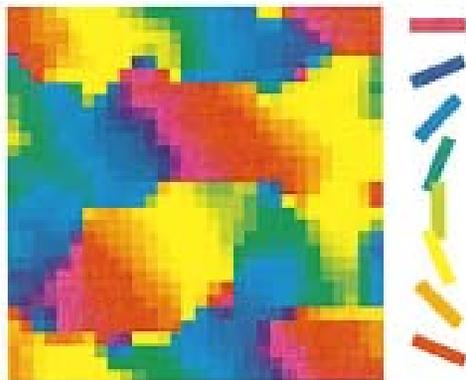


Time is a great teacher, but  
unfortunately it kills all its pupils.

--Hector Berlioz (1803-1869), French composer

Microscopic properties can have surprising qualitative macroscopic effects independent of many details.

(recurrent network theory, ecological stoichiometry,.....)



	N:P ratio
plankton:	16
deep ocean:	15

Premise: biology is fast becoming  
a quantitative field and will  
require quantitative training

~~why~~ ~~whether~~ how when

Get 'em while they're young

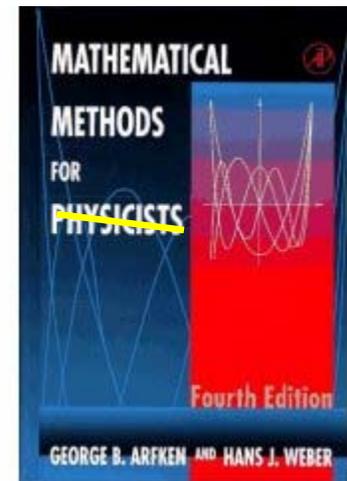
Get 'em while they're young  
(Phillip Morris approach)

technical

cultural

# An early start

require mathematical methods  
course for quantitative biologists



- order of magnitude, dimensional analysis, scaling
- linear algebra
- differential equations
- dynamical systems
- fourier analysis
- convolution, correlation, filters
- probability
- information theory

Emphasize *general/pure* math but include biological problems

# Unifying *qualitative* principles

- linear feedback: amplification, response time
- nonlinear feedback: multistability, w.t.a.
- stochastic optimization: evolution, learning, taxis
- reaction-diffusion: pattern formation
- ...

via diverse biological examples

show that results differ from expectations in cartoons

Another advantage of a mathematical statement is that **it is so definite that it might be definitely wrong**; and if it is found to be wrong, there is a plenteous choice of amendments ready in the mathematicians' stock of formulae. Some verbal statements have not this merit; they are so vague that they could hardly be wrong, and are correspondingly useless.

