

Natural Computation

Natural computation is computation that occurs in nature or is inspired by computation occurring in nature

10/8/04

1

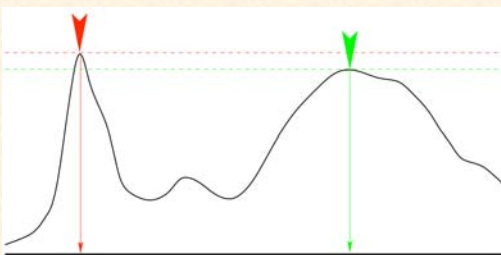
Optimization in Natural Computation

- Good, but suboptimal solutions may be preferable to optima if:
 - suboptima can be obtained more quickly
 - suboptima can be adapted more quickly
 - suboptima are more robust
 - an ill-defined suboptimum may be better than a sharp optimum
- “The best is often the enemy of the good”

10/8/04

2

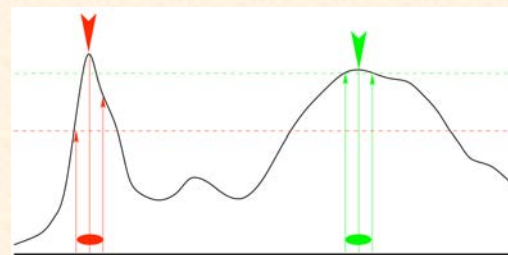
Robust Optima



10/8/04

3

Effect of Error/Noise



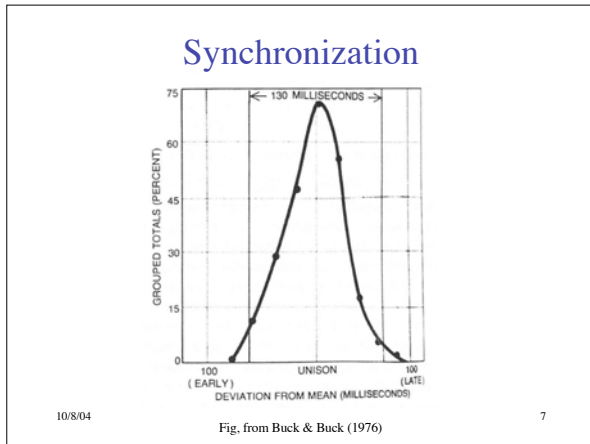
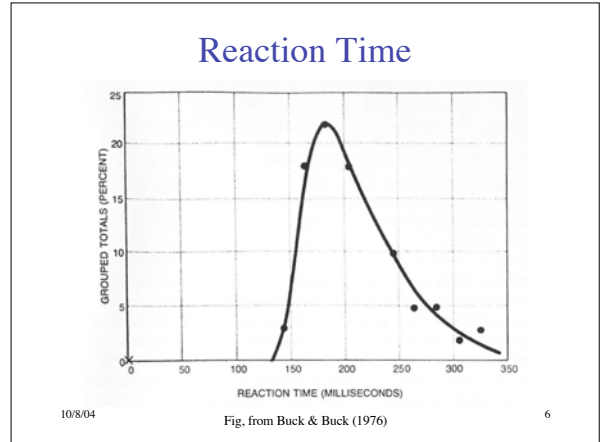
10/8/04

3C

4

Demonstration: Human Synchronization

10/8/04 5



Flashing Among Fireflies

10/8/04 8

Synchronous Flashing

- In only two places enormous numbers of fireflies gather in trees and flash in synchrony
 - SE Asia (India, Philippines, New Guinea)
 - Elkmont in the Smoky Mountains!
- A group of trees spread over 1/10 mile may flash in synchrony
- Only males do synchronous flashing
- Had been unexplained for 300 years
- Early 1900s: claimed to be an illusion because no explanation could be imagined

10/8/04

9

Why Do They Do It?

- Females identify males of their own species by flashing rate
 - difficult to do if they flash chaotically
- Allows males to detect (unsynchronized flashing of nearby females)
 - i.e., enhanced detection
- Allows small groups of males to attract larger numbers of females
 - i.e., signal enhancement

10/8/04

10

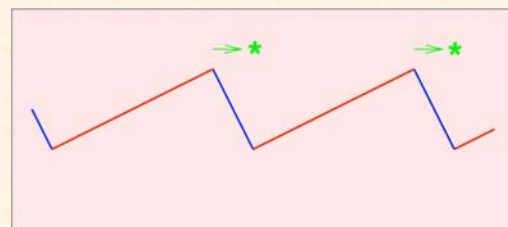
How Do They Do It?

