HPS208 – How we think about life

Key Terms

- Natural purposes
- Self-organization
- Invariance Explanation

Review: What is a machine?

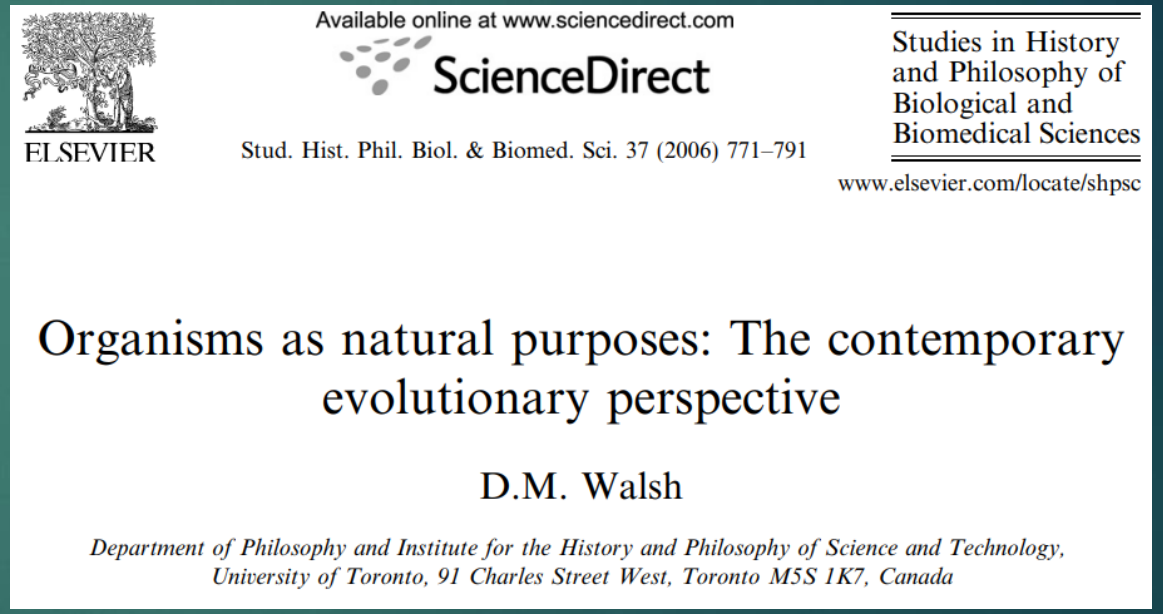
1. Describable by blueprints – a list of parts and how they fit together
2. Designed to efficiently perform a specific function
3. Follow the same sequence of steps every time to achieve that function
4. You can start and stop the machine without it falling apart

Cells and Organisms

- Nicholson's argument was just about single cells
- Some organisms are just one cell, e.g., protozoa, some algae, some fungi
- Supposing we think Nicholson is right about cells, should we therefore conclude that multicellular organisms aren't machines either?
- And if we're not machines, what are we?

The reading

- This week we read this paper by Denis Walsh
- He proposes that we should think of organisms as *natural purposes*
- This is what Kant thought we have to see living things as if we want to understand them, but also can't do mechanistically



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Organisms as natural purposes: The contemporary evolutionary perspective

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Equilibrium vs. Goal Directedness

- Recall from when we talked about plant intelligence Walsh's three criteria for goal directedness:

1. Persistence
2. Plasticity
3. Repertoire

(although I was wrong about which paper this list comes from!)

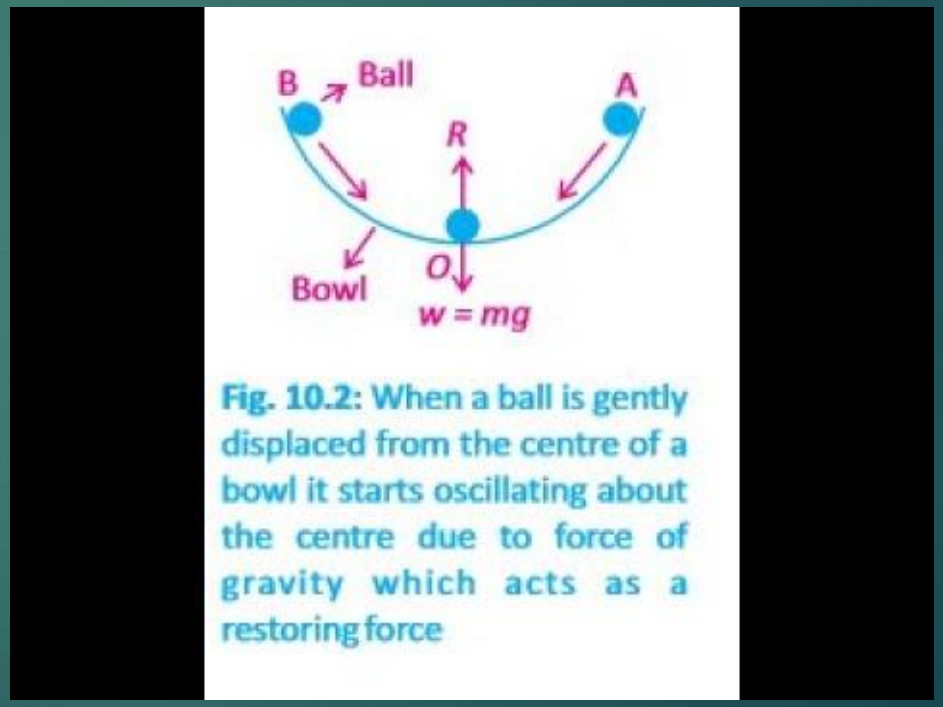


Fig. 10.2: When a ball is gently displaced from the centre of a bowl it starts oscillating about the centre due to force of gravity which acts as a restoring force

Equilibrium vs. Goal Directedness

- Walsh (2006) argues that living things have a wide repertoire of ways to make themselves
- And they try to pick just those parts of their repertoire that let them live and thrive
- And that this goal-directedness of ontogeny (development) has consequences for how we should think about evolution

