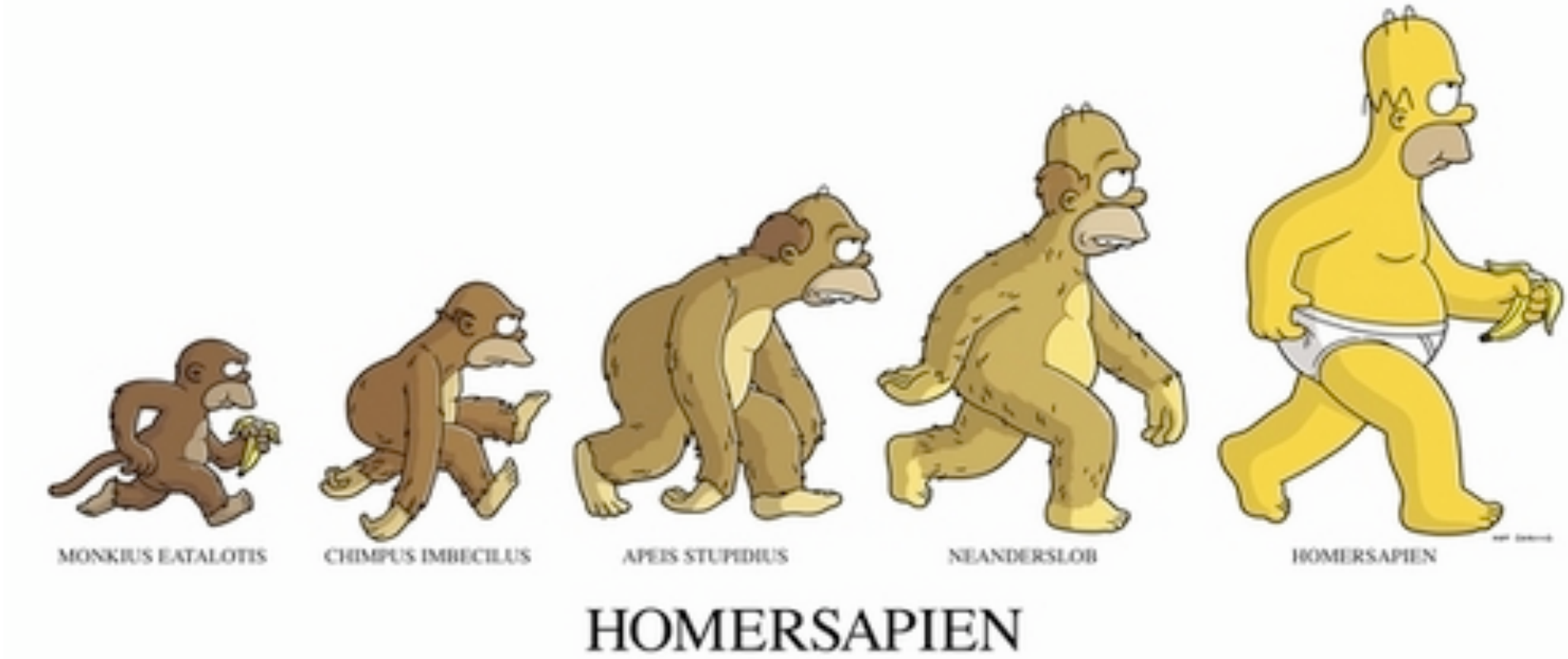
Evolution and Misconceptions



...courtesy of the Simpsons

Outline

- How evolution really works
- Misconceptions about evolution

NOTE: many slides in the four evolution lectures obtained from Web sources: Ken Miller ["Hot Science, Cool Talks" at UT Austin], Elizabeth Saunders, Carl Wozniak, Caltech Bio 1

The Fact of Evolution

- Forms of life change over time, via descent with modification
- That's it!

The Theory of Evolution

- Characteristics of population are most strongly influenced by individuals who leave the most viable offspring
  Seems uncontroversial, even tautological!
- Variation: mutation, sex, horizontal gene transfer, neutral drife, incorporation of cells
- Selection: natural/sexual

Summary of Process

From http://evolution.berkeley.edu/evolibrary:

