The Role of Selective Neutrality in Evolutionary Search

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1. Artificial Evolution

The context of evolution is a **population** (of organisms, objects, agents ...) that survive for a limited time (usually) and then die. Some produce **offspring** for succeeding generations, the **'fitter'** ones tend to produce more.

Over many generations, the make-up of the population changes. Without the need for any individual to change, successive generations, the 'species' changes, in some sense (usually) adapts to the conditions.

Requirements:

– Heredity	(offspring resembles parents)
– Variability	(but not exactly..)
– Selection	(‘fitter’ reproduce more)

2. Genotype-Phenotype Mapping

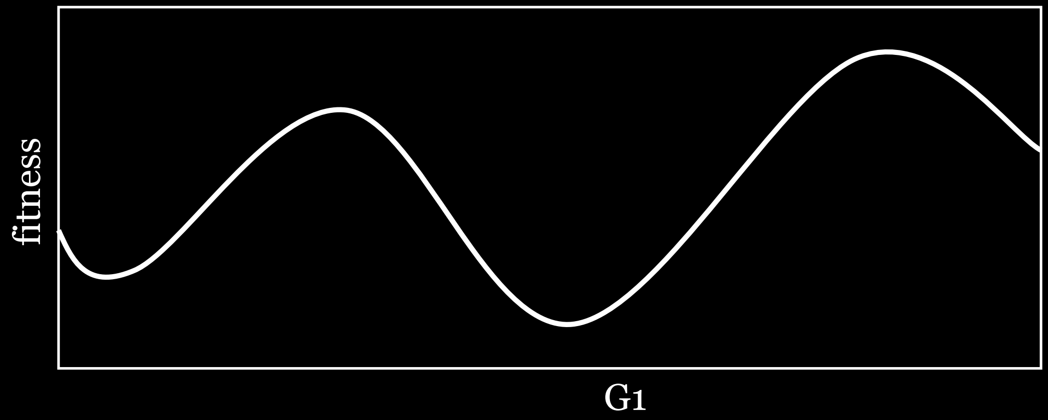
In Genetic Algorithm (GA) terminology, the **genotype** is the full set of genes that any individual in the population has.

The **phenotype** is the individual potential solution to the problem, that the genotype **'encodes'.**

So if you are evolving with a GA the control structure, the 'nervous system' of a robot, then the genotype could be a string of 0s and 1s 001010010011100101001 and the phenotype would be the actual architecture of the control system which this genotype encoded.