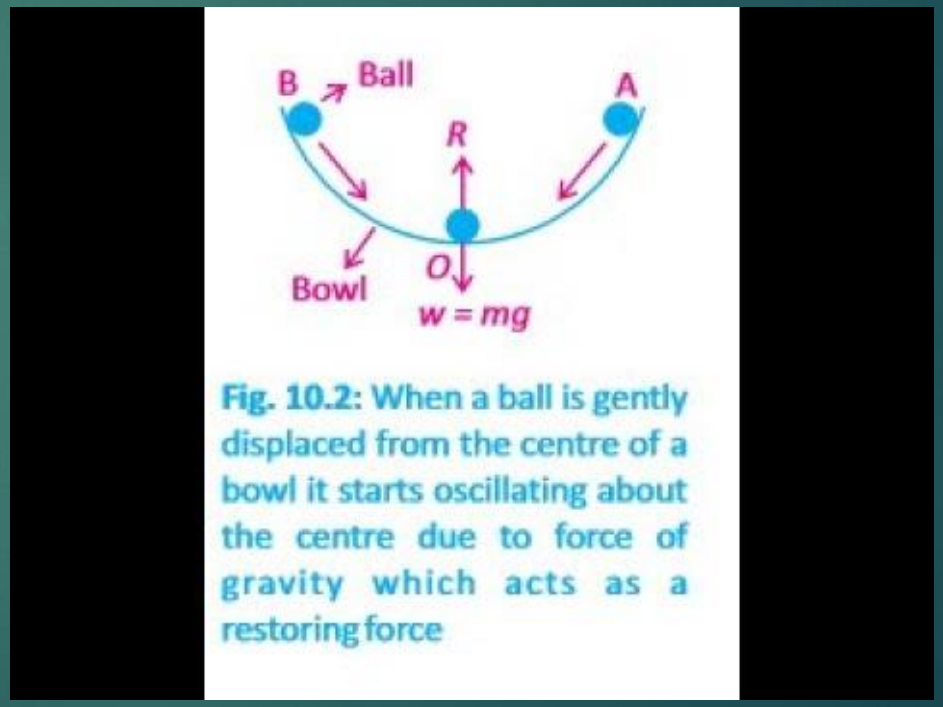


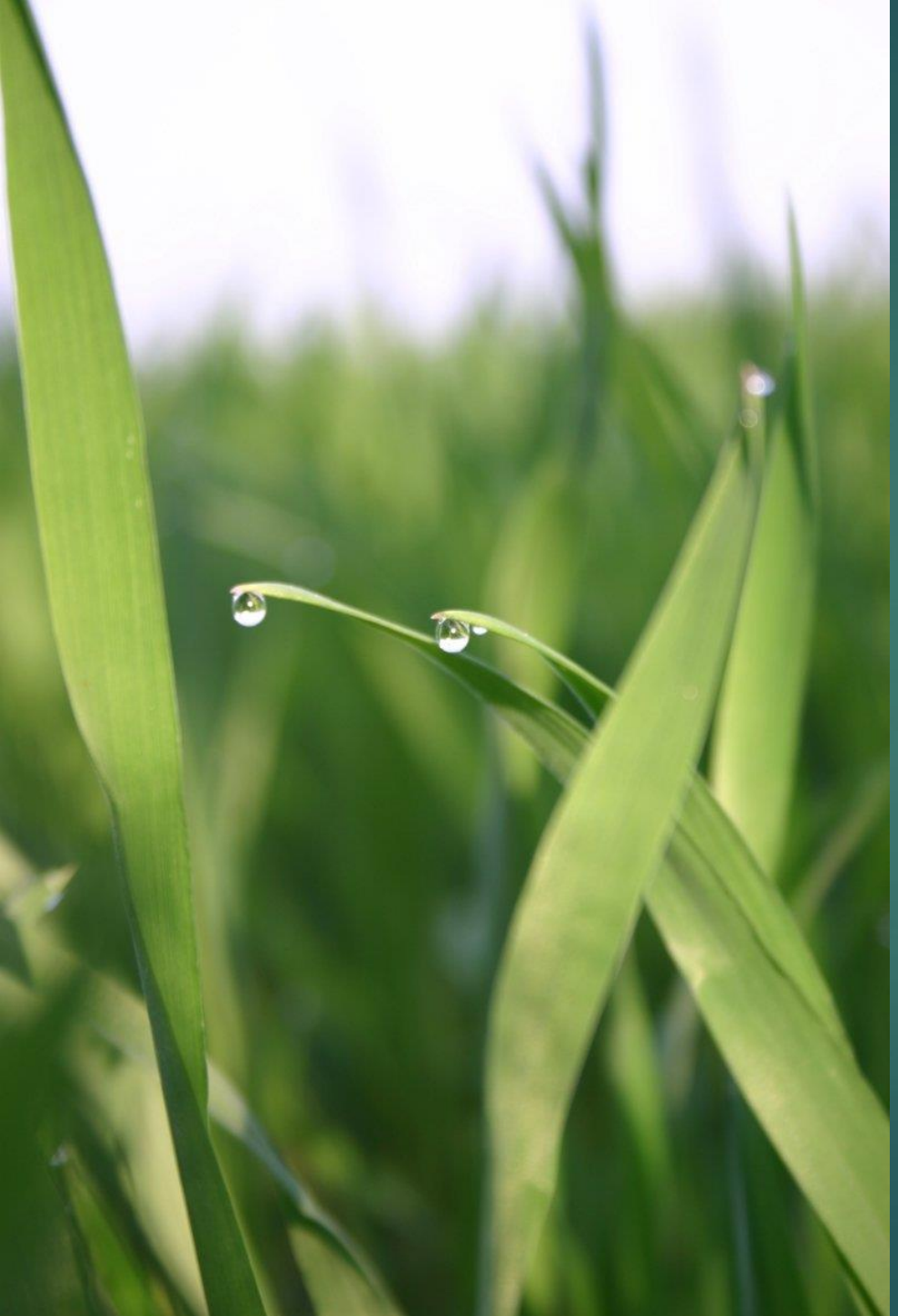
Fig. 10.2: When a ball is gently displaced from the centre of a bowl it starts oscillating about the centre due to force of gravity which acts as a restoring force

The unity of organisms

- "I would provisionally say that a thing exists as a natural end if it is cause and effect of itself."

(Kant, quoted in Walsh 2006)

- The tree, as an organized whole, is the cause of the leaves, roots, etc.
- And the tree is also the effect of the leaves, roots, etc.