variation

+

differential reproduction

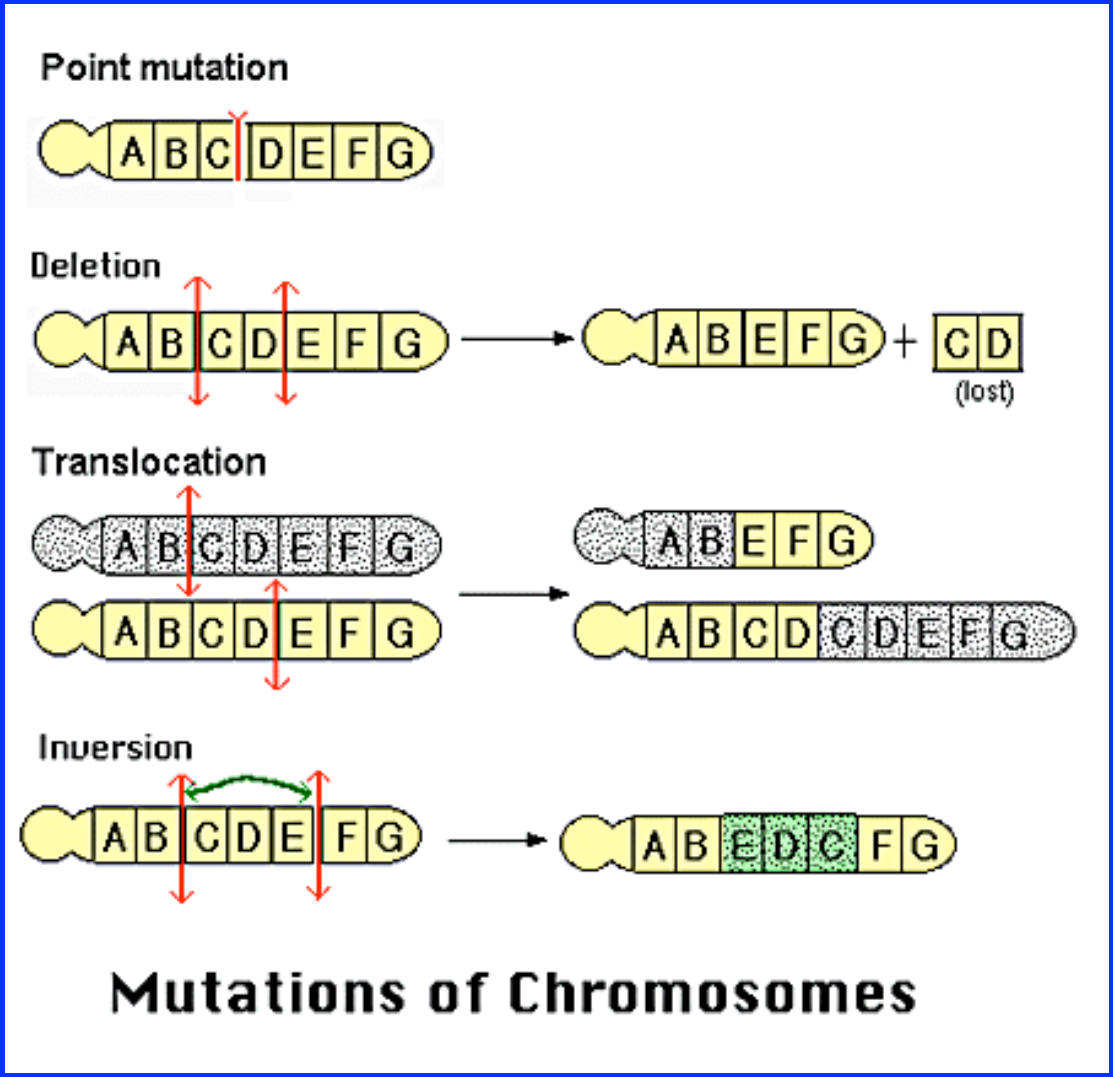
+

heredity

=

natural selection

Examples of Mutation



http://www.accessexcellence.org/RC/VL/GG/images/mutation.gif

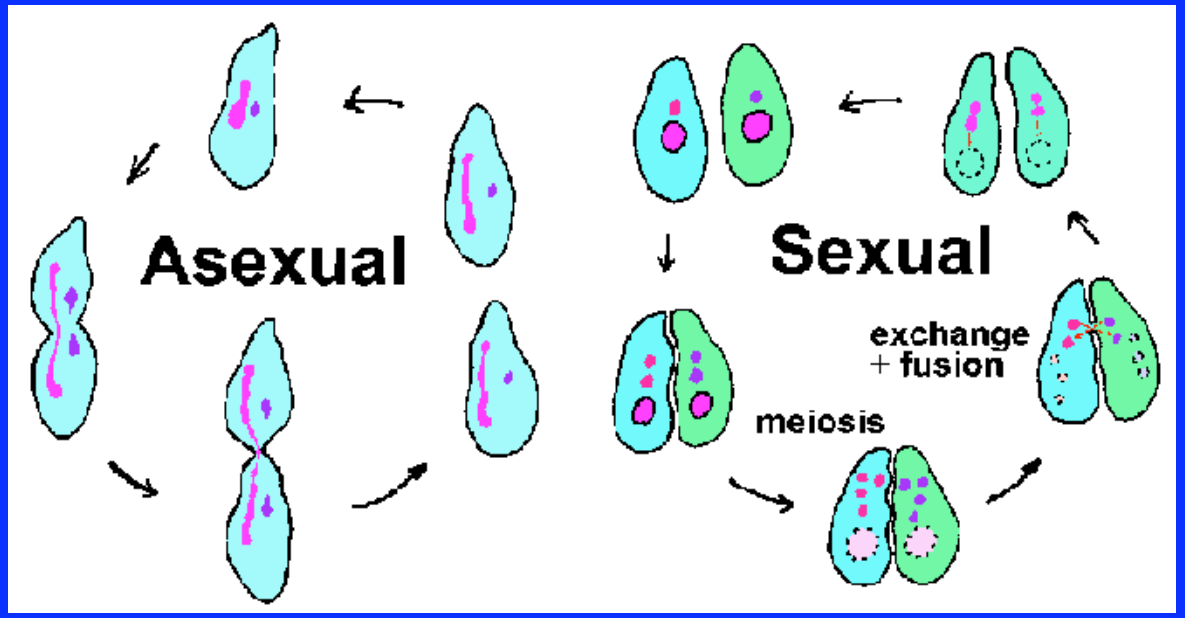
Causes?
Transcription error
Cosmic rays or radioactivity

Worse transcription means more mutations.
Faster evolution or dead organism?

Most mutations bad.
A few good, so are incorporated

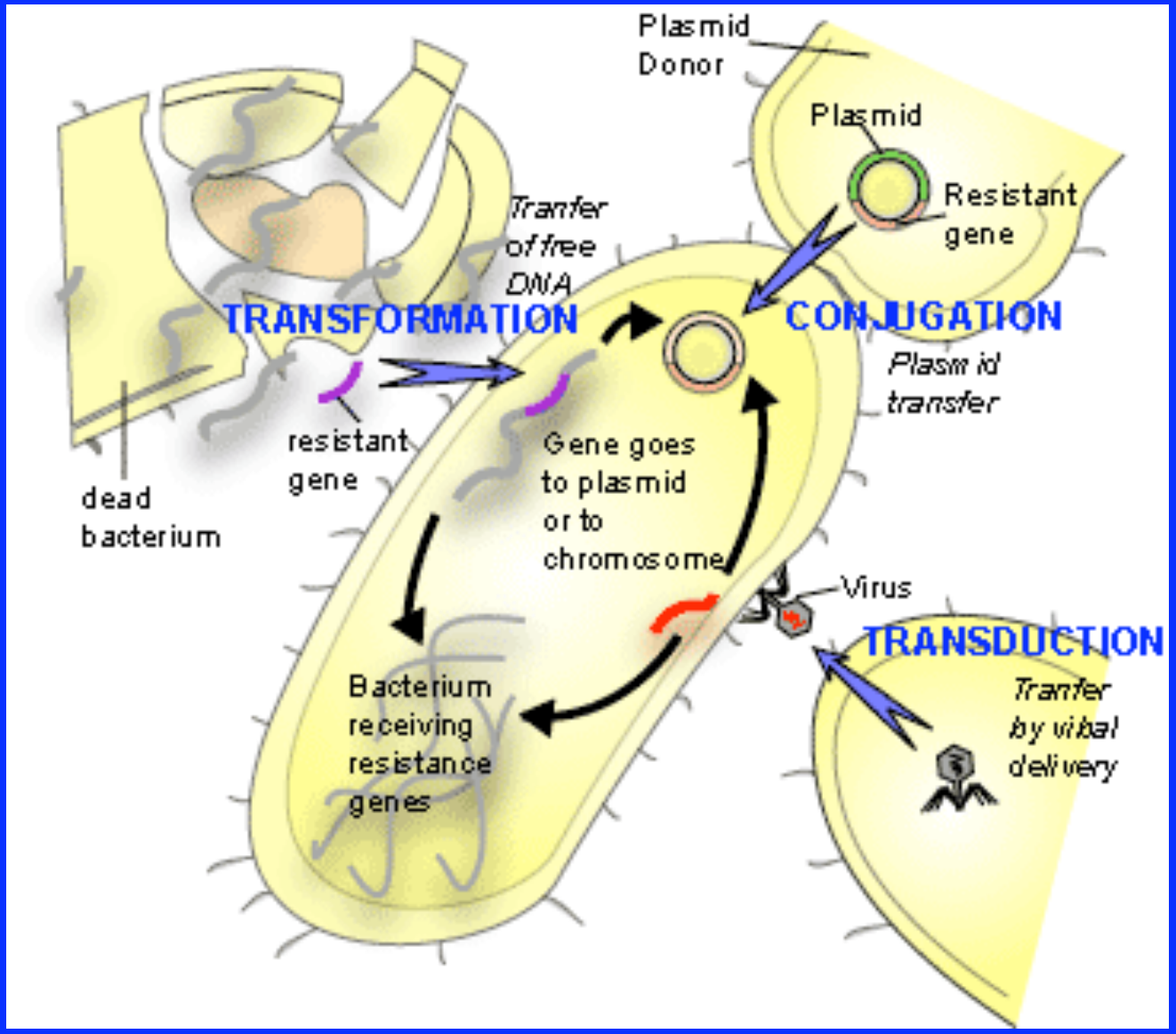
Sexual Reproduction

- Each parent provides set of genes, but mixing is random; two alleles per gene
- Many characteristics rely in complicated ways on genes. Can get surprising results and variation!



http://www.tulane.edu/~wiser/protozoology/notes/images/ciliate.gif

Horizontal Gene Transfer



Bacteria and archea mainly

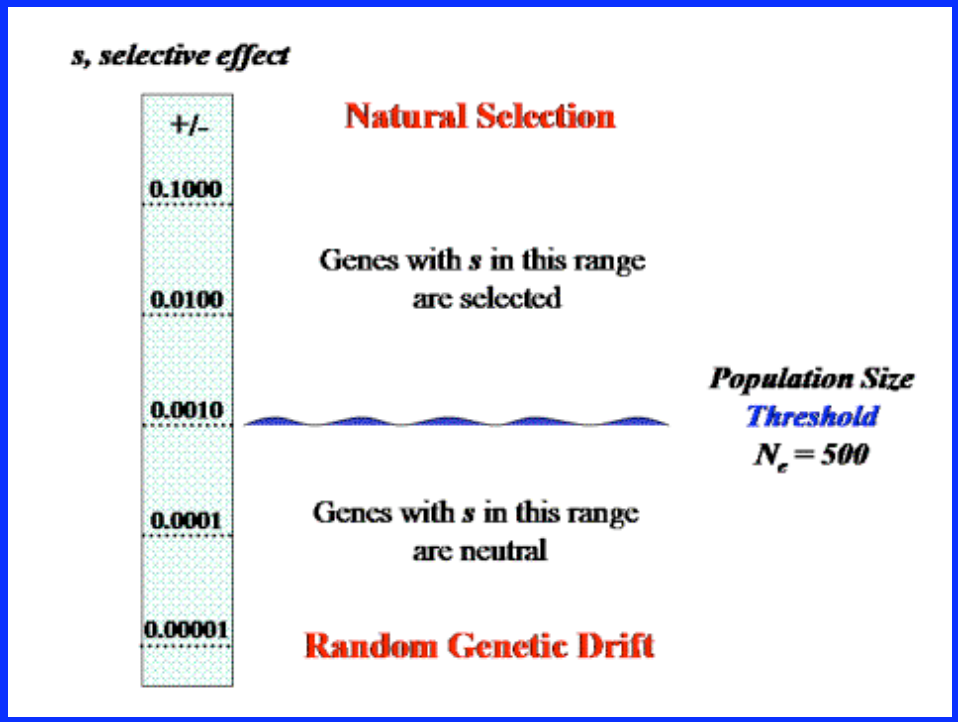
Can transfer parts of DNA between different organisms

