

A few comments (& questions!) from a condensed matter physicist

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Numbers

Evolvability

Models and Extrapolation

Large and Small Numbers

Number of bacteria, N : Total on Earth $\sim 10^{29} - 10^{31}$
 $T = \# \text{ generations} < 10^{12}$

Total bacterial cell divisions ever

$\sim \# \text{ of "attempts"}$ $A \sim NT \sim 10^{39-43} \sim e^{90-100} ??$

Total # vertebrates ever: $N > 10^{13}$ $T \sim 10^9$ $A \sim 10^{22} ?$

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"Niches"?? $\Rightarrow \# \text{ possible problems to solve?}$

Complexity of environments and organisms?

Dimensions? Fitnesses? (Bergstrom)

genome sizes, # chemicals +++

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Rates of genetic change processes: (Livnat, Koonin)
mutations, duplications, recombination, gene transfer

Polynomial or not? (Gang of Five)

$K \sim \# \text{ variables } (= n) \dots \# \text{ mutns to cross valley } \dots$

If **non-poly** but eg $\# \text{ attempts needed } A \sim \exp(c K^{1/3})$

can get $K \sim 10^6$ if $c=1$

$K \sim 2000$ if $c = 8$ (factorization?)

If **polynomial**: $A \sim K^H$ Does recombination change H ?

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What should be **surprised** by?

Are extremely **rare events** needed?

(= Does size of Earth matter?)

If so \Rightarrow rarest that can occur can have specific properties

Nature of Selection & Dynamics?

Is $A \sim NT$ the right combination?

Tradeoff of population size vs time?

Well mixed: all vs all ? (Warmuth)

Spatial structure: local competition? Spatial spread?

Time dependent environment? Multiple scales: Crucial

(Kussell, Watson)

Diversity: creation and maintenance crucial

(Immunology: Luo, Bergstrom)

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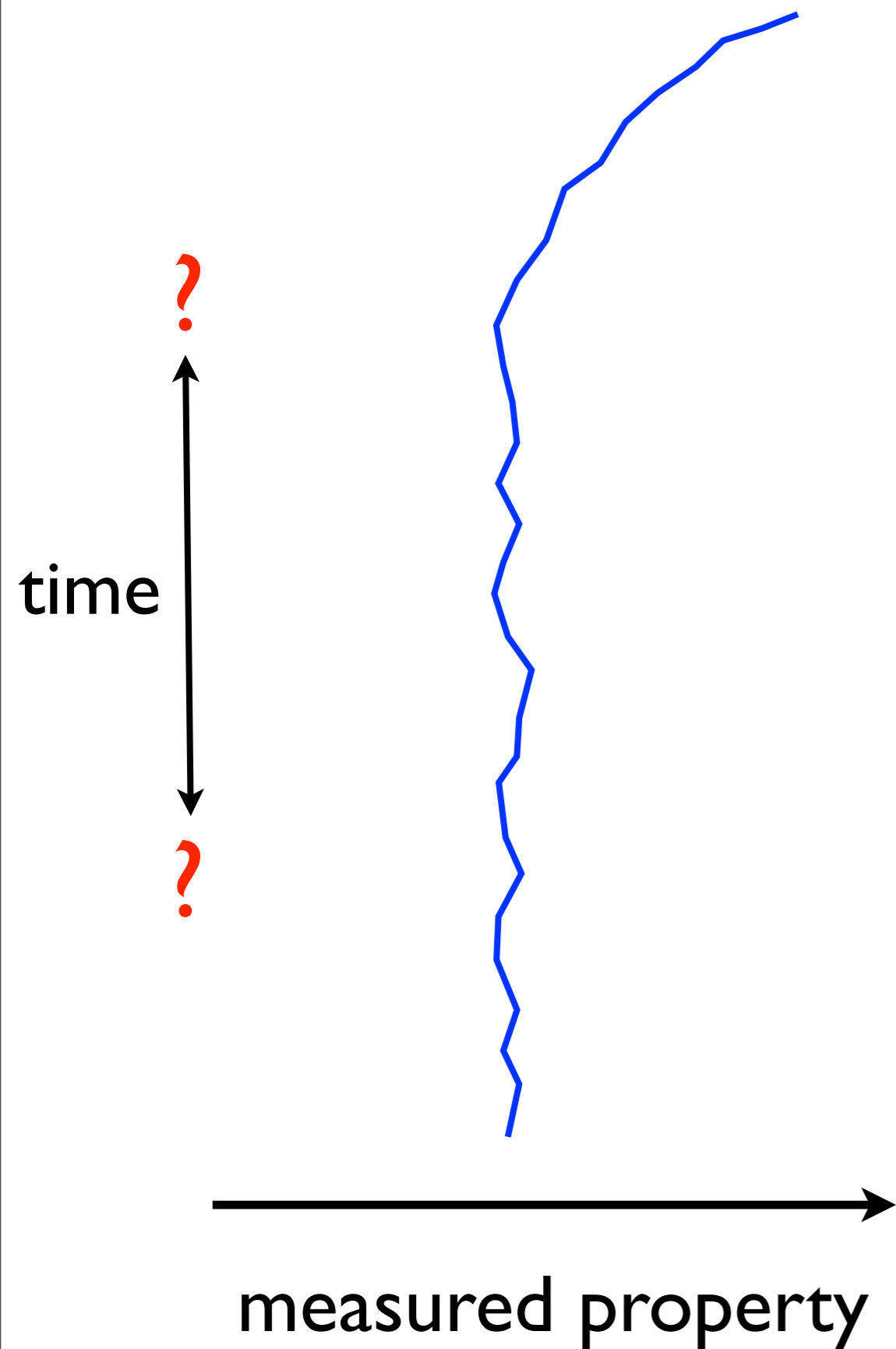
Asymptotics crucial:

eg: time to evolve $\sim 1/N$ vs $1/\sqrt{N}$.. K vs \sqrt{K}

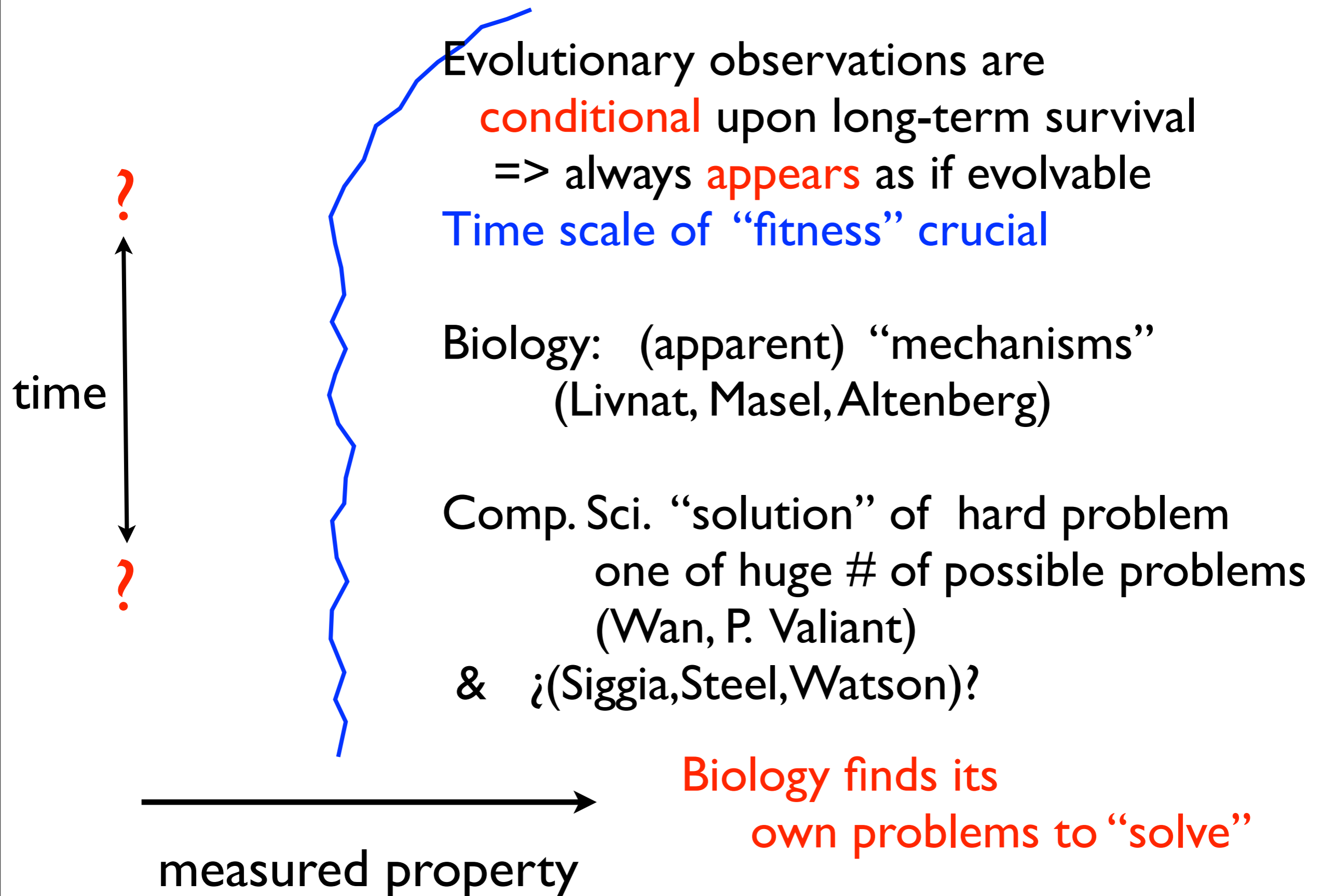
& regimes (Weissman, Pippenger)

Universality??

Evolvability Paradox?



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Evolvability & “Edge of Chaos” ?

Organismic biology: betw. “modular” & “random network”?

Selection on individual genes vs genomes?

Why recombination rates what they are?

Generation of variation & selection ~ same time scale??

Difficulty: polynomial K^H --- exponential e^{CK}

marginal? eg $\exp(C K^{1/3})$

Specific Contexts, Models, & Extrapolation?

Prebiotic autocatalytic sets (Steel)

Morphological development (Siggia)

“Toy” models (Watson)

Extrapolation to
“real” numbers?

Want: Define class of problems

Measures of “size” (K) of problem?

possible problems to solve? (eg virus many poss. hosts)

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Limits to Complexity?

Gene regulation in bacteria

genome sizes $G \sim 10^5 - 10^7$

of transcription factors $\sim c G^2 \Rightarrow \max G$