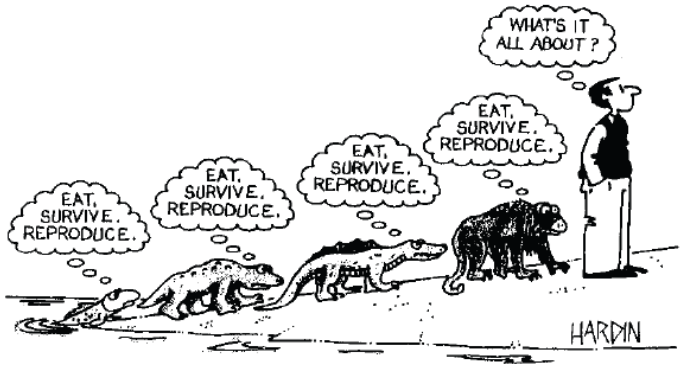
The Abdus Salam
International Centre for Theoretical Physics

IAEA

Advanced School on Complexity, Adaptation and Emergence in Marine Ecosystems

Concluding perspectives



Proprioception: Is the sensory system that supports body posture and movement also the root of our understanding of physical laws?

The body and vestibular organs as our major sense organs.

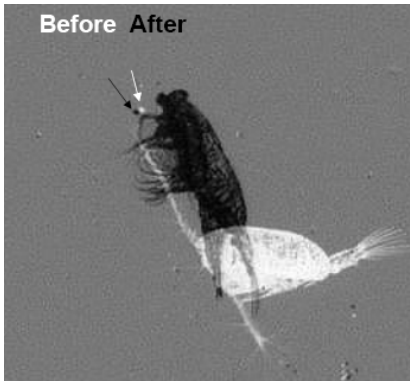
Making sense

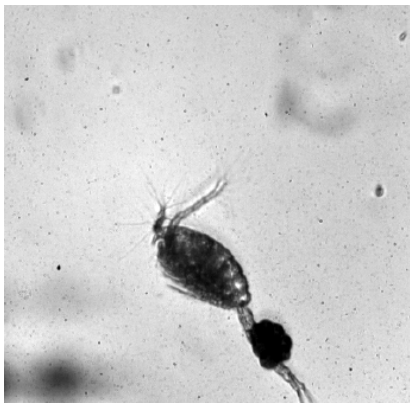
Proprioception: is the sensory system that supports body posture and movement also the root of our understanding of physical laws?

Victor Smetacek and Franz Mechsner

Aristotle argued that human beings have five senses at their disposal. Although various other sense organs have come to light since then, this antique dogma still constrains popular imagination. The term 'sixth sense' resonates with instinct and metaphysics, implying that although the five 'regular' senses represent reality adequately, there is something else lurking in the subconscious. The search for the sensory system with which the blind guide their movements revealed that the body's sense of posture and movement relies on different

writing, skiing or driving. Learning a skill implies developing new patterns of movement by screening, coordinating and calibrating relevant information from the orchestra of signals supplied to the neocortex by the trinity of sensory systems. New neural programmes are encrypted, memorised by repetition and transferred to the more fundamental regions of the brain, from wherethey are run with less





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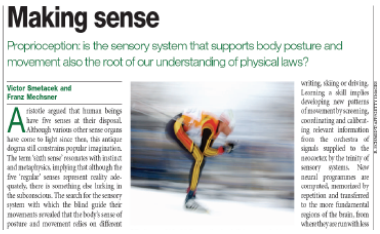