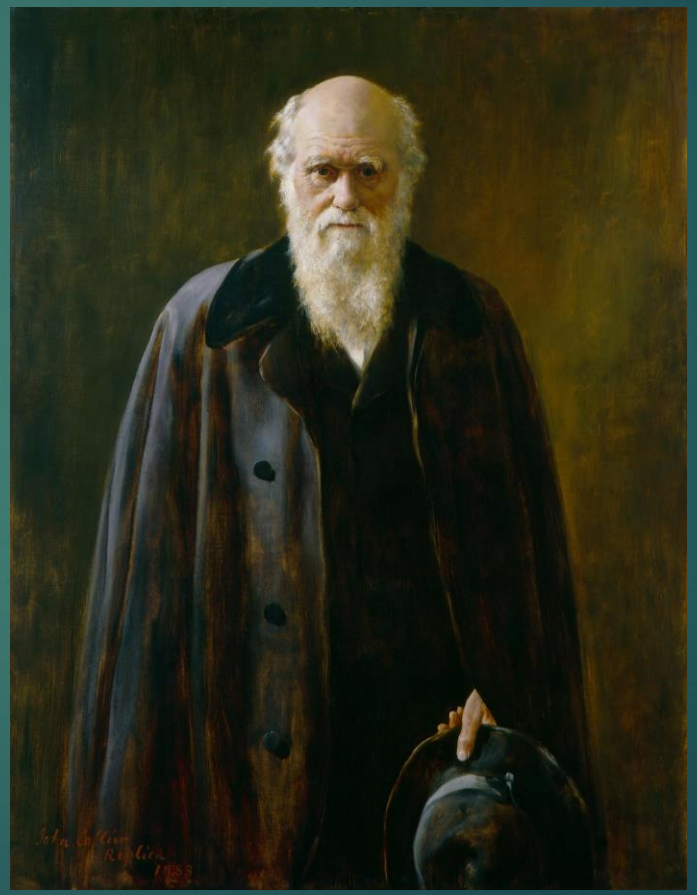


Newton of a blade of grass

- Kant's conclusion from this was that we can never have a science of living things
- Science deals in mechanical causes
- Mechanical causes are insufficient to understand living things
- Therefore, no science of living things!

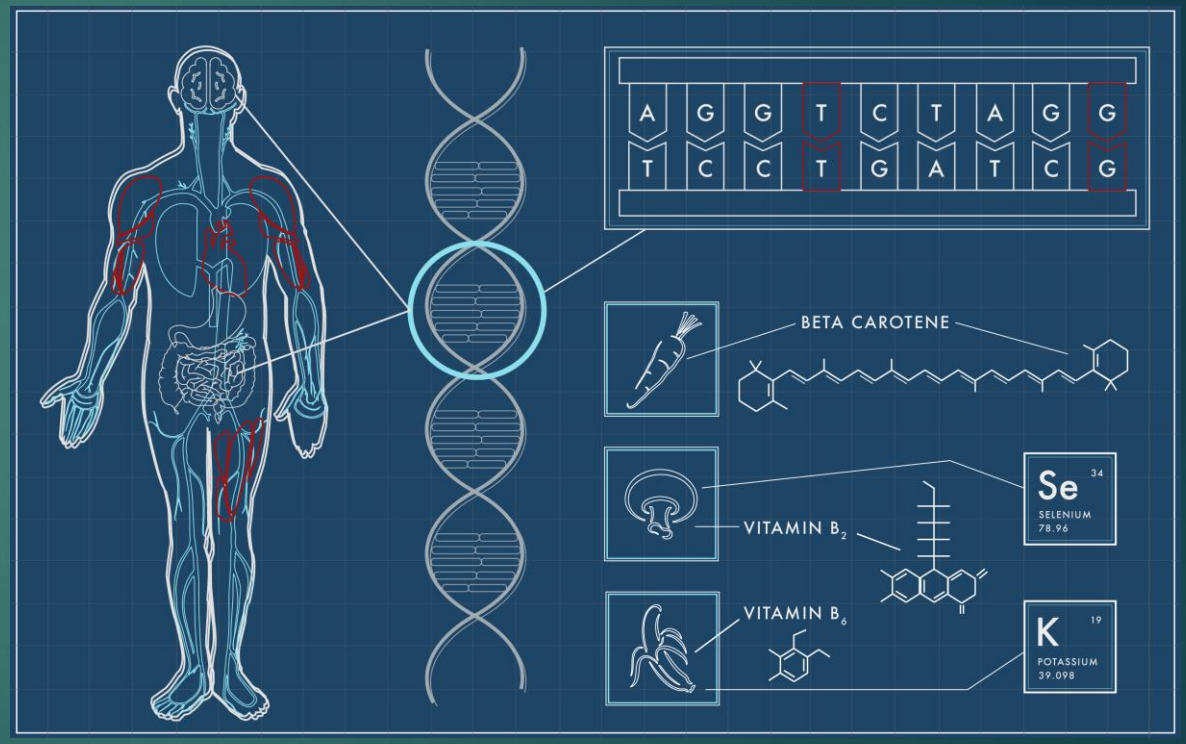
The Origin of Species

- Walsh notes what we talked about last week: most people think Darwin provided the answer to Kant's dilemma
- Natural selection is a mechanism, and it explains why organisms have forms that look both unified in themselves, and fitted to their environments



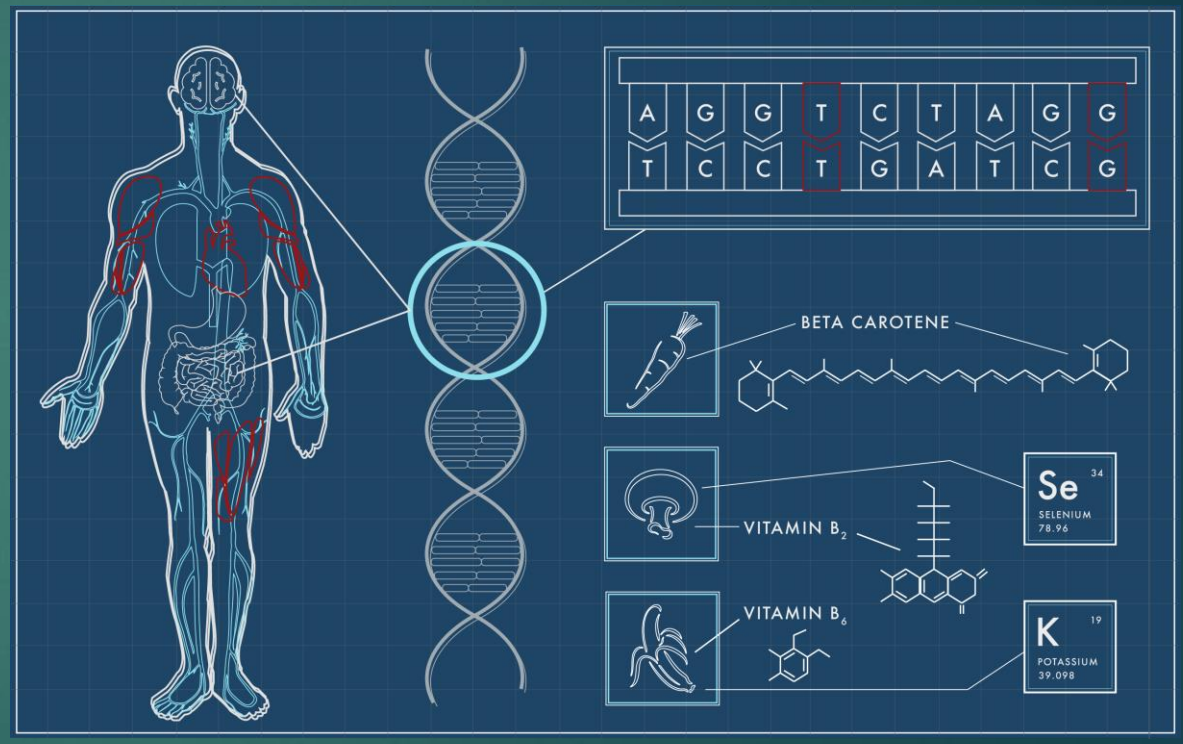
Your Genes and You

- And we talked last time about the development of evolutionary theory in the 100 years or so after Darwin's Origin of Species
- The prevailing view became that genes are a kind of blueprint of the adult form of living things
- The genes "program" the body