- “innate individual rhythmicity with phase-dependent sensitivity to mutual influences”
- Natural flashing period: 965 ± 90 msec (≈ 1 sec)
- Flash from firefly *A* will reset the clock of nearby firefly *B*
 - thereby shifting the *phase* of *B*'s clock
- If *A* flashes in first 840 ms of *B*'s cycle, will inhibit *B*'s next flash & delay until 1 sec after stimulus (i.e. retarded so it is in sync with *A*)
- If *A* flashes in last 160 ms, *B*'s next flash occurs normally, but subsequent flash will be advanced to be in sync with *A*

10/8/04

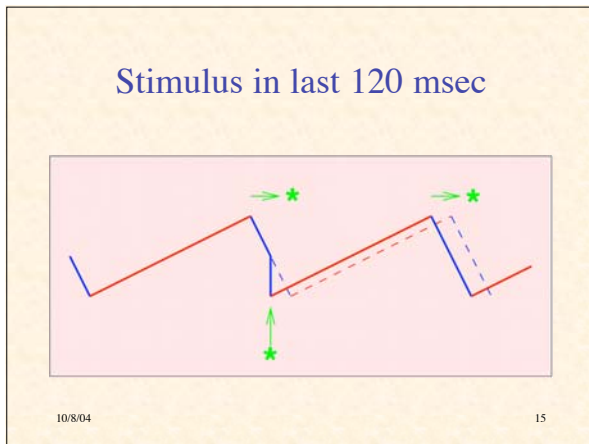
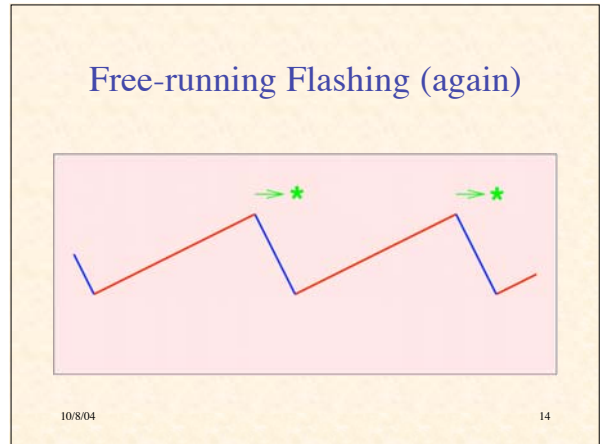
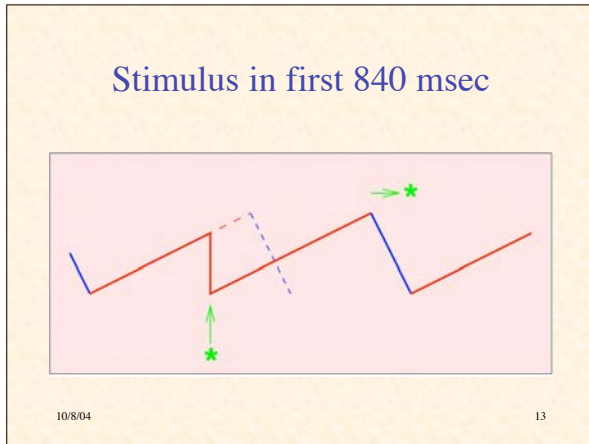
11

Free-running Flashing



10/8/04


12



Starlogo Simulation of Firefly Synchronization

[Run firefly.slogo Simulation](#)

10/8/04 16



Schools, Flocks, & Herds

“and the thousands of fishes moved as a huge beast, piercing the water. They appeared united, inexorably bound to a common fate. How comes this unity?”

— anon., 17th cent.

10/8/04 images from EValife site 17

Coordinated Collective Movement

- Groups of animals can behave almost like a single organism
- Can execute swift maneuvers
 - for predation or to avoid predation
- Individuals rarely collide, even in frenzy of attack or escape
- Shape is characteristic of species, but flexible