Making sense

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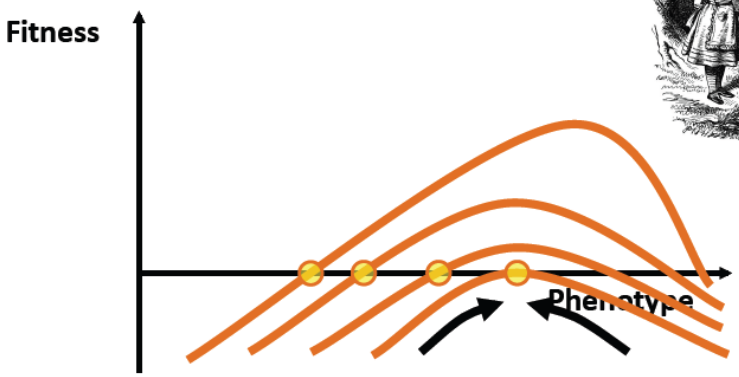
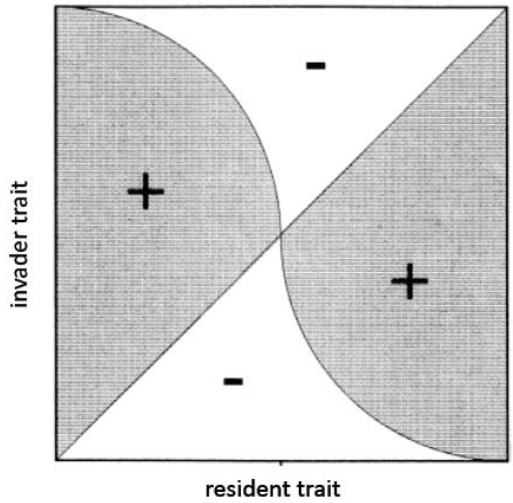
Game theory

Fitness in a population



"It takes all the running you can do, to keep in the same place"
The Red Queen – Alice in Wonderland

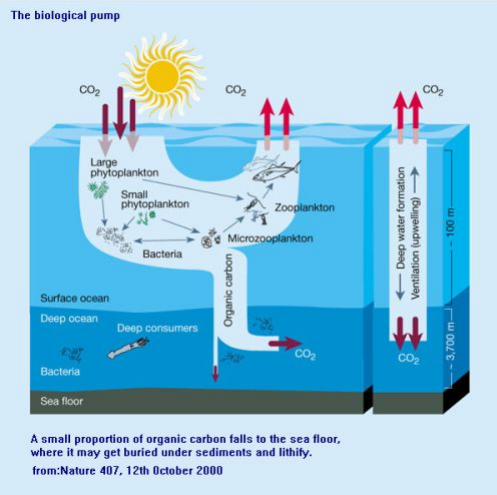
Evolutionary Stable Strategies



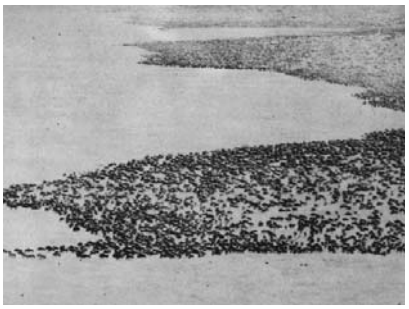
(Geritz et al. 1998, Evol. Ecol)