Your Genes and You

- Something like this picture is necessary for Darwin's theory to be a complete answer to Kant
- To explain organic form using just natural selection, it needs to be that genes have clear consequences for organic form
- Ideally, each would contribute the plan for one 'trait', and that trait would either contribute to or reduce the fitness of the organism

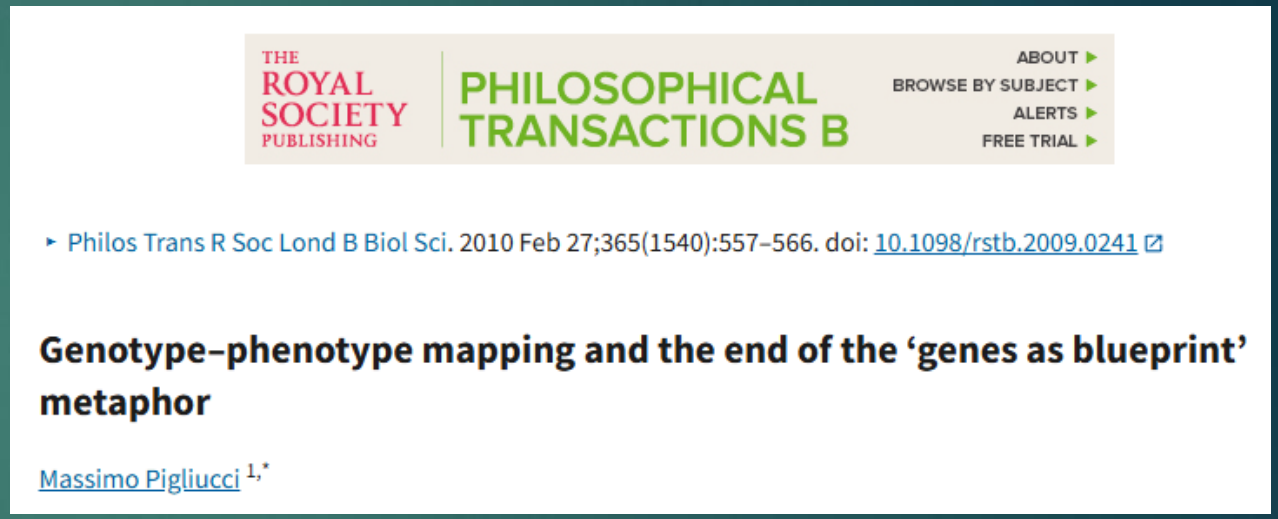


Organisms as Middle-Men

- If we define evolution as "changes in gene frequency in a population", the organism barely features in evolution
- Organisms run the genetic code, but they're not the thing undergoing selection (only genes are selected)
- And they're not where selection has effects – only populations show this
- (E.g., no one ever died from "natural selection")

Genotype-Phenotype Mapping

- One problem with this picture, according to Walsh, is that genes do not straightforwardly code for the traits we care about
- Genes code for proteins! That's it!
- It turns out to be much more complex than was assumed to understand how a given gene contributes to aspects of our form
- This is the genotype-phenotype mapping question



Bean Bag Genetics

- "The Mendelian was apt to compare the genetic contents of a population to a bag full of colored beans. Mutation was the exchange of one kind of bean for another. This conceptualization has been referred to as "beanbag genetics". Work in population and developmental genetics has shown, however, that the thinking of beanbag genetics is in many ways quite misleading. To consider genes as independent units is meaningless from the physiological as well as the evolutionary viewpoint."
- Mayr, Animal Species and Evolution, p. 263

Evolvability

- Randomly changing one line of code in a computer program, or one connection in the circuits of my laptop, is wildly unlikely to improve it
- In fact, the likelihood of catastrophic failure is pretty high!
- Yet according to a 2011 study, the average human has on the order of 40 novel mutations in our genetic code
- "Variation in genome-wide mutation rates within and between human families." Nature genetics 43, no. 7 (2011): 712-714.

Evolvability

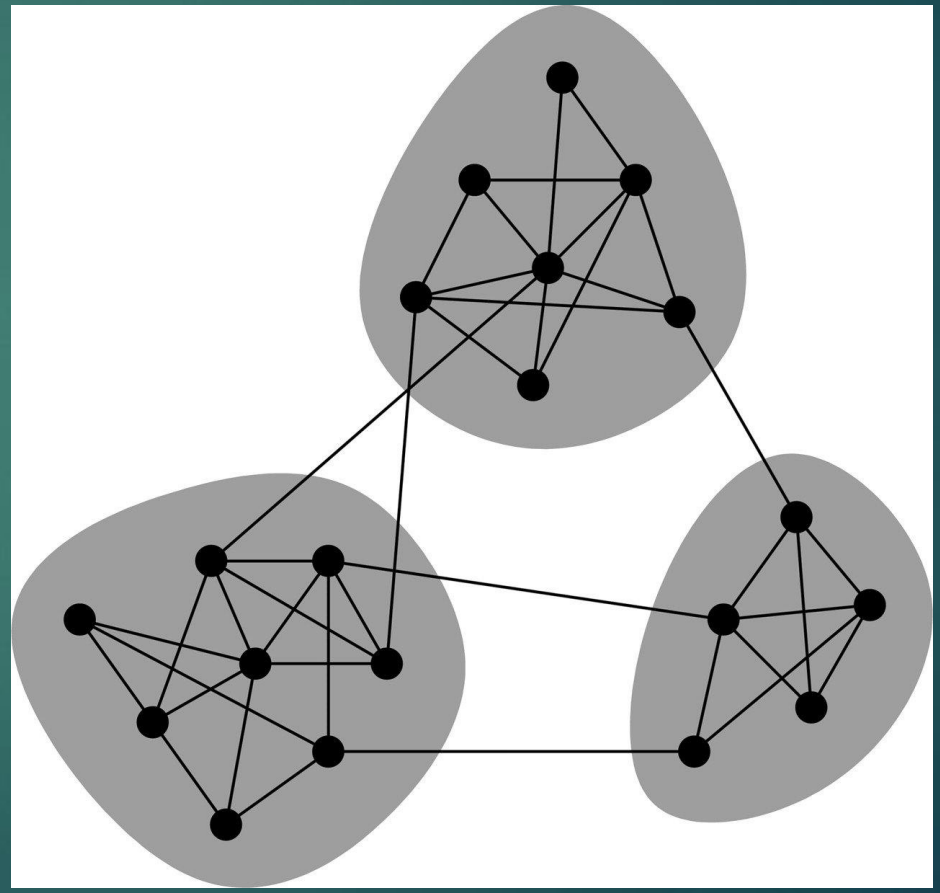
- Evolvability is the ability to undergo adaptive evolution
- If any little change collapses the whole system, that's low evolvability
- But if major changes make no difference, that's also low evolvability!
- We need the right balance between those two