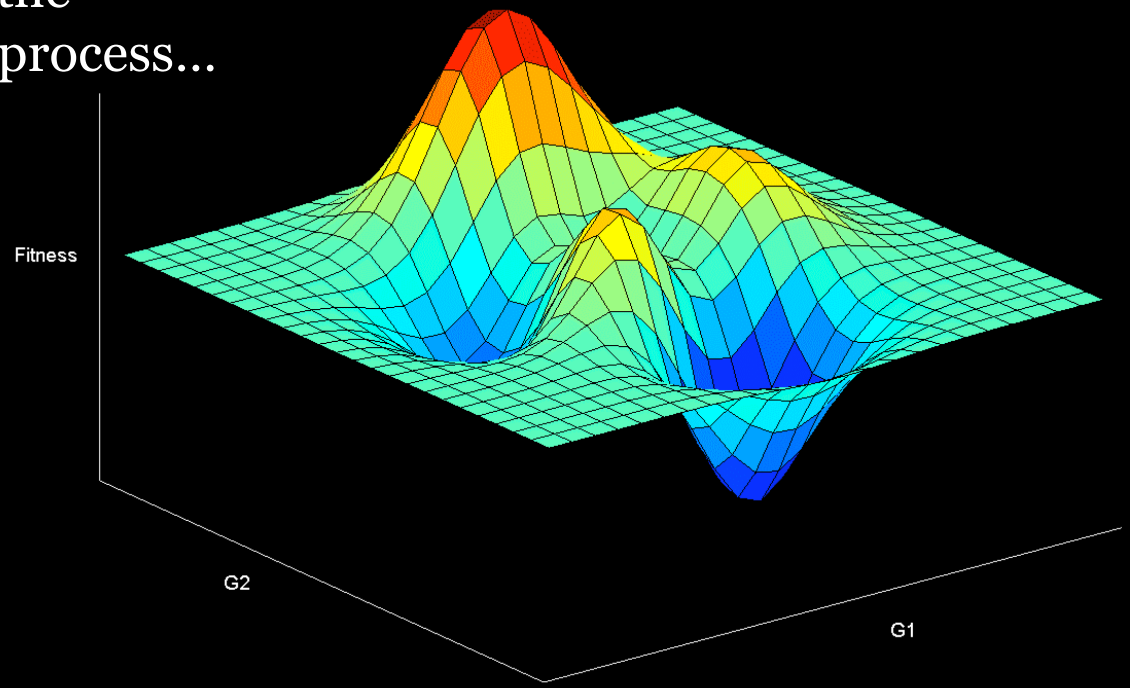
3. Fitness Landscape

Sewall Wright 1932



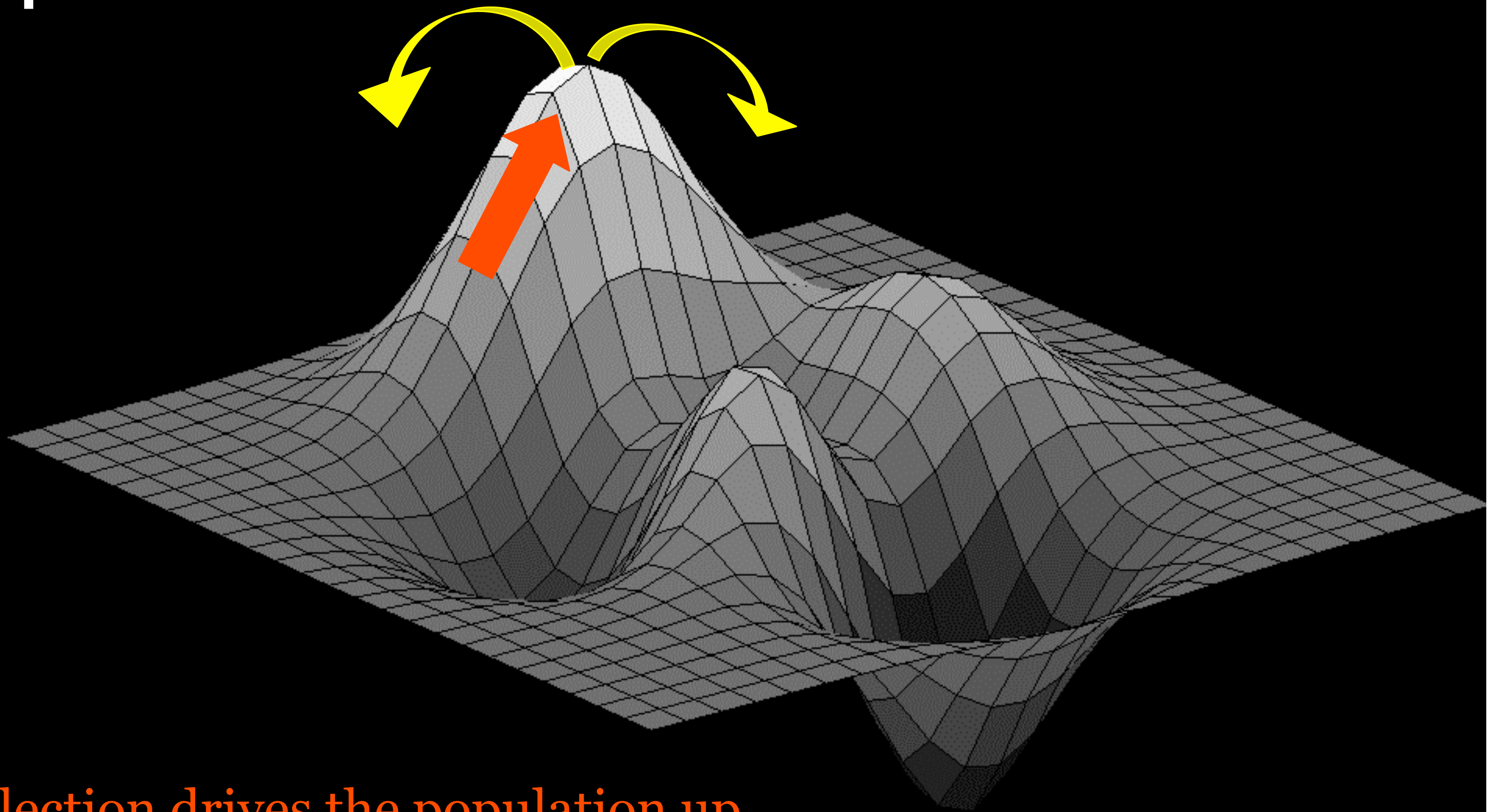
1D+fitness

The arena of the evolutionary process…



2D+fitness

4. Mutation Vs Selection

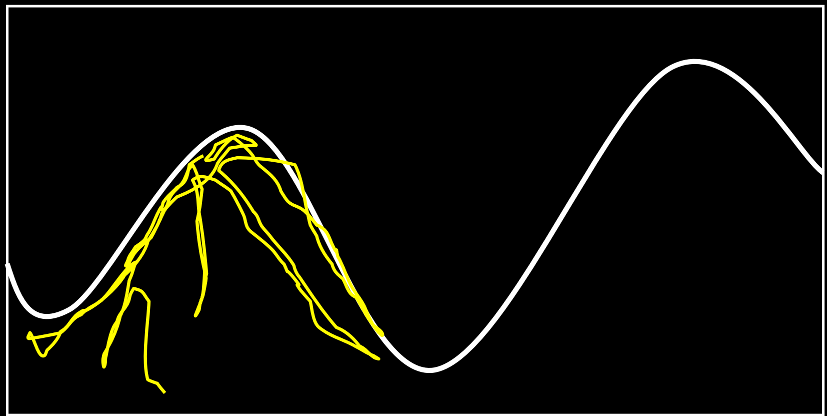


Selection drives the population up…

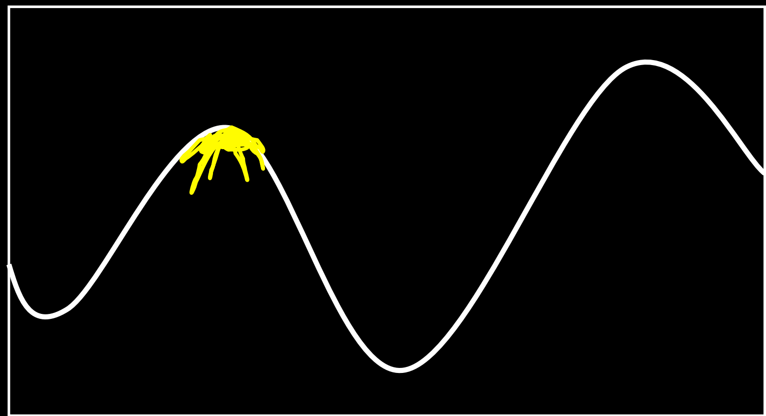
Mutation explores the neighbours…

4. Mutation Vs Selection (2)

Too much mutation relative to selection

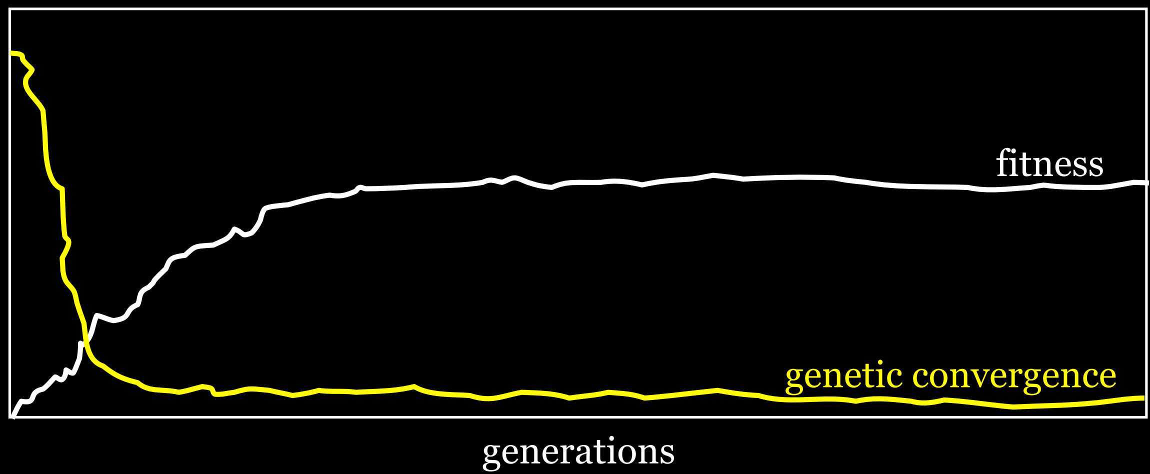


Too little mutation relative to selection