Megafauna shape the environment

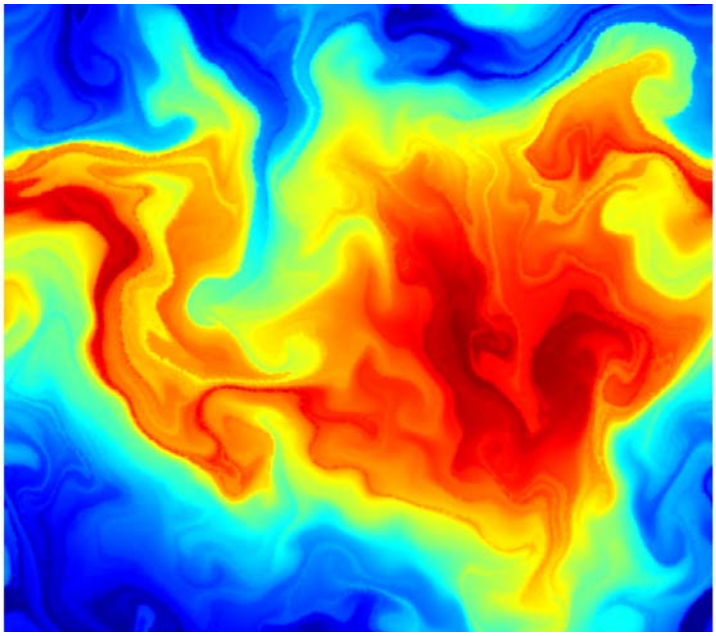
Megafauna shape the environment

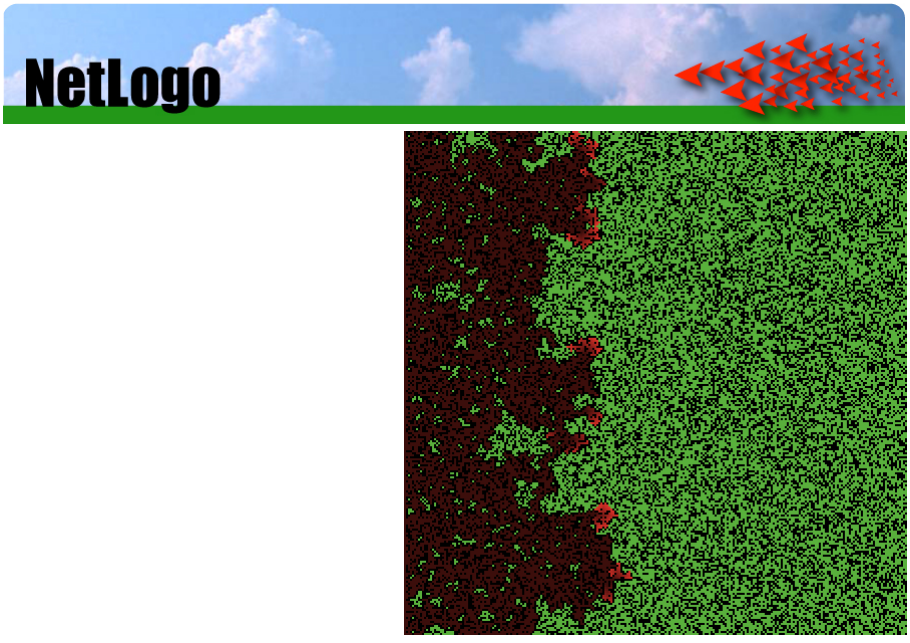


Herds, flocks, schools and ants

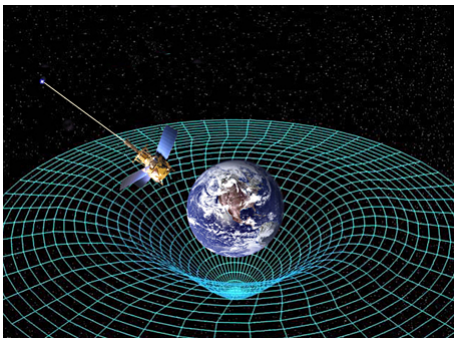


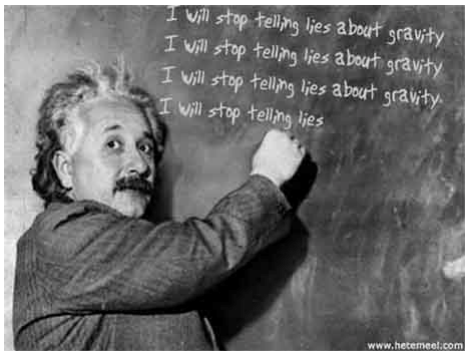
Patchiness

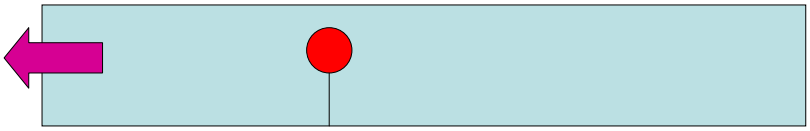




Going off the deep end?