Development

- Walsh argues that the bean bag picture of what genes contribute to life isn't adequate for understanding organismal development
- Particularly, he thinks organisms are highly plastic (can change) in a way that lets us be adaptive
- And this adaptive plasticity, he thinks, is made possible by the modularity of development

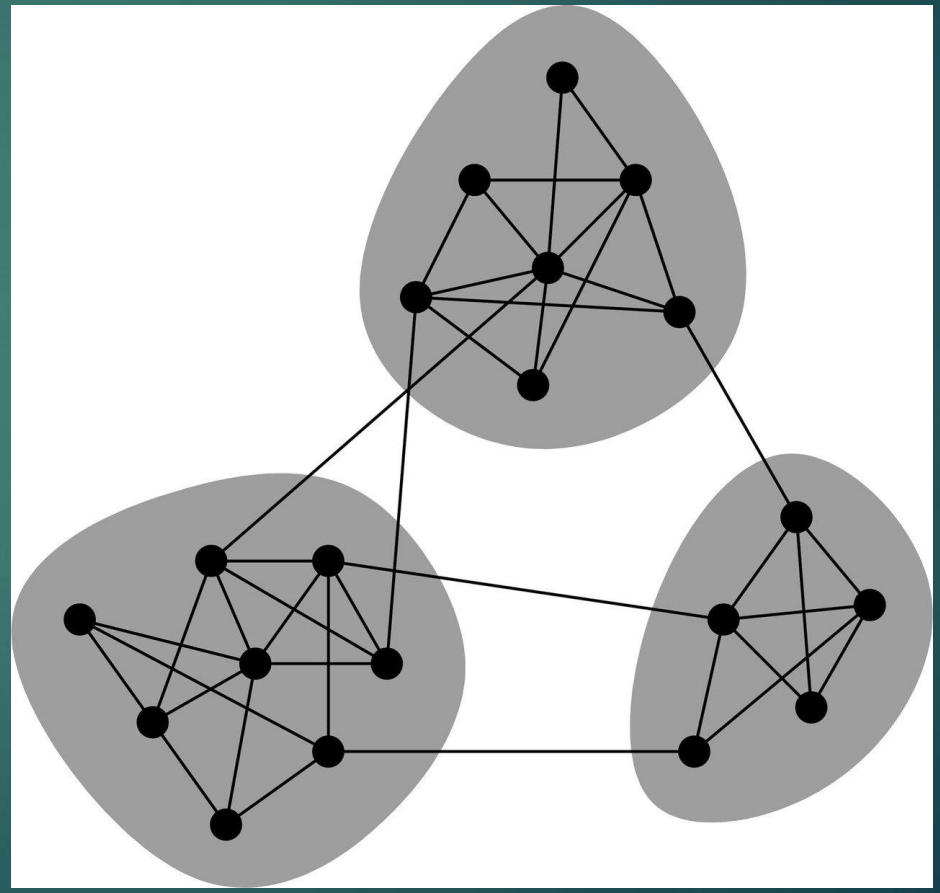
Modularity of Development

- Our genes do not act by themselves, and they are not on/off
- Each gene has an activity level, which can be tuned up or down by a variety of factors
- And the activity level of one gene can tune up or down the activity level of other genes
- Some set of connections like this between the activity of genes is called a gene regulatory network



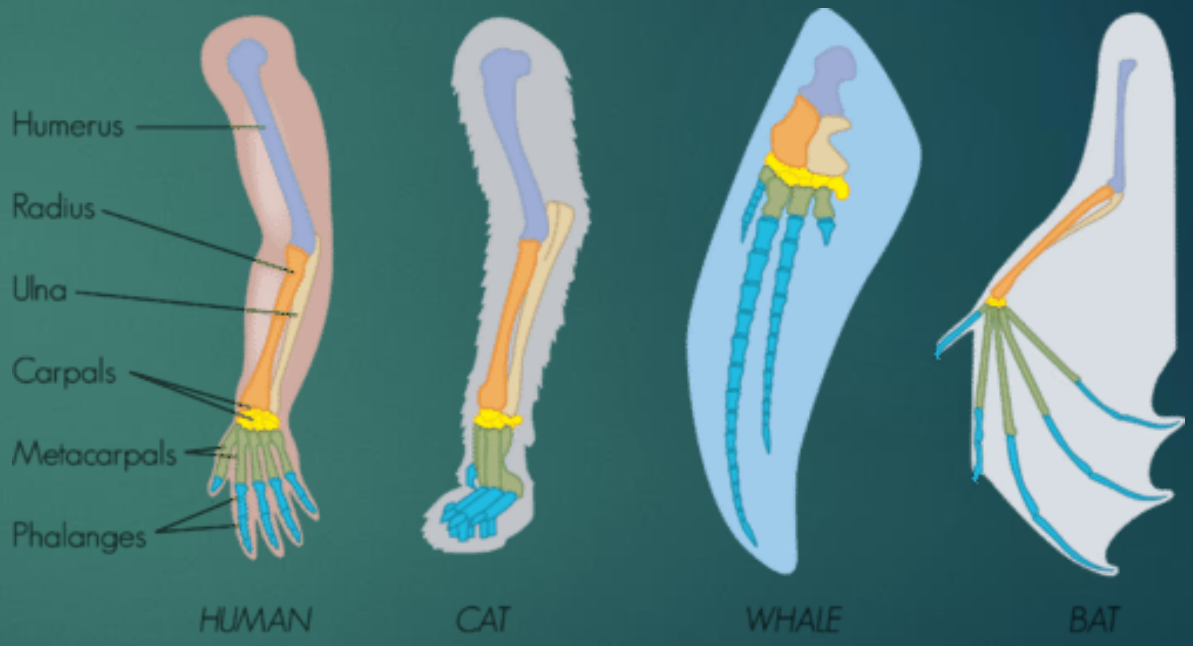
Modularity of Development

- And gene regulatory networks seem to be modular
- That is, they have a lot of connections with some small collection of genes, and relatively few with others
- Within a module, many changes can be buffered out by other genes
- And changes within a module do not necessarily cause changes to other modules
- (this is all by degrees, not absolute)