Muddles up "tree of life" but probably has played major role

http://www.textbookofbacteriology.net/HorizontalTransfer.gif

Neutral Genetic Drift

- Mutations with no effect can tag along passively
- Later, they may find use
- More significant than people thought decades ago



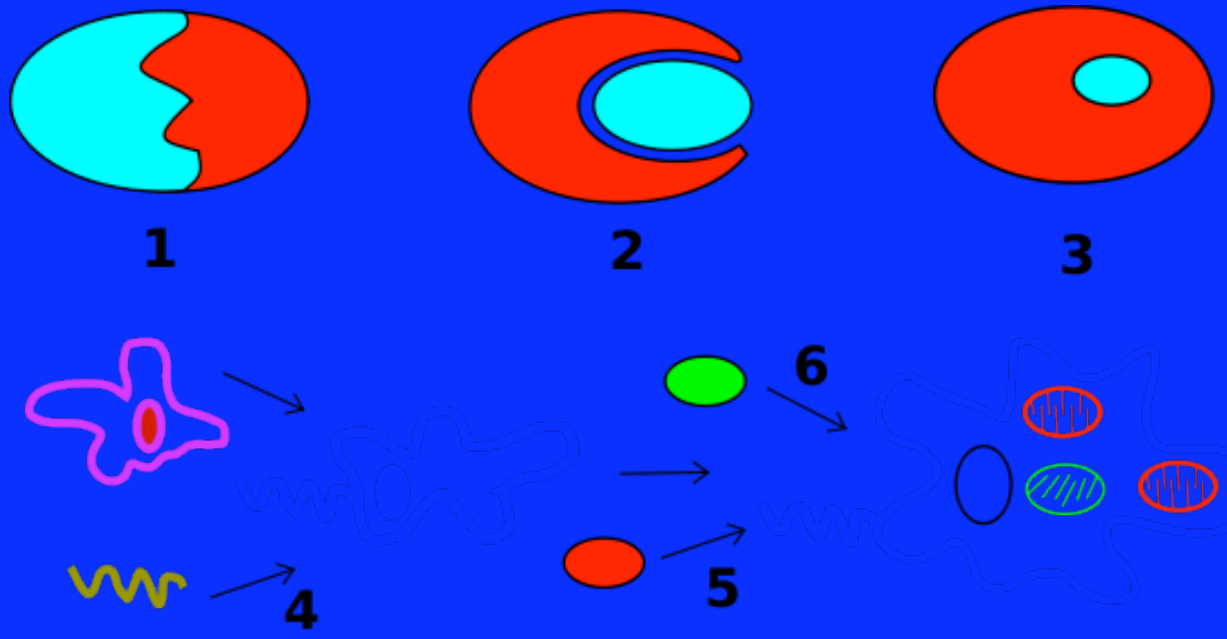
http://plato.stanford.edu/entries/evolutionary-genetics/figure1.gif

Digital Life Simulations

- http://dllab.caltech.edu/**avida**/
- Can evolve population of organisms and track every mutation and fitness change
- Example insight: negative mutations can sometimes enable steps forward
- Very cool; check it out!

Endosymbiosis

- Possible origin of eukaryotes
- Simple cell (prokaryote) incorporated into larger one
- Maybe made organelles; mitochondria etc.

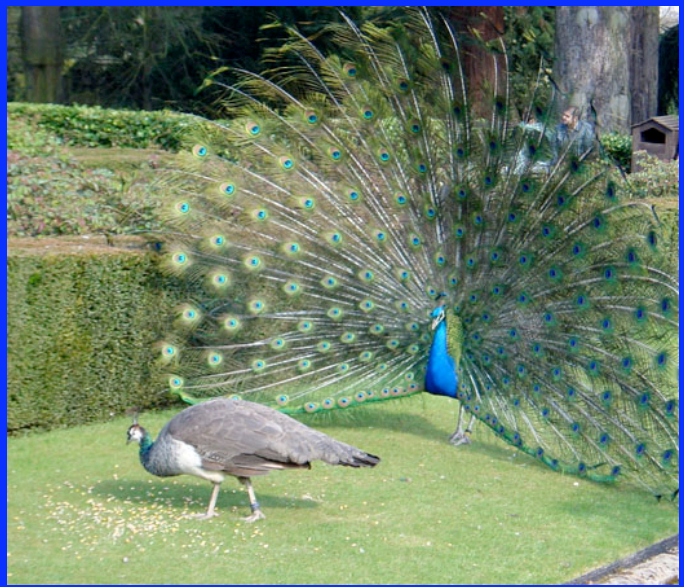


http://upload.wikimedia.org/wikipedia/commons/thumb/0/00/Eukarya_endosymbiosis.svg/563px-Eukarya_endosymbiosis.svg.png

Selection Mechanisms

- What can be done with all that variation?
- "Natural" selection
  Need to survive to reproduce!
  Luck plays big role
- Sexual selection
  Need to be able to attract mate
  Can lead to odd effects!

http://www.cactusmountain.com/Photos/Patches/PP116.jpg



http://subjunctive.net/photoblog/2003/peacock-wooing-peahen.jpg

Misconceptions About Evolution

- The fact of evolution has been established, and the theory of evolution is highly successful
- Yet most Americans do not believe that evolution has happened, at least for humans
- What are some major misconceptions?

Misconception 1: Evolution is Incompatible with Religion

- Question 1a: if I accept evolution, must I be an atheist?
- Question 1b: if we agree we are descended from animals, do we have no ethical guides?

Incompatible With Religion?

- No!
- Clergy letter project: >11,000 ministers signed in US alone
- Affirms evidence for evolution; not at all in conflict with personal religious beliefs

http://openparachute.files.wordpress.com/2008/02/charles-darwin.jpg

http://www.clergyletterproject.net/clp140_100.gif

Must We Act Like Animals?

- No, how silly!
- Does gravity mean that you have to push people down stairs???
- Evolution is a description of what happened, not a guide
- Ethics comes from other sources

http://www.looptvandfilm.com/blog/homerevolution.jpg

Misconception 2: Evolution Has Never Been Observed

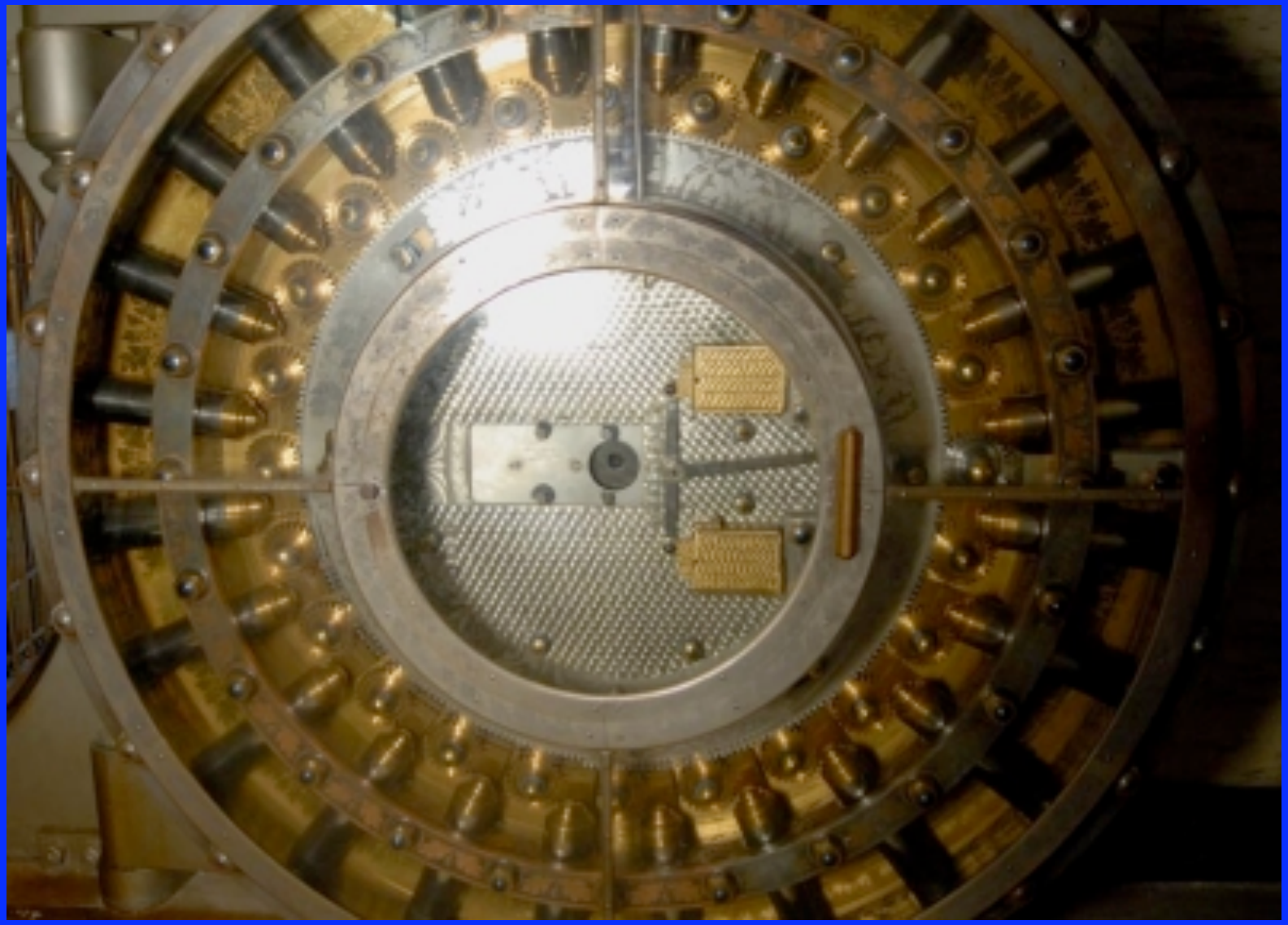
- Sure it has!
  Fossils, in labs, in field, microbiology...
- Mostly a misconception spread by those with Misconception 1 on their brains
- Some honest misunderstanding is possible: we live a short time, evolution takes a long time