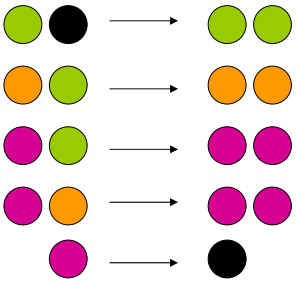


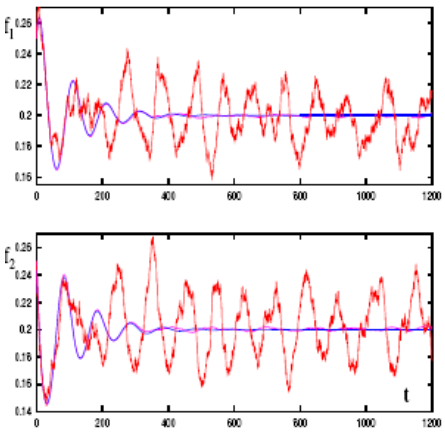




The boy, the balloon and the accelerating aeroplane

Stochastic processes





Complex patterns emerge from simple rules

letters to nature

Nature **381**, 413 - 415 (30 May 1996); doi:10.1038/381413a0

Lévy flight search patterns of wandering albatrosses

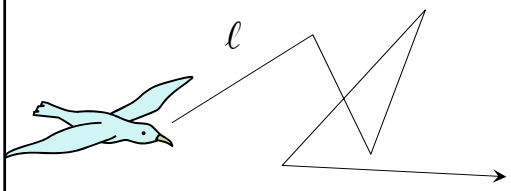
G. M. Viswanathan*, V. Afanasyev†, S. V. Buldyrev*, E. J. Murphy†, P. A. Prince† & H. E. Stanley*

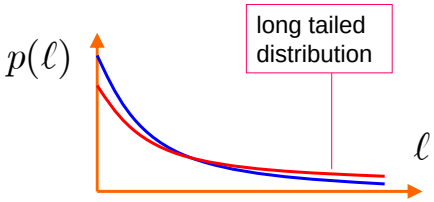
Measure the time distribution of foraging events

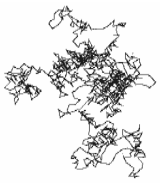
many short intervals interspersed with episodic long intervals

Lèvy walk

What is a Lèvy walk?





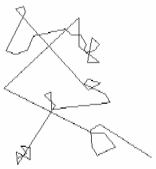


$p(\ell) \sim \ell^{-\mu}$

$\mu \geq 3$, Brownian – random walk

$1 < \mu < 3$, Levy walk

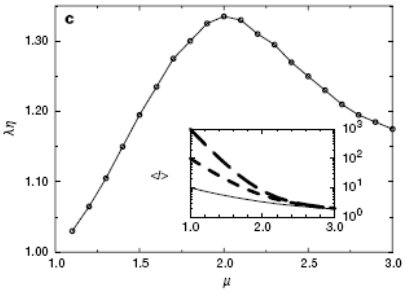
$\mu = 1$, ballistic – straight line motion



letters to nature

Optimizing the success of random searches

G. M. Viswanathan*†‡, Sergey V. Buldyrev*, Shlomo Havlin*§, M. G. E. da Luz‖¶, E. P. Raposo‖# & H. Eugene Stanley*



Theoretical analysis and numerical models ⇒

$\mu = 2$

gives the most efficient search strategy[1]

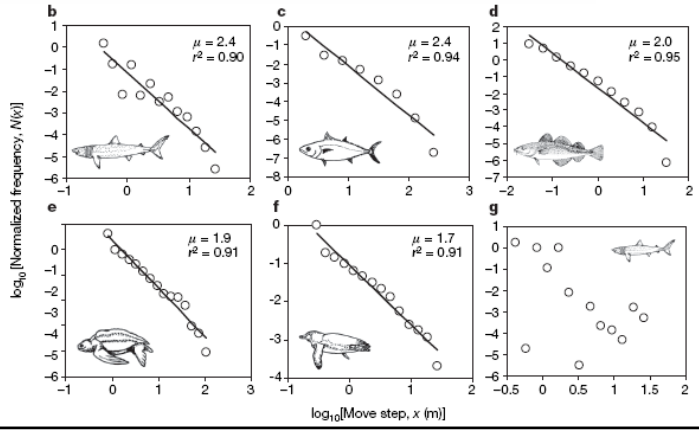
[1](under certain conditions)