Modularity and Development

- When genetic changes do cause phenotypic changes, modularity allows those changes to be relatively local
- Changes to say, the length of a particular bone, do not necessarily cause all the bones in the body to lengthen
- And feedback mechanisms within modules allows for other parts to accommodate those changes in an adaptive way



Phenotypic accomodation

- Phenotypic accommodation is the phenomenon of organisms developing bodies to fit novel circumstances, with no genetic change
- E.g., Slijper's goat

- West-Eberhard, M. J. (2005). Phenotypic accommodation: adaptive innovation due to developmental plasticity. Journal of Experimental Zoology Part B: Molecular and Developmental Evolution, 304(6), 610-618.

Phenotypic accomodation

- “When the goat died an accidental death at the age of 1 year, Slijper dissected it and published a description of its altered morphology, which included changes in the bones of the hind legs, the shape of the thoracic skeleton and sternum, changes in the shape and strength of the pelvis, which developed an unusually long ischium. Changes in the pelvic muscles included a greatly elongated and thickened gluteal tongue whose attachment to the bone was reinforced by a novel trait, a set of numerous long, flat tendons.” West-Eberhardt p.611

Phenotypic accomodation

- Many of the novel, adaptive traits this goat had look like the kind of thing that bipedal animals like us have
- E.g., its pelvis looked (somewhat) like a human pelvis
- This is an example of the plasticity of organisms keeping them adaptive under totally novel circumstances

Phenotypic accomodation

- West-Eberhardt argues that when we think of genetic change due to natural selection, we should keep this in mind
- The phenotype will adapt to specific circumstances
- The selective pressure genes face is shaped by the ways the phenotype adapts
- So the organism leads, in a sense, the genes, rather than the other way around

Phenotypic accomodation

- "Without developmental plasticity, the bare genes and the impositions of the environment would have no effect and no importance for evolution." (West-Eberhard, 2005, p.6544)

Inheritance and Organisms

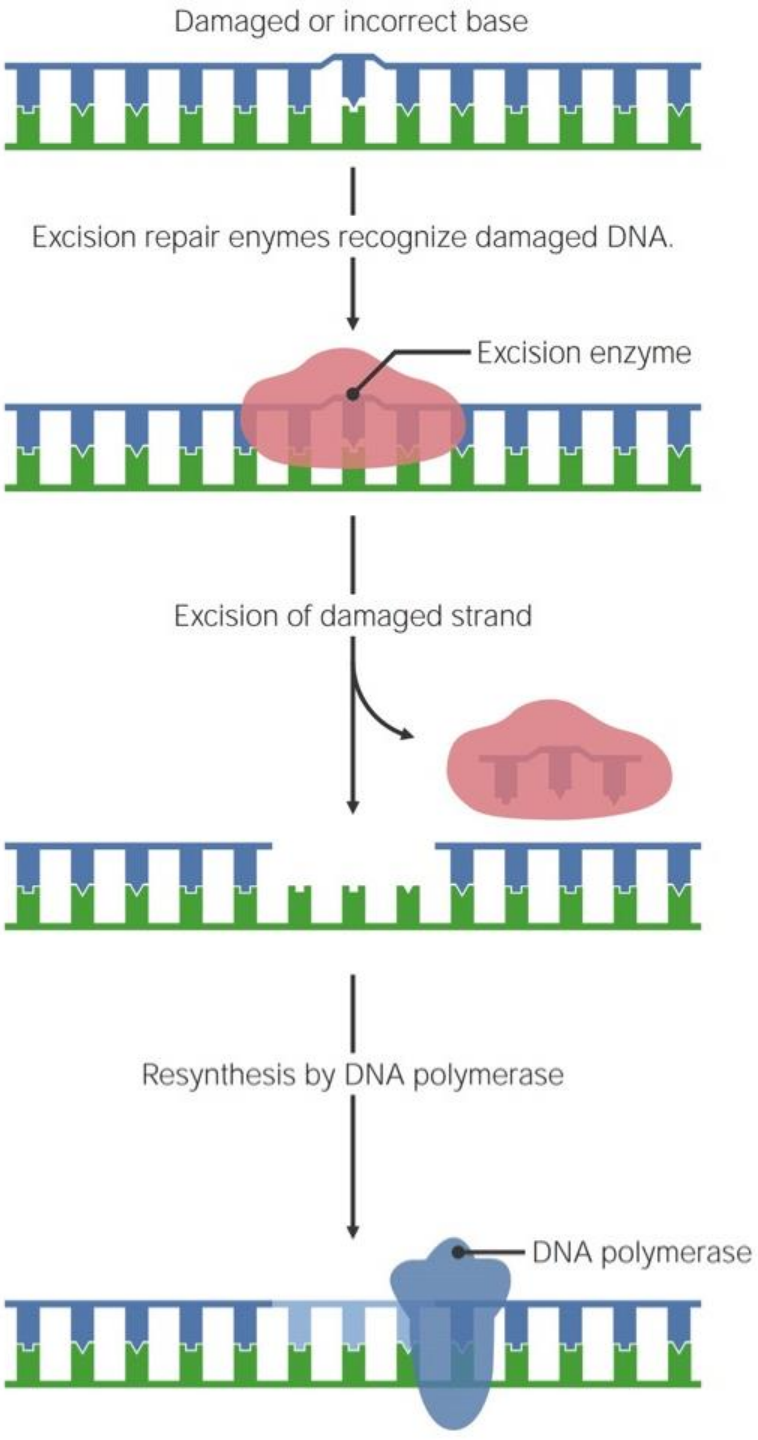
- For natural selection to act, there needs to be heritable variations which affect fitness
- But as we've seen, identical genes do not mean identical organisms (due to phenotypic plasticity)
- And non-identical genes don't always mean differences in phenotype
- What is inherited then seems to be a host of developmental resources, which each living thing uses to creatively make and re-make itself

The Piano Metaphor

- A metaphor (which seems to be attributable to a few different sources) suggests the genome is like a piano with 30,000 keys
- Rather than a blueprint, it is a set of affordances which can be ‘played’ in many different ways
- And the organism tries to play a tune which is harmonious

The Stability of DNA

- DNA is an enormous and delicate molecule, and it is constantly being damaged by various chemical processes (e.g., UV light)
- A variety of cellular processes identify DNA damage, and repair it
- The cell does this by either directly repairing the damage, or cutting out the damaged section and re-synthesizing it



The Organism Centred View

- "On the organism-centred view the capacities of organisms, by which Kant identifies them as natural purposes – their self-organization, self-regulating, goal-directed capacities – constitute the ground for the possibility of sub-organismal, replicator biology." (Walsh, p.780)

Explaining Individuals and Explaining Regularities

- Walsh suggests that viewing organisms as mechanisms, and viewing them as natural purposes, are complementary
- In principle, you could explain every molecular interaction in the body of any living thing
- But if you want to understand why it has the form it does, or why organismal forms in general are they way they are, you need to see it as a natural purpose

Explaining Individuals and Explaining Regularities

- To see the difference, consider a class of students who all read at a third grade level
- We could want to know, of each student individually why they can do that
- Or, we could ask about the class as a whole
- Different explanations will be relevant!