POTENTIAL DANGER: If selection is strong enough to pull a population up a hill it might be strong enough to hold it there.

5. Genetic Convergence

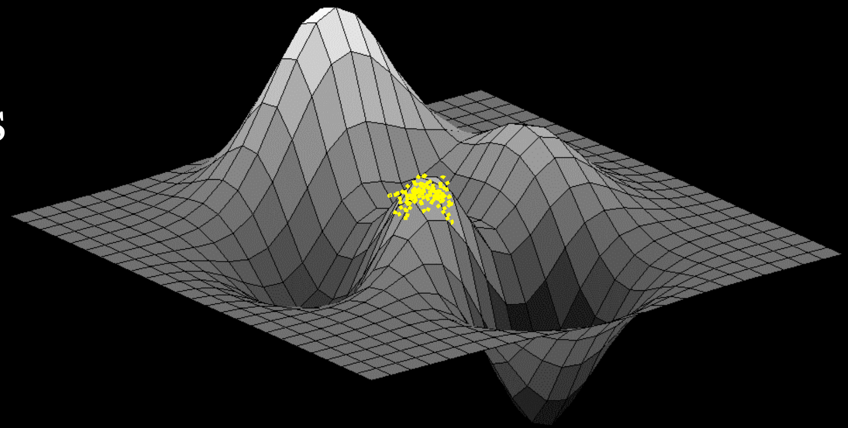


The genetic 'spread‘ of the population settles down to its 'normal' value, which is some balance between:

- selection of the fittest -> reduces spread, and
- mutation -> increases spread.

5. Genetic Convergence (2)

Traditionally GA practitioners use direct mappings… (redundancy has been considered inefficient)