Misconception 3: Evolution is Random

- Here is a genuine possibility of confusion
- Yes, mutations (for example) have no final goal in mind, and are basically random
- But natural selection is the opposite of randomness!
  Favorable traits more likely to be retained

Let's think of an analogy that might help explain this.

Suppose we have a vault...



...protected by a combination lock

Suppose this lock has 100 numbers from 0 to 9.

Say it's a good lock, and only the right combination will do anything.

- Analogy: no competitive advantage for deviations from the combination.

At 1 second per try, how long will it take us?

- Expect about 10^{100} seconds!!!
- Age of universe: 4×10^{17} seconds
- We're out of luck...

But now suppose that the lock has a flaw: any right number in any place will stick there.

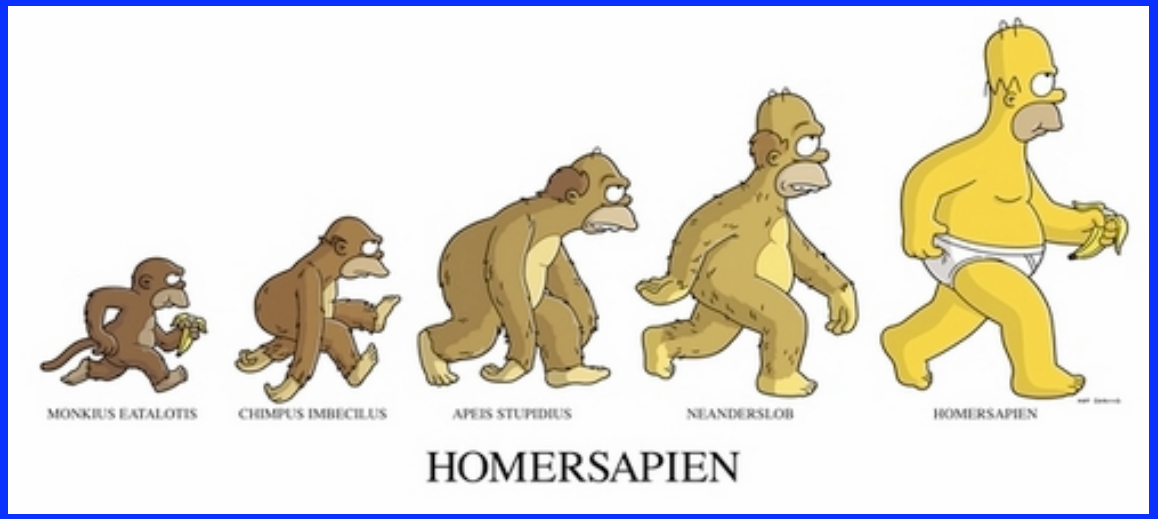
Analogy: competitive advantage for any step towards optimal configuration*

Then with a spin per second we'd get there in about a minute

Moral of the story: natural selection makes a huge difference!

*Note: there is no single optimal configuration in natural systems, so this analogy isn't perfect!

Misconception 4: Evolution is about the ladder of progress



- Are we "more evolved" than apes, bacteria, etc.?
- Better to think in terms of ecological niches
  Each organism adapts to its niche
  Some niches change slowly, some radically
  Without dino-stomper asteroid, we wouldn't be here!

Misconception 5: Evolution gives organisms what they need

Natural selection does not grant organisms what they "need".

http://evolution.berkeley.edu/evosite/misconceps/images/misconceptions_beavers.gif

Misconception 5: Evolution gives organisms what they need

- No! In nature, variations are random.
  Evolution gropes blindly in many directions
  Favorable ones are passed on
- Proceed by small modifications, none of which can be big problems for organism
- Sexual selection can go in favored directions, but not always a good idea...
  European royalty and hemophilia!

Misconception 6: Some structures shown to be too complicated for small changes

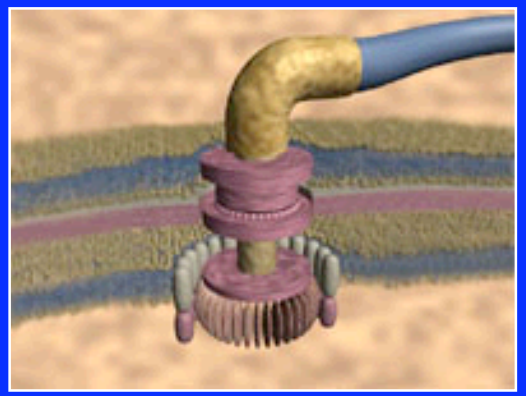
- Originally: William Paley, 1802
  Resurrected as "new" by anti-evolutionists
- This is the most common concern for thinking people, so we'll examine it in depth

Biochemical Claim: Evolution cannot explain the origin of Complex Cellular Machines

Why not?

Because these structures possess “Irreducible Complexity,” and that means they could not have been produced by evolution — even in principle.

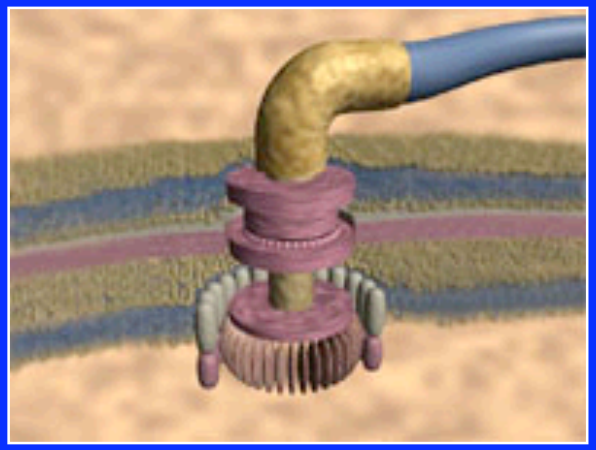
Electron micrograph of an E. coli showing several flagella at the apex of the cell.