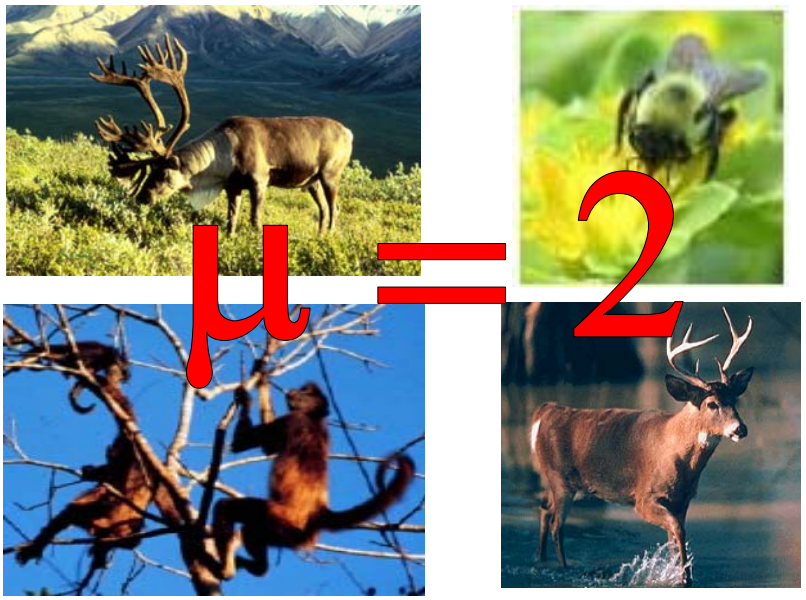
nature Vol 451|28 February 2008|doi:10.1038/nature06518

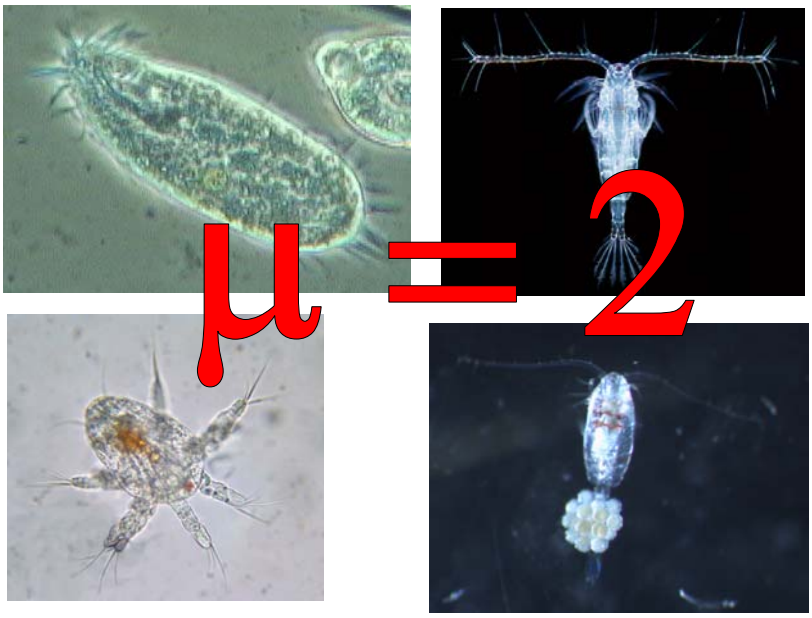
LETTERS

Scaling laws of marine predator search behaviour

David W. Sims[1,2], Emily J. Southall[1], Nicolas E. Humphries[1], Graeme C. Hays[4], Corey J. A. Bradshaw[5†], Jonathan W. Pitchford[6], Alex James[6,7], Mohammed Z. Ahmed[3], Andrew S. Brierley[8], Mark A. Hindell[9], David Morritt[10], Michael K. Musyl[11], David Righton[12], Emily L. C. Shepard[4], Victoria J. Wearmouth[1], Rory P. Wilson[4], Matthew J. Witt[13] & Julian D. Metcalfe[12]






μ = 2


G. hybrid
Tracks:
- ACTIVE LOG 124
- ACTIVE LOG 125
- ACTIVE LOG 126
- ACTIVE LOG 127
- ACTIVE LOG 128
- ACTIVE LOG 129
- ACTIVE LOG 130
- ACTIVE LOG 131
- ACTIVE LOG 132
- ACTIVE LOG 133
- ACTIVE LOG 134
- ACTIVE LOG 135
- ACTIVE LOG 136
- ACTIVE LOG 137
- ACTIVE LOG 138
- ACTIVE LOG 139
Center: 28.35885,-81.59078
Map created by GPSVisualizer.com