As a consequence, genetic convergence has been associated with phenotype and fitness convergence.. And thus getting stuck in local optima.

Recombination is usually considered the main genetic operator hoping that as much genetic variance will be introduced..

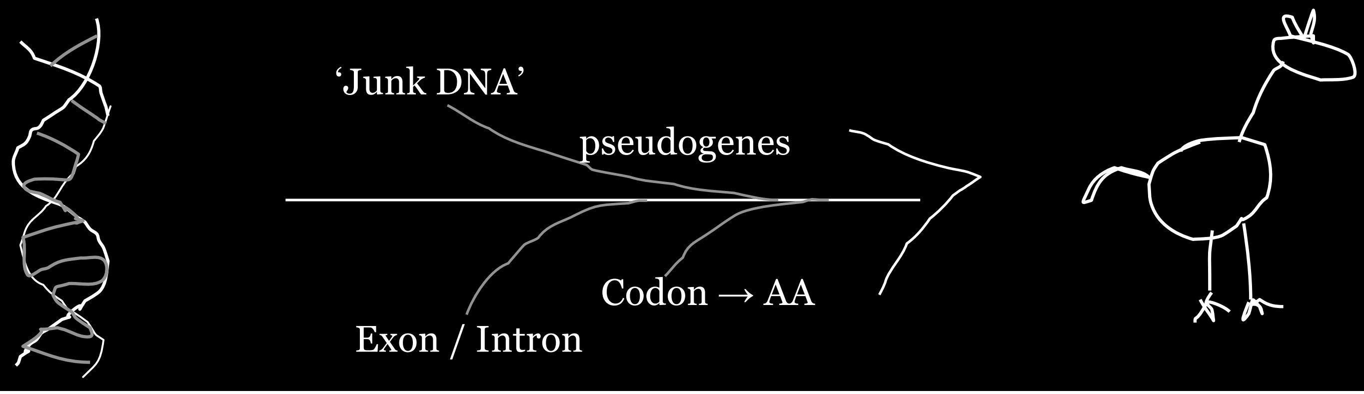
And the typical solution has been to start off with a huge population and evolve for only few generations…

6. Selective Neutrality

However, this is not the case for Biological Evolution… In nature, evolution works over many generations with no fear of loosing innovative adaptations after a long time.