**Richardson, Lewis Fry (1881 - 1953)**

*Mathematics of War and Foreign Politics.*

# Goal: *quantitative* results

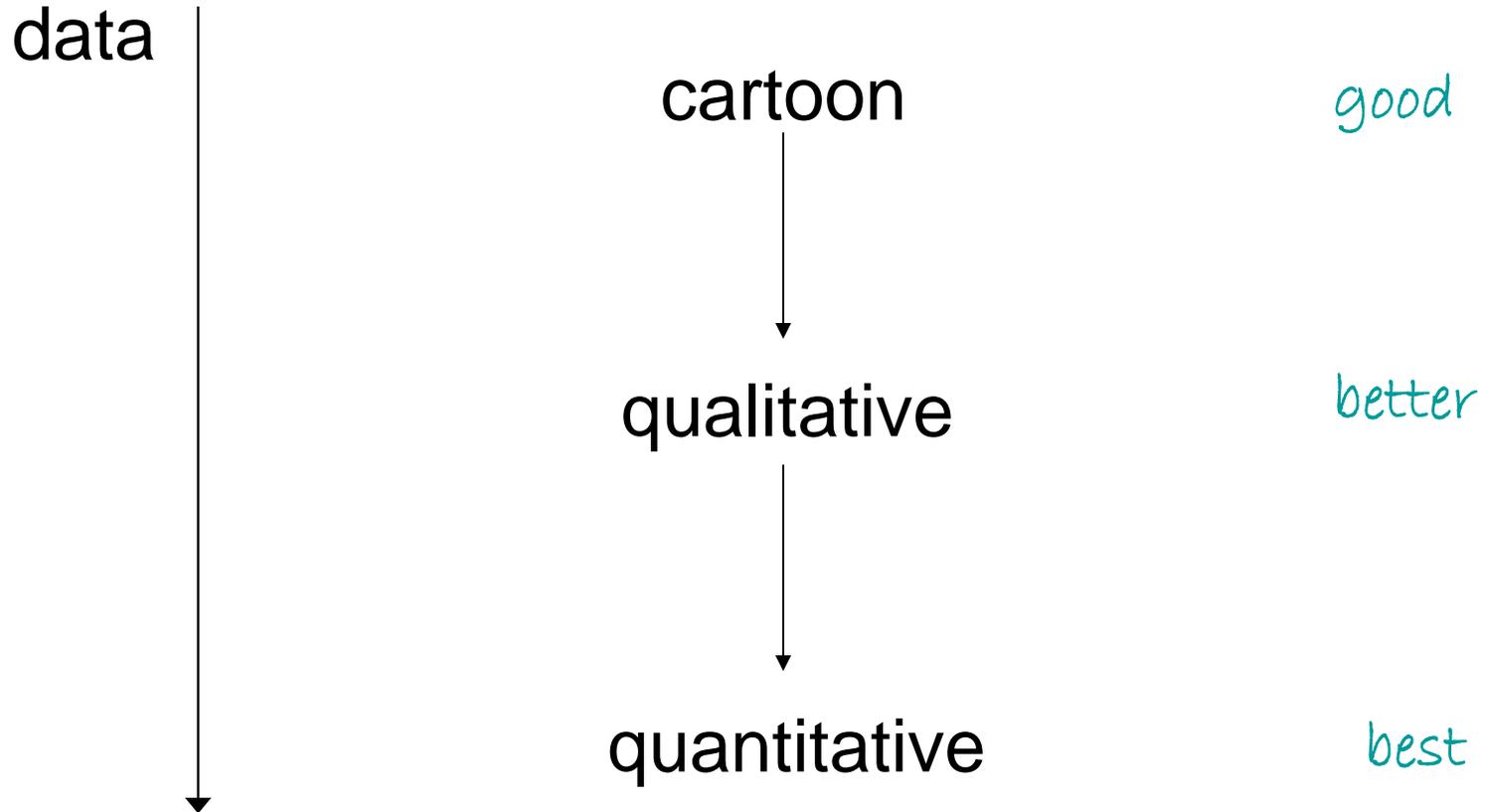
- start small but detailed: stoichiometry, reaction rates, trends, response times, scaling in laboratory and biological data analysis
- development of toy model
- quantitative prediction
- test quantitative prediction

qualitative data/model → quantitative data/model →  
better quantitative data/model → new qualitative insights