Bacterial Flagellum

Prime Example

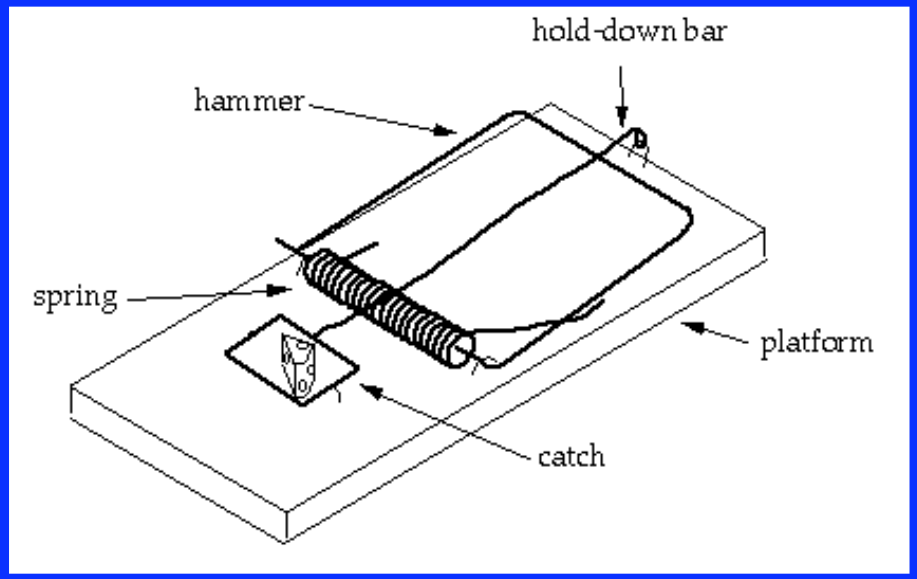
- Bacterial flagellum



Bacterial Flagellum

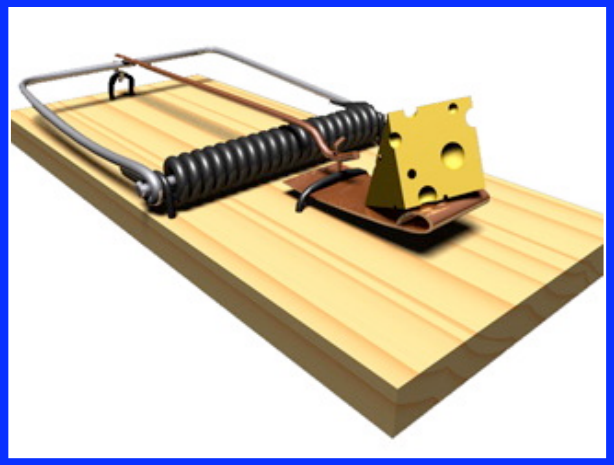
"An irreducibly complex system cannot be produced directly ... by slight, successive modifications of a precursor system, because any precursor to an irreducibly complex system that is missing a part is by definition nonfunctional."

Michael Behe. *Darwin's Black Box, p. 39*

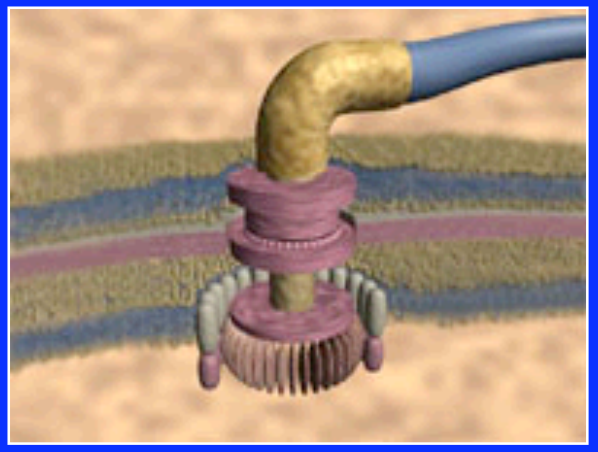


"A good example of such a system is a mechanical mousetrap. ... The function of the mousetrap requires all the pieces: you cannot catch a few mice with just a platform, add a spring and catch a few more mice, add a holding bar and catch a few more. All of the components have to be in place before any mice are caught. Thus the mousetrap is irreducibly complex."

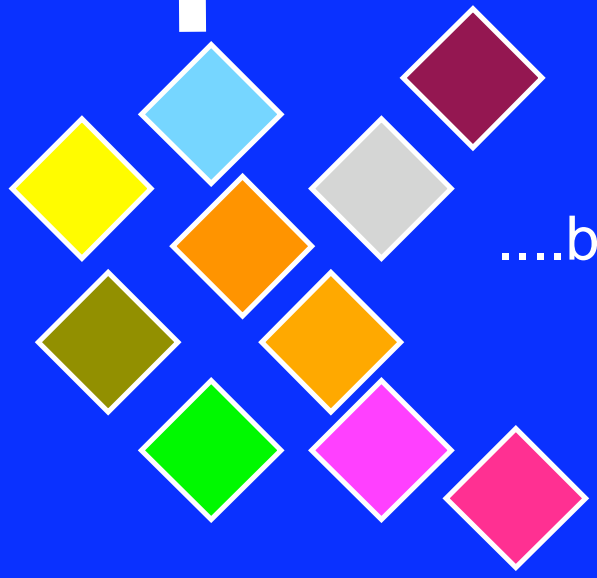
MJ Behe, 1998, "Intelligent Design Theory as a Tool for Analyzing Biochemical Systems," in Mere Creation, p. 178



The complete machine has a function...



"Since natural selection requires a function to select, an irreducibly complex biological system ... would have to arise as an integrated unit for natural selection to have anything to act on."



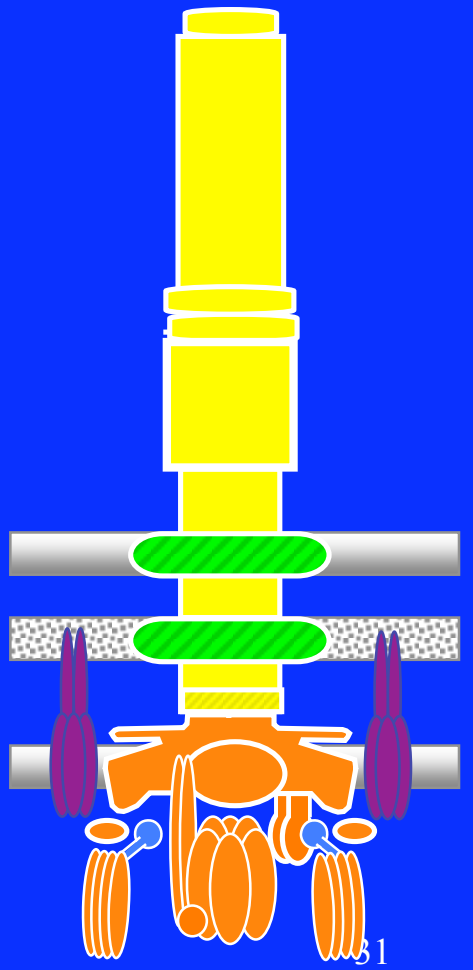
....but its component parts do not.

Poster-Child for Intelligent Design

The Bacterial Flagellum

The Turn of the Screw:
The Bacterial Flagellar Motor

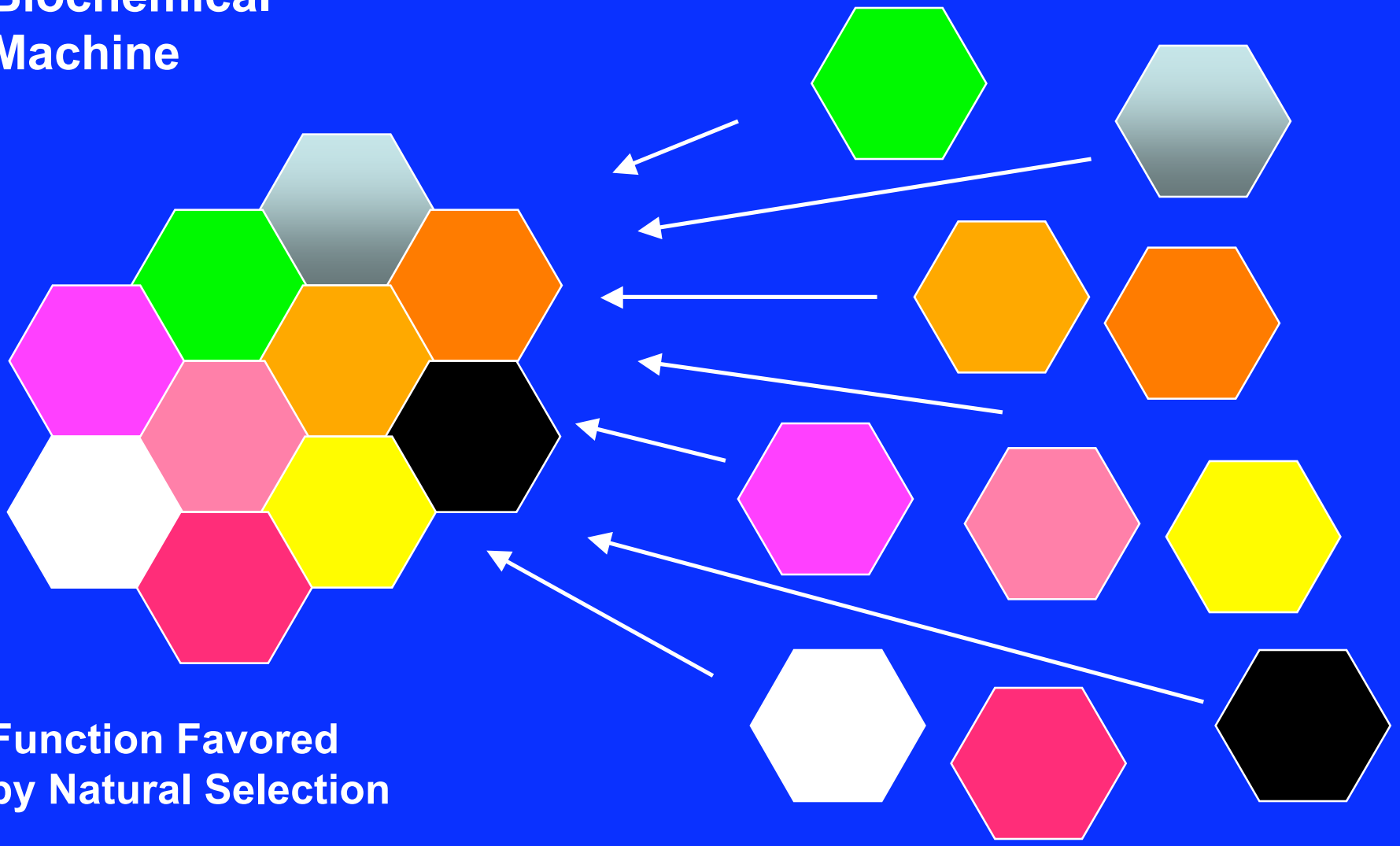
Cell, Vol. 93, 17–20, April 3, 1998
David J. DeRosier