10/8/04 18

Adaptive Significance

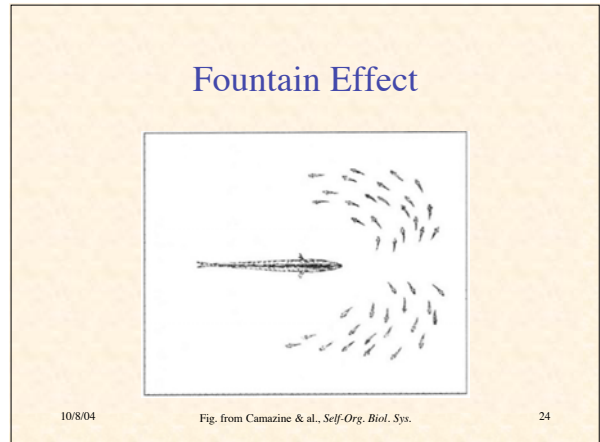
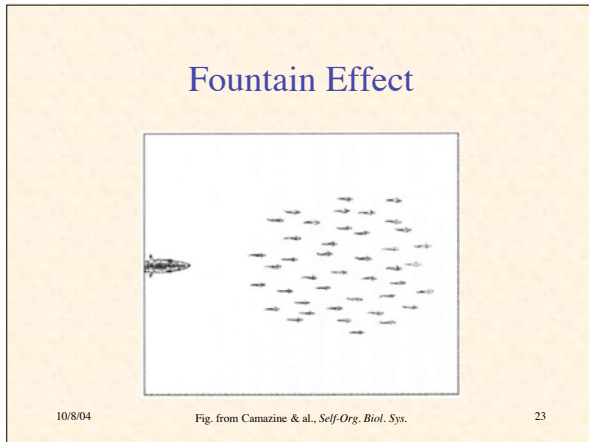
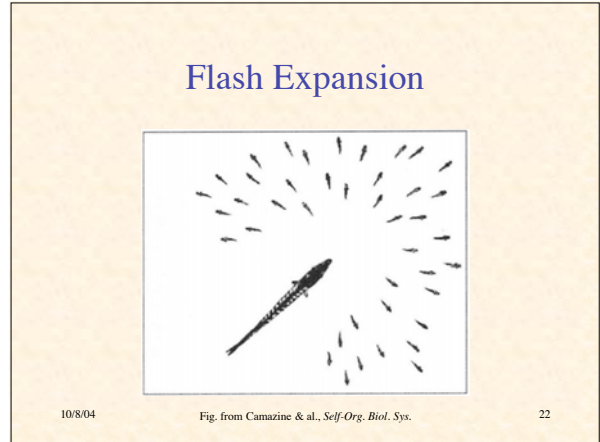
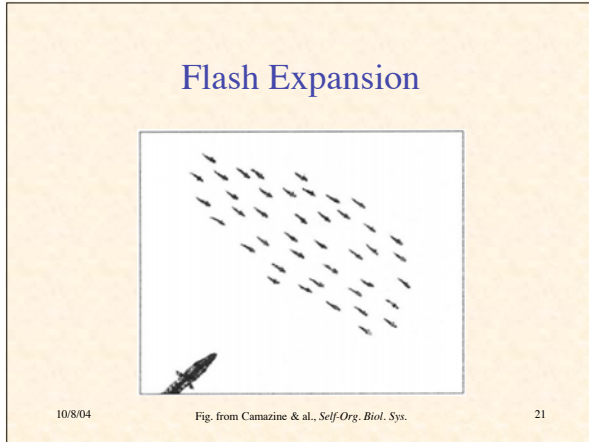
- Prey avoiding predation
- More efficient predation by predators
- Other efficiencies

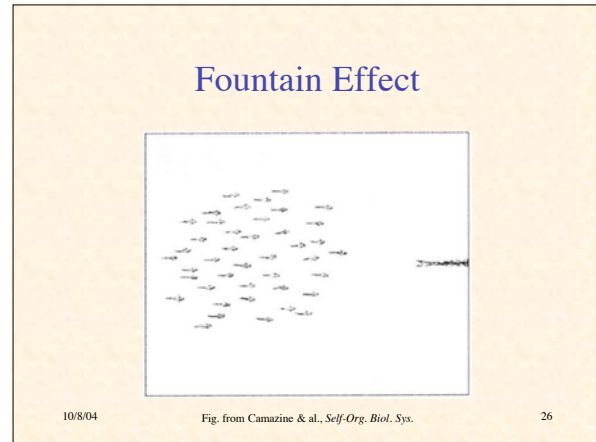
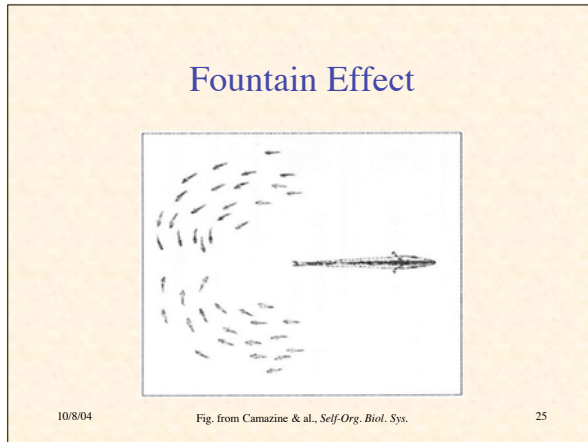
10/8/04 19

Avoiding Predation

- More compact aggregation
 - predator risks injury by attacking
- Confusing predator by:
 - united erratic maneuvers (e.g. zigzagging)
 - separation into subgroups (e.g., flash expansion & fountain effect)

10/8/04 20





Better Predation

- Coordinated movements to trap prey
 - e.g. parabolic formation of tuna
- More efficient predation
 - e.g., killer whales encircle dolphins
 - take turns eating

10/8/04 27

Other Efficiencies

- Fish schooling may increase hydrodynamic efficiency
 - endurance may be increased up to 6x
 - school acts like “group-level vehicle”
- V-formation increases efficiency of geese
 - range 70% greater than that of individual
- Lobsters line up single file by touch
 - move 40% faster than when isolated
 - decreased hydrodynamic drag

10/8/04 28

Characteristic Arrangement of School

- Shape is characteristic of species
- Fish have preferred distance, elevation & bearing relative to neighbors
- Fish avoid coming within a certain minimum distance
 - closer in larger schools
 - closer in faster moving schools

10/8/04

29