… but then

cracks started to appear

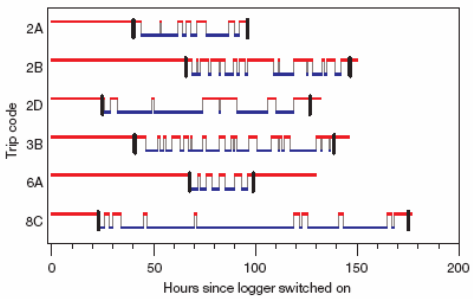
…

nature Vol 449|25 October 2007|doi:10.1038/nature06199

LETTERS

Revisiting Lévy flight search patterns of wandering albatrosses, bumblebees and deer

Andrew M. Edwards[1]†, Richard A. Phillips[1], Nicholas W. Watkins[1], Mervyn P. Freeman[1], Eugene J. Murphy[1], Vsevolod Afanasyev[1], Sergey V. Buldyrev[2,3], M. G. E. da Luz[4], E. P. Raposo[5], H. Eugene Stanley[2] & Gandhimohan M. Viswanathan[6]



... and the certain conditions

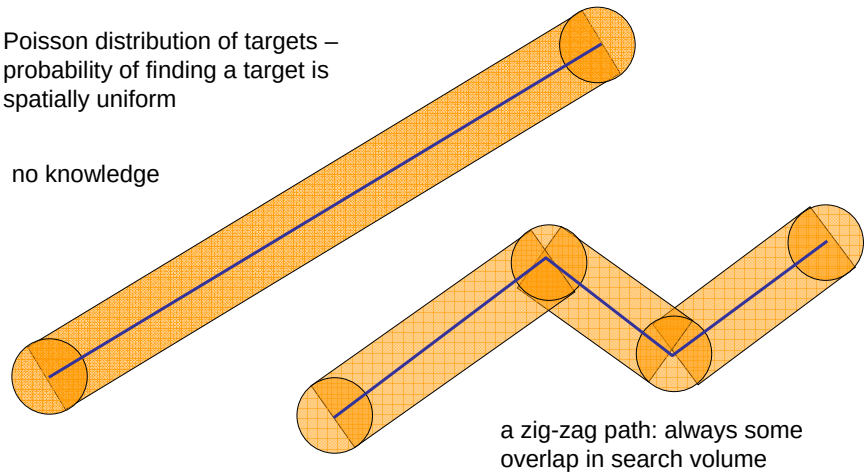
$\mu = 2$ gives the most efficient search strategy for a nondestructive search!!

that is ...
forager can revisit the same target time after time

?

Poisson distribution of targets – probability of finding a target is spatially uniform

no knowledge



a zig-zag path: always some overlap in search volume irrespective of turning statistics

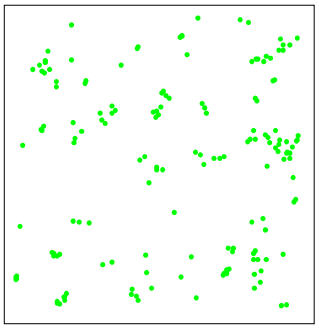
In a uniformly random target field, the optimal search strategy is go in a straight line – i.e. ballistically.

Patchiness ?

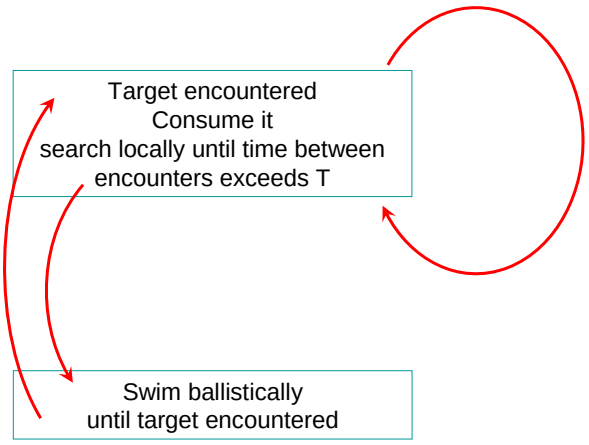
Target distributions are clumpy

1. if forager has just found a target, there is a high likelihood of another one being close by
   - **– concentrated search.**
2. if forager has not found a target recently, it is not likely there is one close by
   - **– don't waste time searching (go ballistic).**