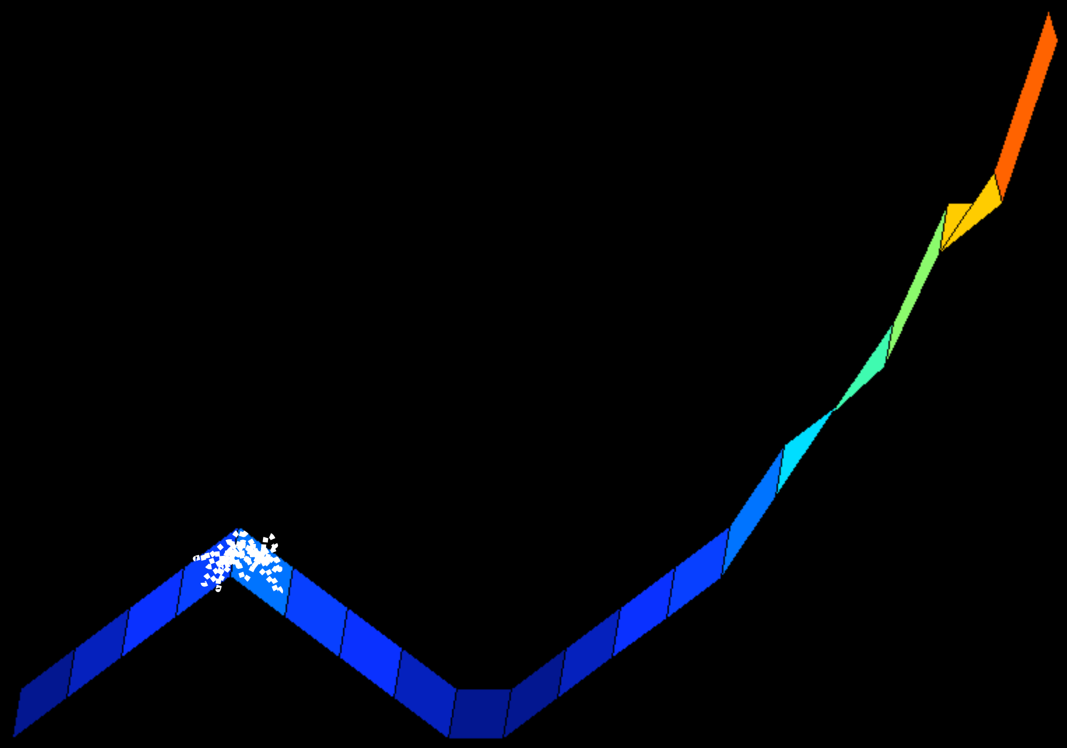
In biological systems, the genotype-phenotype mapping is much more complex…

At the molecular level, the mapping is very redundant – with many (most) mutations having no effect on fitness.