technical

cultural

# Data limited? A philosophy.



# Data limited? A philosophy.

data



cartoon



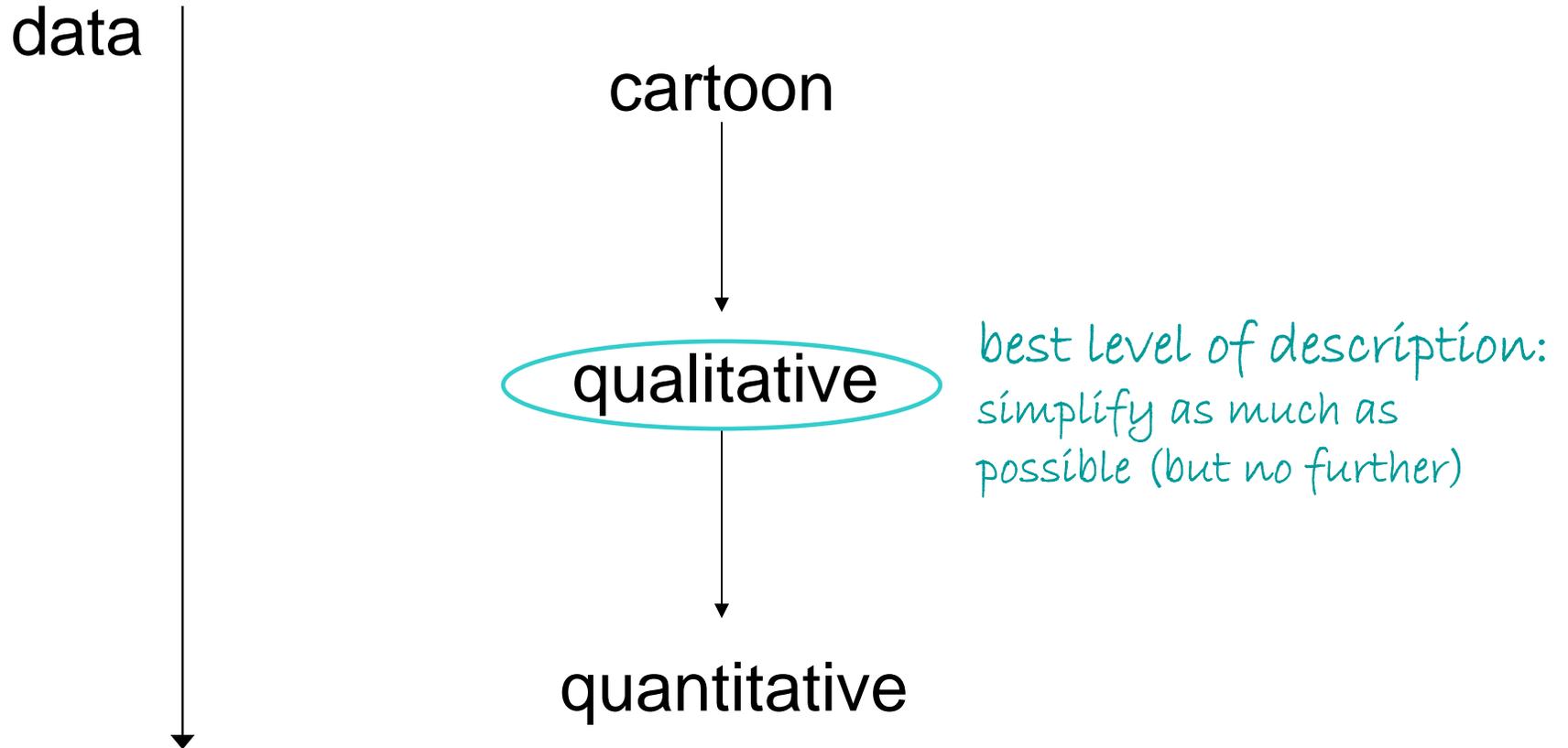
qualitative



quantitative

*best level of description:  
simplify as much as  
possible (but no further)*

# Data limited? A philosophy.



*w/o data limits, sacrificing detail can be important for generalization*

# Criteria for good research, publishing, review

- in absence of quantitative data or theory, qualitative predictions are good
- theoretical `speculation' is good if consistent, minimal, and based on principle
- incremental progress is good, being clearly wrong is good
- specialization is necessary: get away from immediate `high-impact-only' mentality
- adapt bureaucratic infrastructure to quantitative bio: 5-year detailed proposals; research paper structure



- basic toolbox (Mathematical methods course -- fourier transforms, diff eqs, linear algebra, info theory, ...): everybody, early
- units, order of magnitude estimates, probabilities - qualitative dynamics: feedback, wta, evolution, learning
- quantitative problems:
  - biology observation, data, lab
  - development of toy model
  - quantitative prediction
- emphasize examples where quantitative and qualitative results differ from expectations in cartoons
- show use of qualitative and quantitative results, and show that qualitative more valuable than cartoon or quantitative when only so much data exists (occam's razor)
- show that if possible quantitative model-> quantitative data-> qualitative insight; that quantitative is goal.