this gives some rudimentary knowledge of the prey distribution

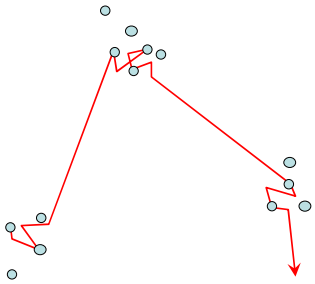


A simple behavioural algorithm

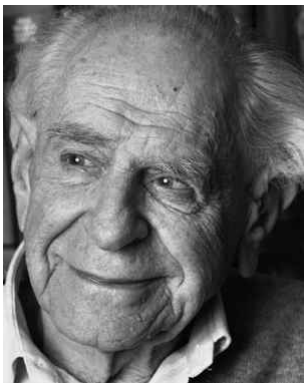


A simple behavioural algorithm

This behavioural algorithm will produce a pattern of movements that looks like a Lèvy walk, even though the behaviour itself has no Lèvy component



Observed Lèvy search patterns are more likely to be the **imprint** of a **patchy distribution** of targets than determined by an inherent (*i.e*. evolutionarily determined) behavioural algorithm.

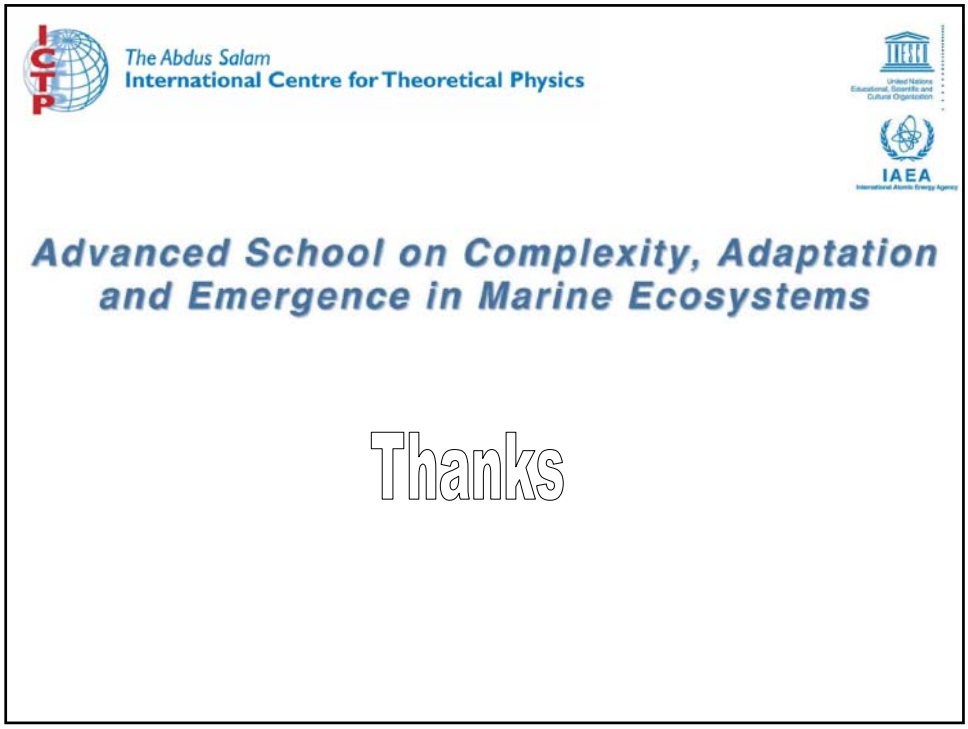


Karl Popper (1902 – 1994)

$$\mu = 2$$

"If we are uncritical we shall always find what we want: we shall look for, and find, confirmations, and we shall look away from, and not see, whatever might be dangerous to our pet theories."

The Poverty of Historicism (1957)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Thanks