“More so than other motors, the flagellum resembles a machine designed by a human.”

Individual Parts

Biochemical Machine

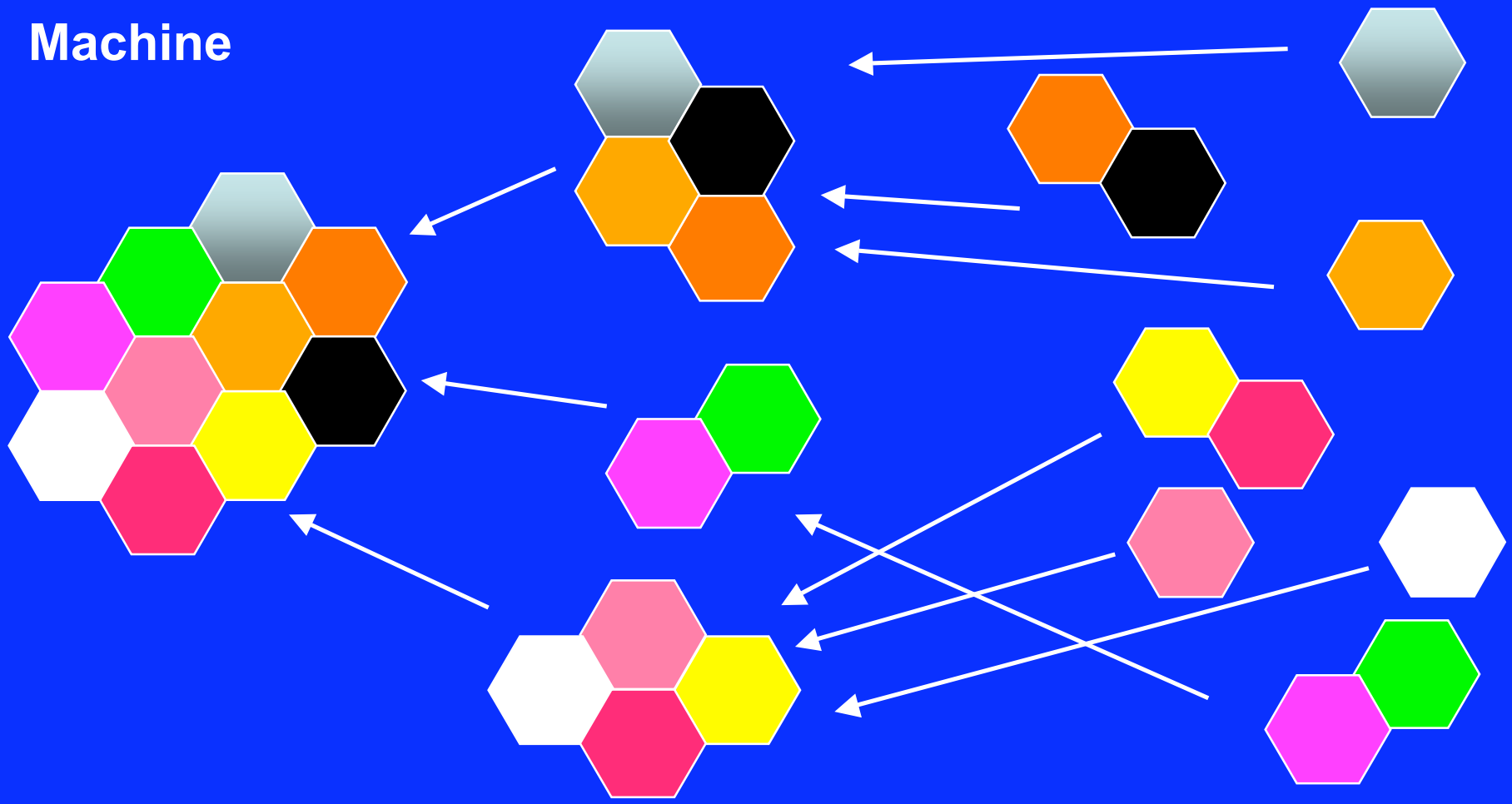


Function Favored by Natural Selection

No function. Therefore, natural selection cannot shape components.

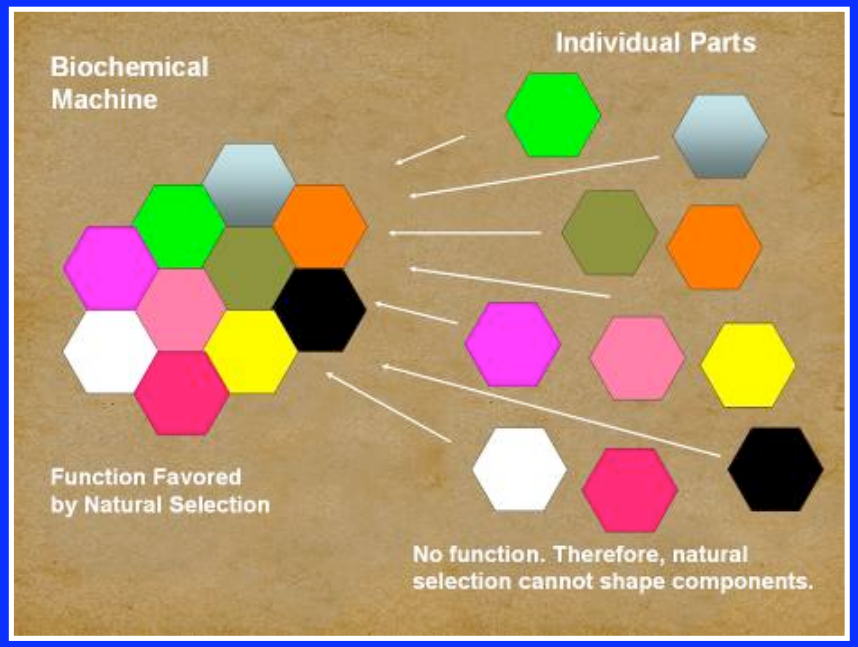
Biochemical Machine

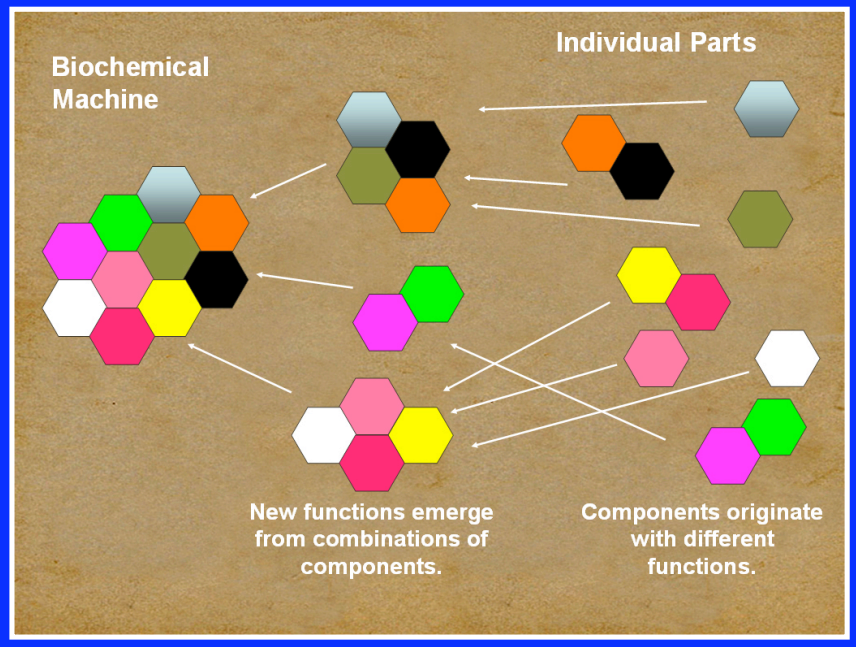
Individual Parts



New functions emerge from combinations of components.