Robustness and Self-Organization

- A hurricane is a self-organized system, in the sense that it has lower entropy than wind just going any which way
- You can perturb a hurricane quite a bit, and it will re-form – it is a robust phenomenon
- But that robustness doesn't depend on the exact initial conditions, or any particular arrangement of molecules
- Rather, it is a properly of the system as an organized whole

Robustness and Self-Organization

- Our status as natural purposes is like this, Walsh argues
- We are agents, adapting to our environments to live and flourish
- That can look like a lot of different things at the molecular level
- And what we now know is that the molecular level of our bodies self-organizes in a way that keeps us robust against perturbations

The unity of organisms

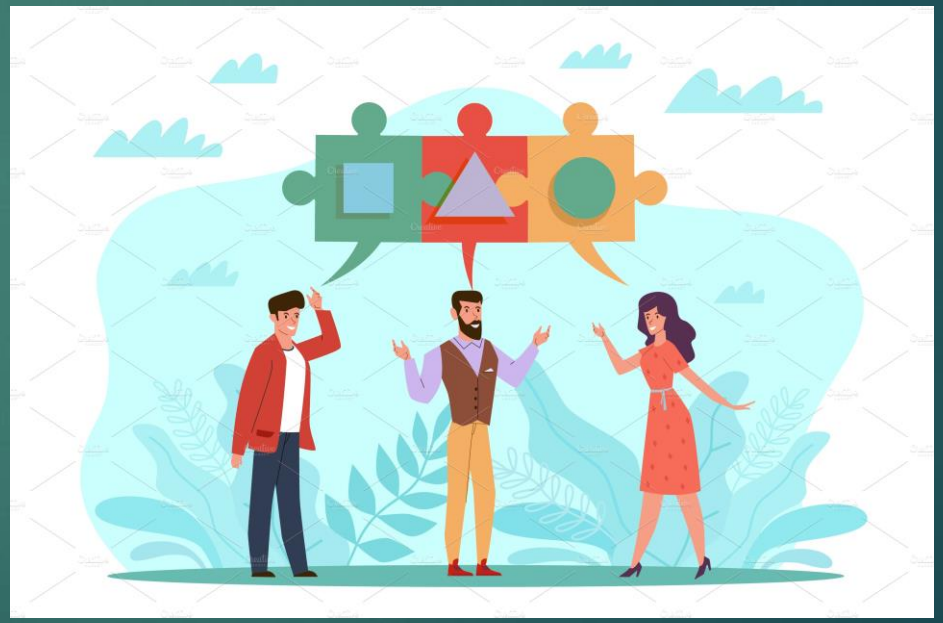
- So why does it look like organisms have this property of being both cause and effect of themselves?
- For any given organism, there is a mechanical explanation for any feature they have

The unity of organisms

- But Walsh thinks that if we want to know why living things appear to have purposes, we need to appeal to their overall structural features
- Purposive behaviour is an emergent property of living things, explained by their organization

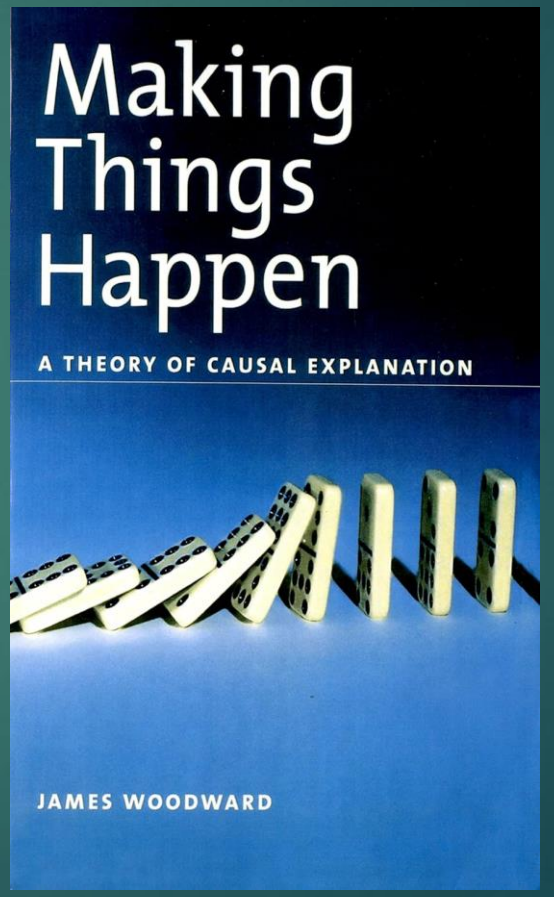
Ways of Explaining

- So this claim is about explanation and understanding
- Walsh is not claiming there is some mysterious force of self-organization at play here
- Rather, that there are two different styles of explanation required
- But having explained living things in terms of mechanical causes, is there room for anything else?