6. Selective Neutrality (2)

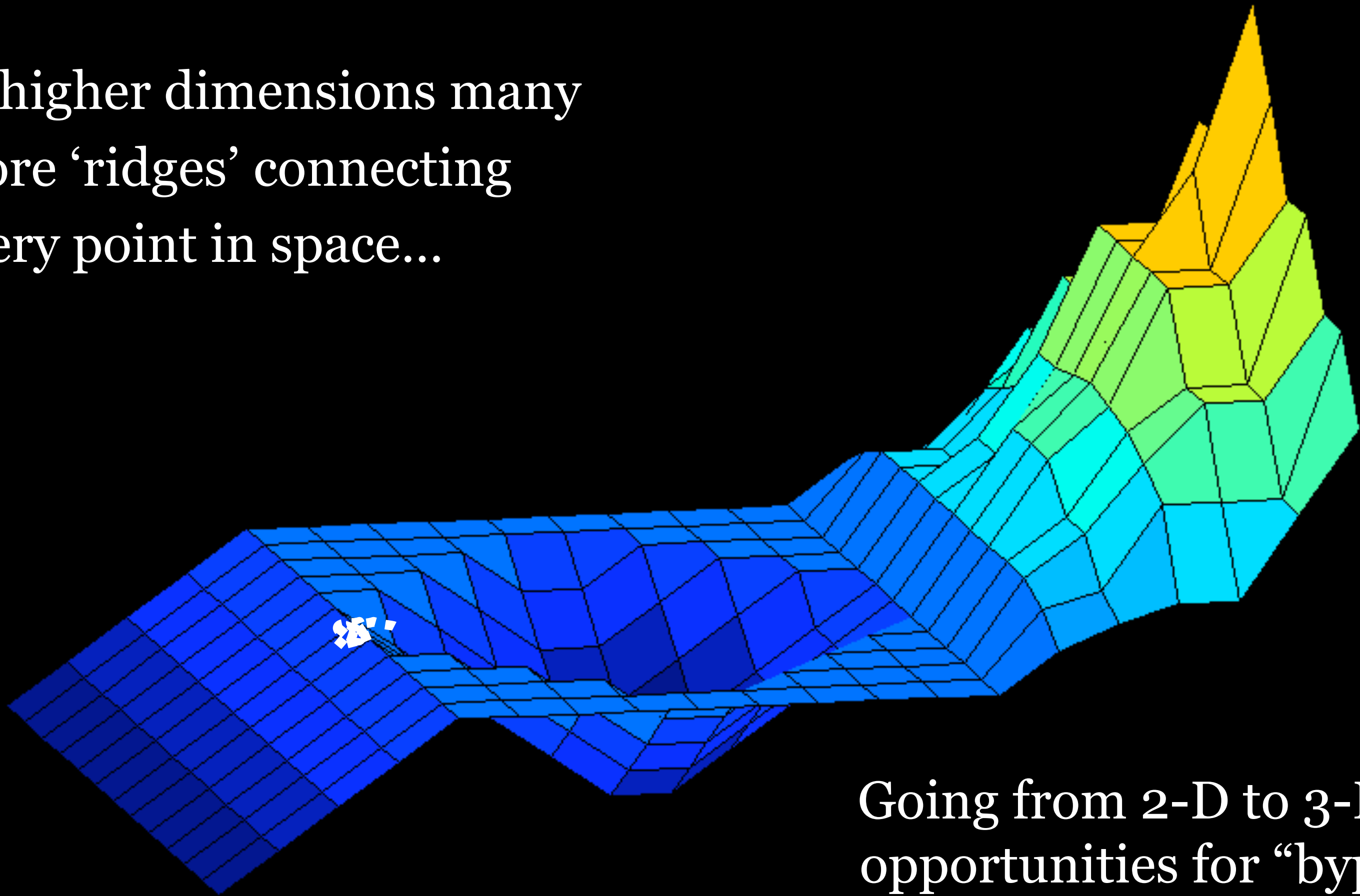
If there are no better or neutral mutations then is likely that the population will get stuck on local optima…



But if there is a redundant mapping (this implies moving the fitness landscape into higher dimensions…)…

6. Selective Neutrality (3)

In higher dimensions many more ‘ridges’ connecting every point in space…



Going from 2-D to 3-D allows extra opportunities for “bypasses around a valley without dropping height”

Going up to 100-D or 1000-D potentially allows many many more such opportunities -- hyper-dimensional bypasses.

7. Implications

- Need not worry about getting stuck on local optima (constant innovative property)
- Need not worry about small population sizes
- Need not worry about recombination to produce genetic variation (mutation is the driving force behind evolution, recombination is not as likely to be effective…)
- Should worry about how to get the population running around selectively neutral neighbours as fast as possible until finding fitter neighbours.

8. Conclusions

Research in molecular and evolutionary biology have pointed towards *selective neutrality* as an important factor in evolution.

This has been the cause of three decades of a selectionist-neutralist debate… and is an area central in understanding the dynamics of evolutionary process.

In artificial evolution these ideas have been generally ignored…

There is gathering evidence that neutrality is prevalent in many real-world engineering problems..

Furthermore, appropriate techniques for effective evolutionary search on landscapes featuring substantial neutrality may well differ quite radically from more traditional approaches to evolutionary search.

Thank You

Time for questions…