to relation between relationships ("Bigger is better").

Poets have to compare candidate metaphors, however, requiring all manner of superstitious practices in order to shore up their mental house of cards and stabilize a new level. We invent new levels on-the-fly.

If a cerebral code can represent a *relationship* as well as a *category* or *motor program*, the poet could just run a copying competition between *candidate metaphors*.

The code is just *information* detached from its roots in sensation and movement.

Things other animals probably don't do

You can have competitions between categories, between movement programs, between relations, between analogies.

That's what a Darwin Machine in neocortex could buy you: **a general process for quality creativity** at various levels.

Finding the appropriate level at which to address a problem – not too concretely, not too abstractly – is an important aspect of intelligence that is probably not seen in the great apes.

You usually cannot get the joke without locating the correct level of organization to which it refers – and it is often the alternative interpretations at different possible levels that makes it so funny.

"**And about how many people work here?**" the visitor politely asks the boss.

"**About half.**"

Things other animals probably don't do

"There are many subconscious aspects of mind operating in the background, such as our agendas, but in the foreground is the narrator of our life story, always at a crossroads between past and future, swimming in speculation, capable of aspirations and reflections…."

W. H. Calvin, *A Brief History of the Mind*, Oxford University Press 2004

I hope you all will explore the Darwin Machine circuitry as a homework exercise.

The End

My books and talks may be found at:

WilliamCalvin.org