Components originate with different functions.





DESIGN:

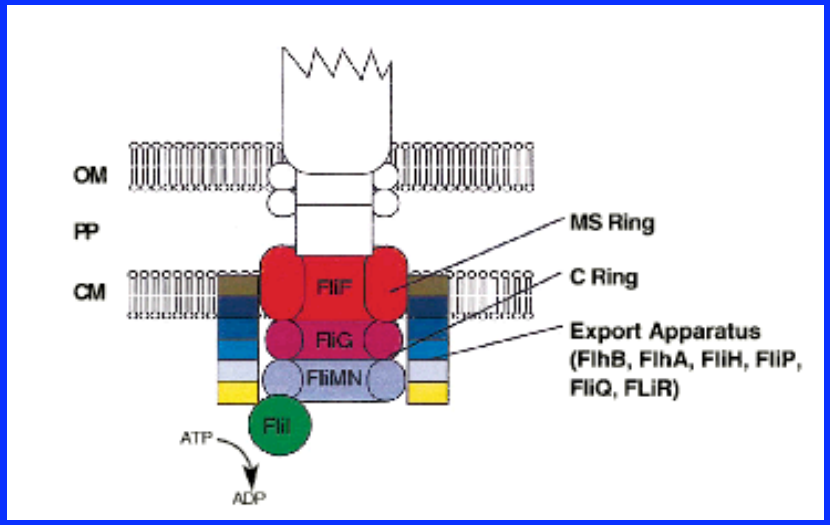
Parts useless on their own

EVOLUTION:

Parts do other jobs

"Irreducible Complexity" makes a specific claim, and so does evolution.

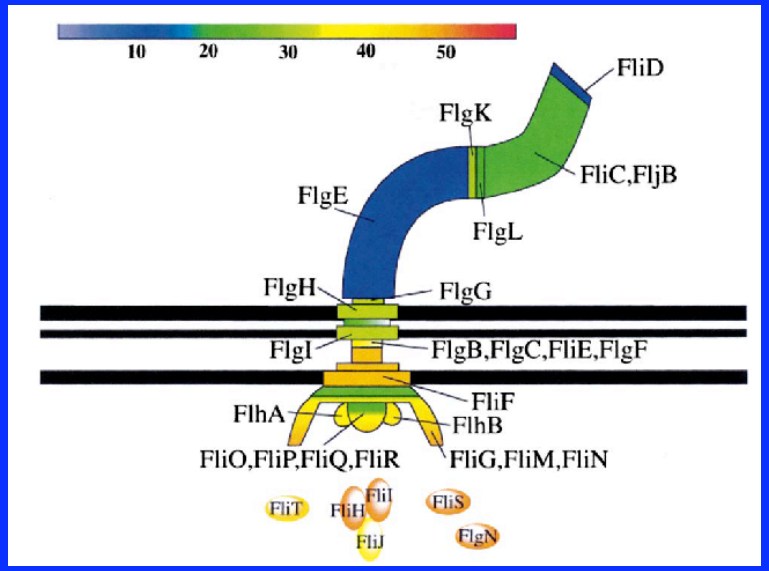
Therefore, if we take away 40 of the flagellum's parts:



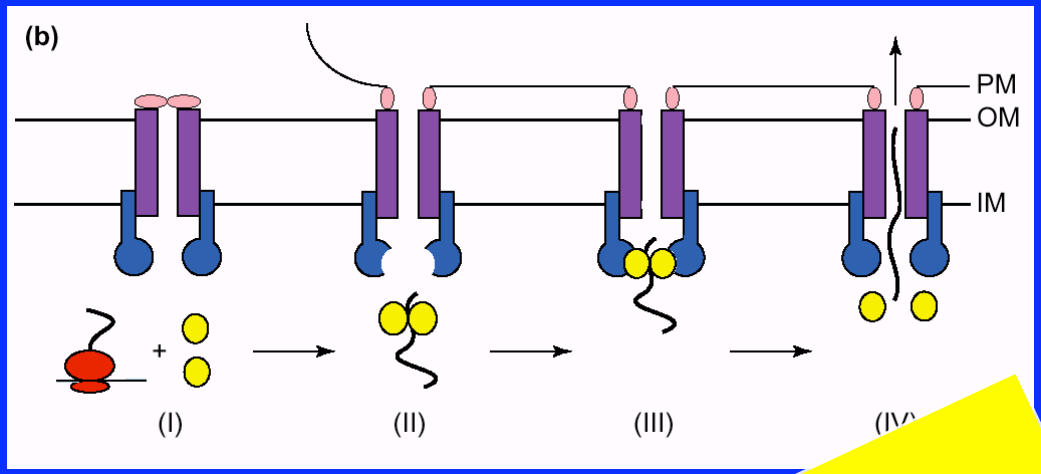
Leaving just 10. What's left should be non-functional. Right?

But they're not!

But it's not. In fact, those 10 parts are fully-functional!



Bacterial Flagellum (~50 parts)

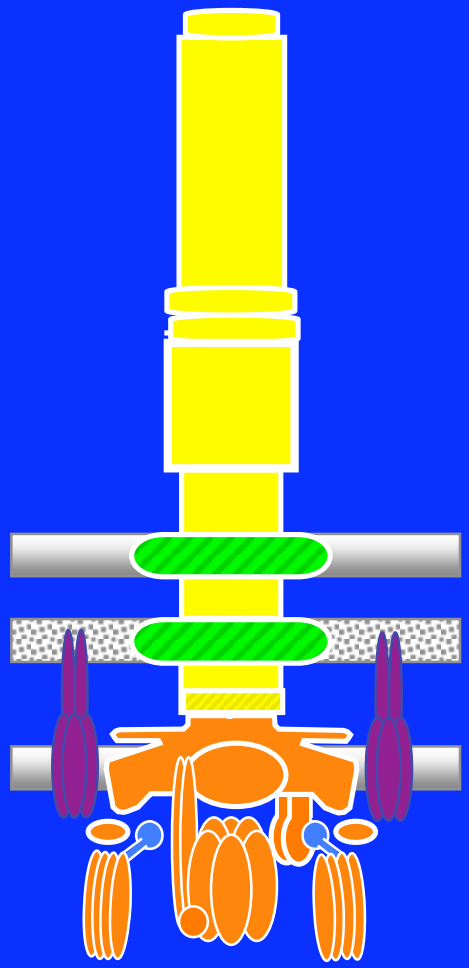


Type-III Secretory System (10 parts)

"...any precursor ... bly complex system that is missing a pa... definition nonfunctional."