Invariance Explanation

- Walsh asks us to consider one modern theory of explanation, the Invariance account
- This is from James Woodward, a philosopher of science who (as far as I know) has no strong opinions about organismal form etc.
- The short version is that to explain something is to identify the factors that make a difference to it

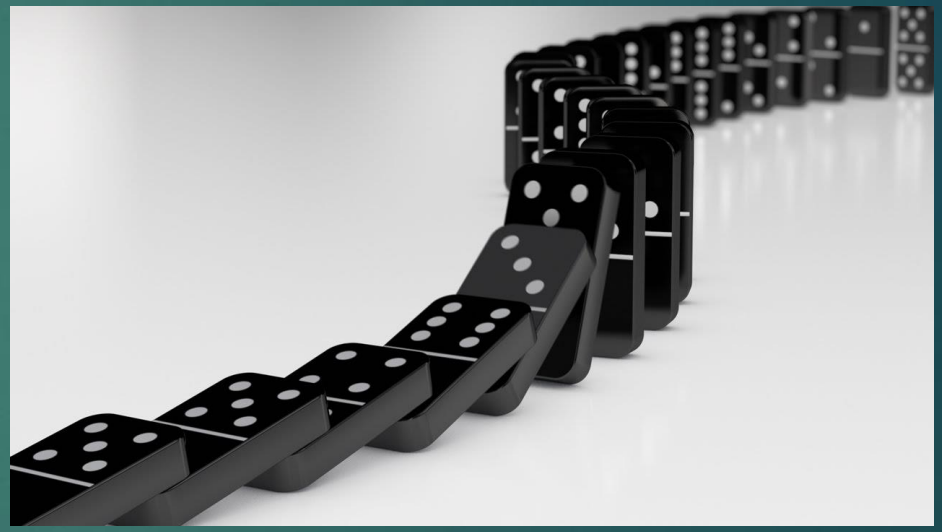


Difference Makers

- Finding an explanation is then about finding difference makers
- If I ask "Why isn't my car working?" one possible answer is "because you didn't put gas in it."
- If that's true, then in the scenario where I had put gas in it, it would run
- If the problem is instead the spark plugs, then gasoline may not have been a difference maker, so isn't an explanation

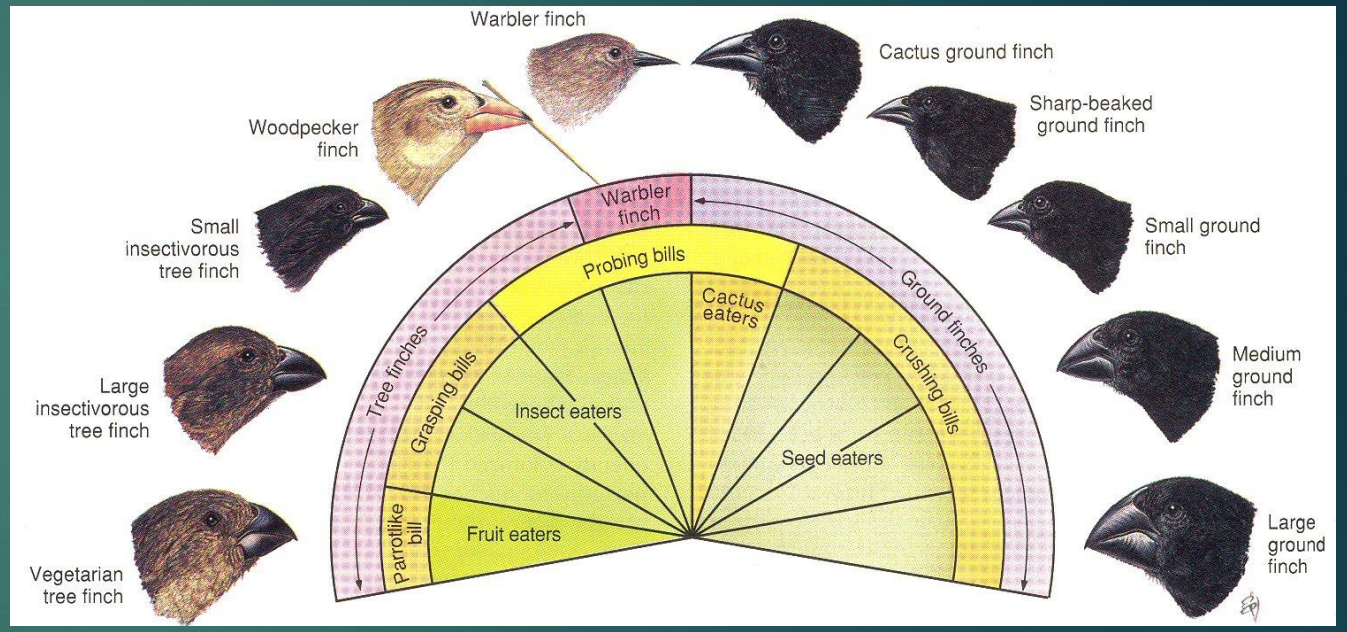
Mechanical Difference Makers

- Woodward mostly has in mind what you could call ‘mechanical’ difference makers
- If the first domino hadn’t been pushed, the next one wouldn’t fall, etc.
- But recall what we said about genes
- Our bodies are such that, very often, changing one gene doesn’t change the sorts of bodies we have!



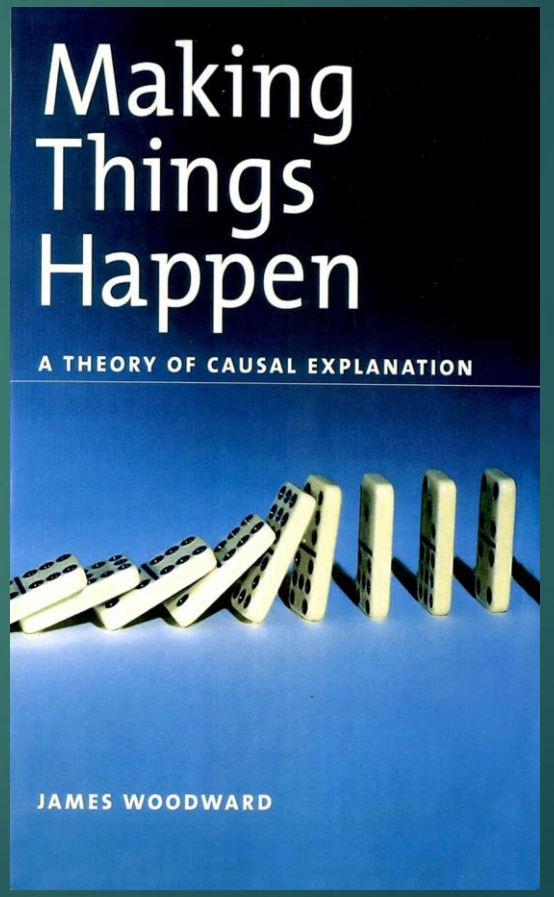
Purposive Difference Making

- Walsh suggests that we can use this basic framework, but think about differences in goals
- Organisms employ their adaptive plasticity to achieve various goals
- If their goals change, then we can expect to see phenotypic accommodation
- And changes in genes will then follow along with these changes in goals over time



Invariance Explanation

- Therefore, Walsh argues, purposes can do explanatory work just as well as mechanisms
- They tell us what would have happened if things had been different
- And they do that for a different set of possibilities (what if the overall organization had been different?) than mechanisms (what if this gene had been different?)



The unity of organisms

- So, Walsh claims, we can coherently say that living things are both caused by molecular mechanics, and by their own purposive activities
- Both perspectives are needed, and they don't conflict in the way Kant argued

Next time: Astrobiology