Wrong

In fact, the flagellum contains many parts homologous to other systems



Flagellar component
FliF
FlhA
FlhB
FliI
FliH
FliJ
FliO
FliP
FliQ
FliR
FliG
FliN
FliM, C-term
FliC
FliD
FlgD
FlgJ
FlgL
FlgK
FlgE
FlgB
FlgC
FlgF
FlgG
FliE
FlgH
FlgI
MotA
MotB
FliM, N-term.
CheY
CheA
CheW
CheR
MCPs

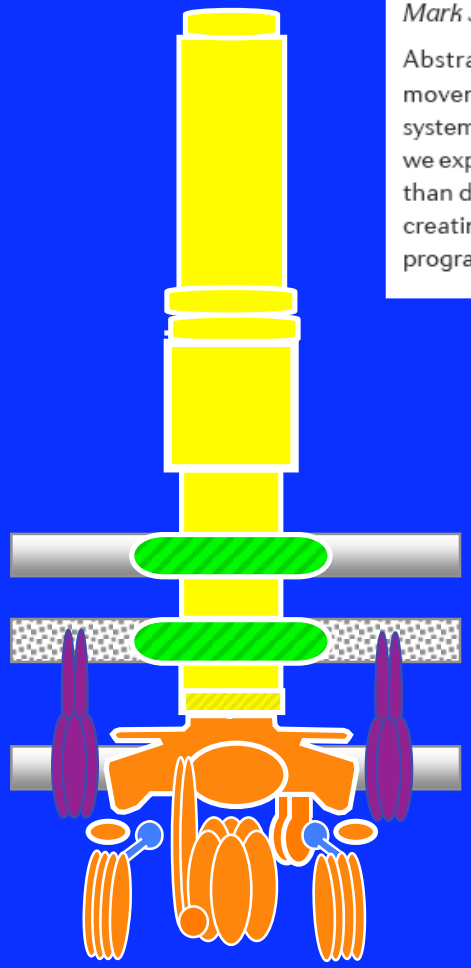
Type III Secretion apparatus

Axial protein family

Type II secretion

Ion transport

Signal transduction



SCIENCE AND SOCIETY

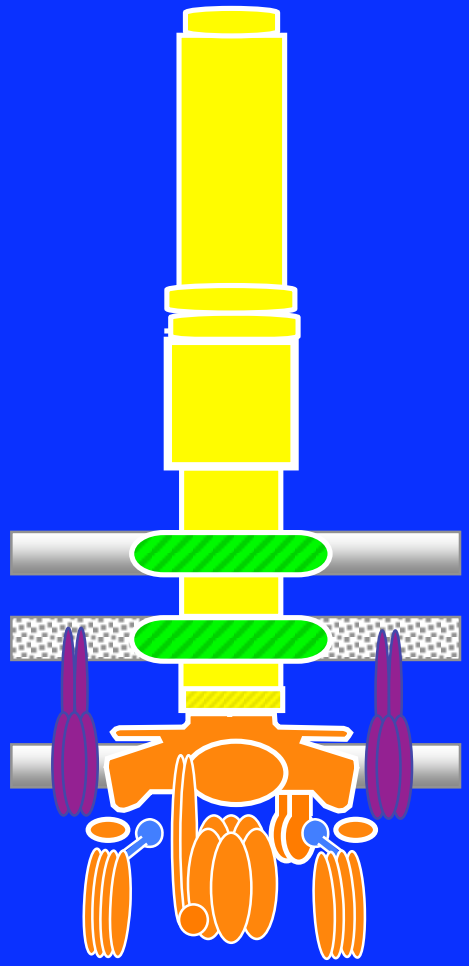
From *The Origin of Species* to the origin of bacterial flagella

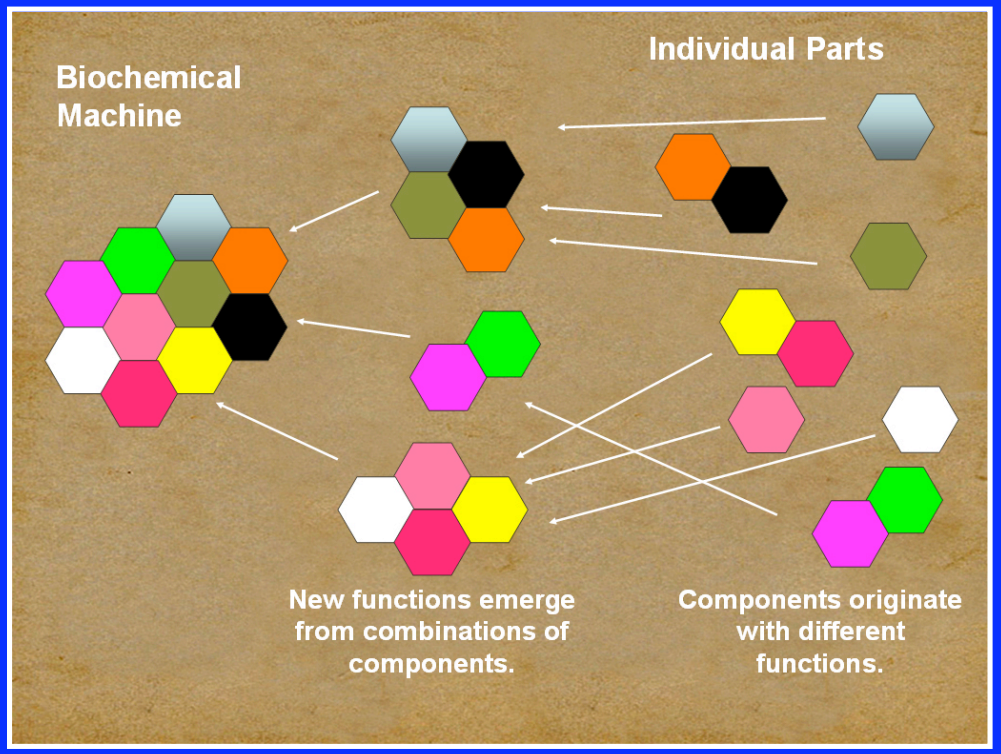
Mark J. Pallen and Nicholas J. Matzke

Abstract | In the recent Dover trial, and elsewhere, the 'Intelligent Design' movement has championed the bacterial flagellum as an irreducibly complex system that, it is claimed, could not have evolved through natural selection. Here we explore the arguments in favour of viewing bacterial flagella as evolved, rather than designed, entities. We dismiss the need for any great conceptual leaps in creating a model of flagellar evolution and speculate as to how an experimental programme focused on this topic might look.

Table 1 | **Homologies of flagellar proteins**

Protein	Location	Function	Indispensable?	Homologies*	Refs
FlgA	P ring	Chaperone?	Absent from Gram-positive bacteria	CpaB[‡]	25, 29
			Yes	FlgBCEFGK[§]	25
			Yes		25
			Yes	FlgBCEFGK	25
			Absent from Gram-positive bacteria	None yet known	25
			Absent from Gram-positive bacteria	None yet known	25
			FlgJ N-terminal domain absent from some systems	None yet known	25
			Yes	FlgBCEFGK[§]	25
			Yes	FliC[§]	25
			Absent from *Caulobacter*	None yet known	25
			Undetectable in some systems	None yet known	25
			Yes	LcrD/YscV[‖]	25
			Yes	YscU[‖]	25
			Absent from many systems	Other activators[‖]	25
FlhE	Unknown	Unknown	Mutant retains full motility		25
FliA	Cytoplasm	σ factor	Absent from *Caulobacter*	RpoD, RpoH, RpoS[‖]	25
FliB	Cytoplasm	N-methylase	Absent from *Escherichia coli*		25
FliC	Filament	Flagellin	Yes	FlgL[§], EspA[¶]	25, 78
FliD	Filament	Filament cap; hook-associated protein 2	Absent from *Caulobacter*	None yet known	25
FliE	Rod/basal body	MS ring–rod junction	Yes	None yet known	25
FliF	T3SS apparatus	Protein export	Yes	YscJ[‖]	25
FliG	Peripheral	Motor	Yes	MgtE[¶]	25
FliH	T3SS apparatus	Regulates FliI	Mutant retains some motility	YscL*, AtpFH[¶]	38, 79
FliI	T3SS apparatus	ATPase for protein export	Yes	YscN[‖], AtpD[‖], Rho[‖]	38
FliJ	Cytoplasm	Chaperone	Undetectable in some systems	YscO[¶]	25
FliK	Hook/basal body	Controls hook length	Yes	YscP[¶]	25
FliL	Basal body	Unknown	Mutant retains full motility	None yet known	80
FliM	T3SS apparatus	Protein export	Yes	FliN[‖], YscQ[‡]	25
FliN	T3SS apparatus	Protein export	Yes	FliM[‖], YscQ[‡]	25
FliO	T3SS apparatus	Protein export	Undetectable in some systems	None	25
FliP	T3SS apparatus	Protein export	Yes	YscR[‖]	25
FliQ	T3SS apparatus	Protein export	Yes	YscS[‖]	25
FliR	T3SS apparatus	Protein export	Yes	YscT[‖]	25
FliS	Cytoplasm	FliC chaperone	Absent from *Caulobacter*	None yet known	25
FliT	Cytoplasm	FliD chaperone	Absent from many systems	None yet known	25
FliZ	Cytoplasm	Regulator	Absent from many systems	None yet known	25
MotA	Inner membrane	Motor	Yes	ExbB[‡], TolQ[‡]	25
MotB	Inner membrane	Motor	Yes	ExbD[‡], TolR[‡], OmpA[‡]	25





Careful analysis of the bacterial flagellum matches evolutionary theory, not the design-creation model.

Summary

- Evolution is a simple and powerful mechanism
- Many misconceptions exist
  None hold up under scrutiny
- But what is the evidence for evolution?
  Topic of next two classes