Acknowledgements

Karen

Katarina

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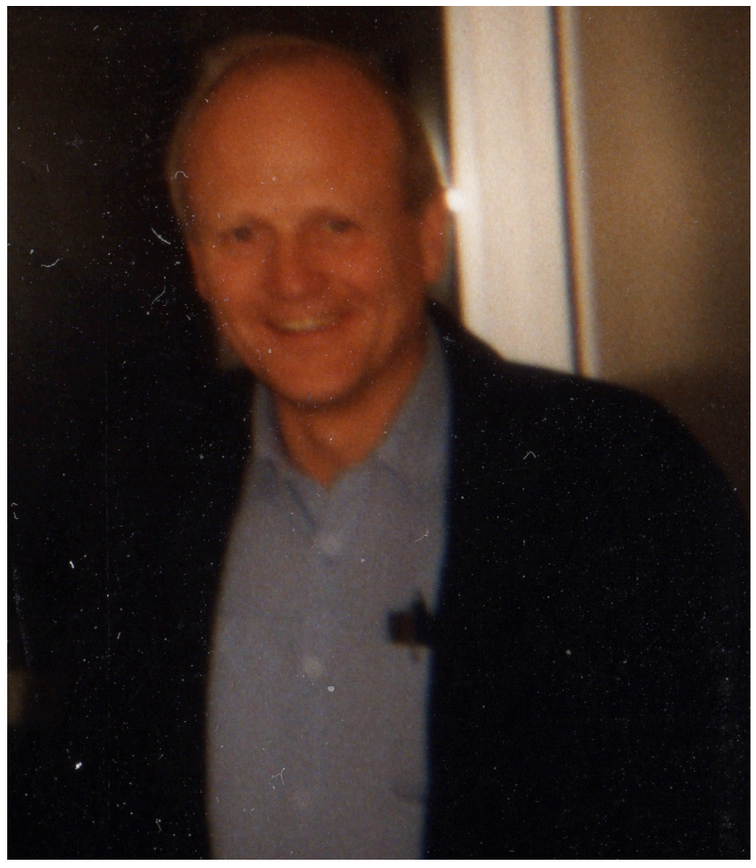
Prof. Frank Moss

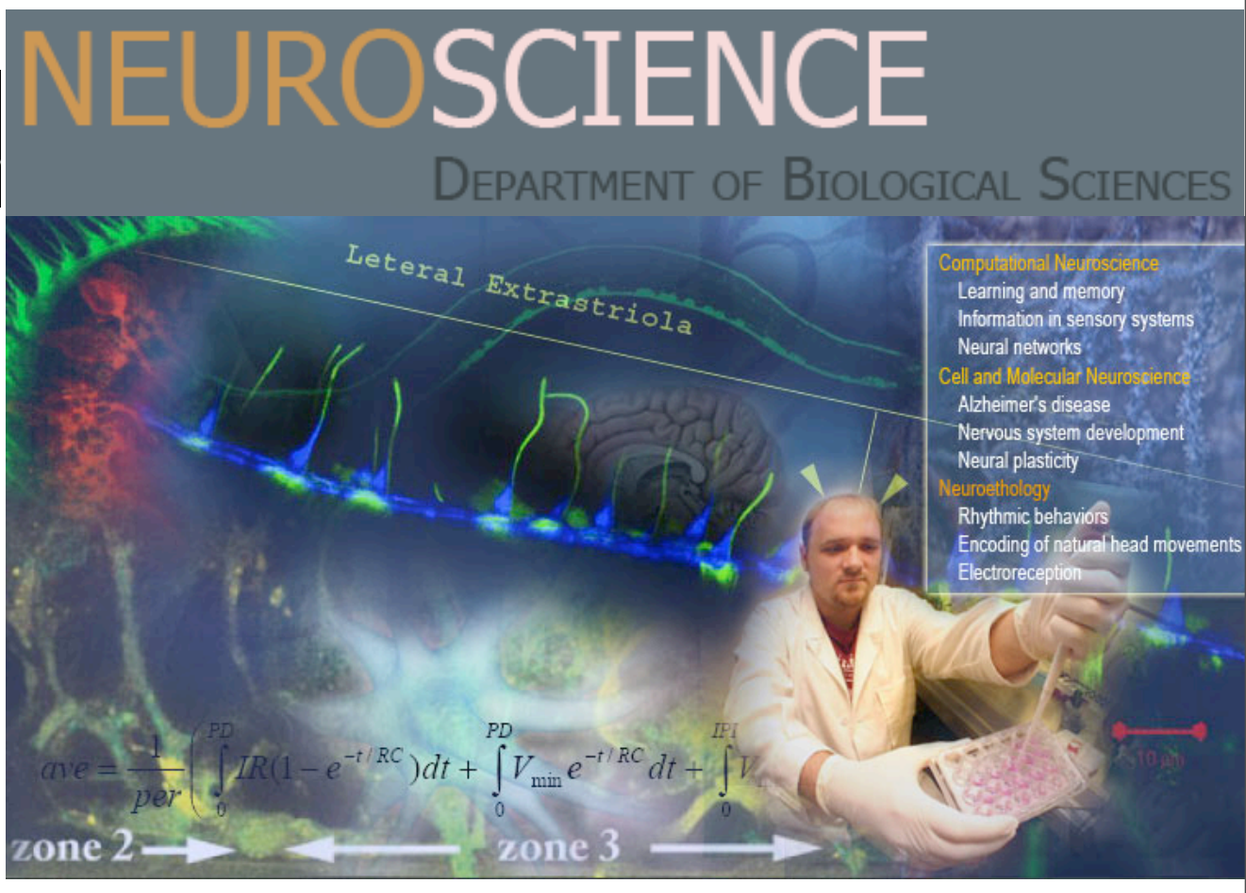


Prof. Hannes Risken

Prof. Peter Hänggi

Acknowledgements

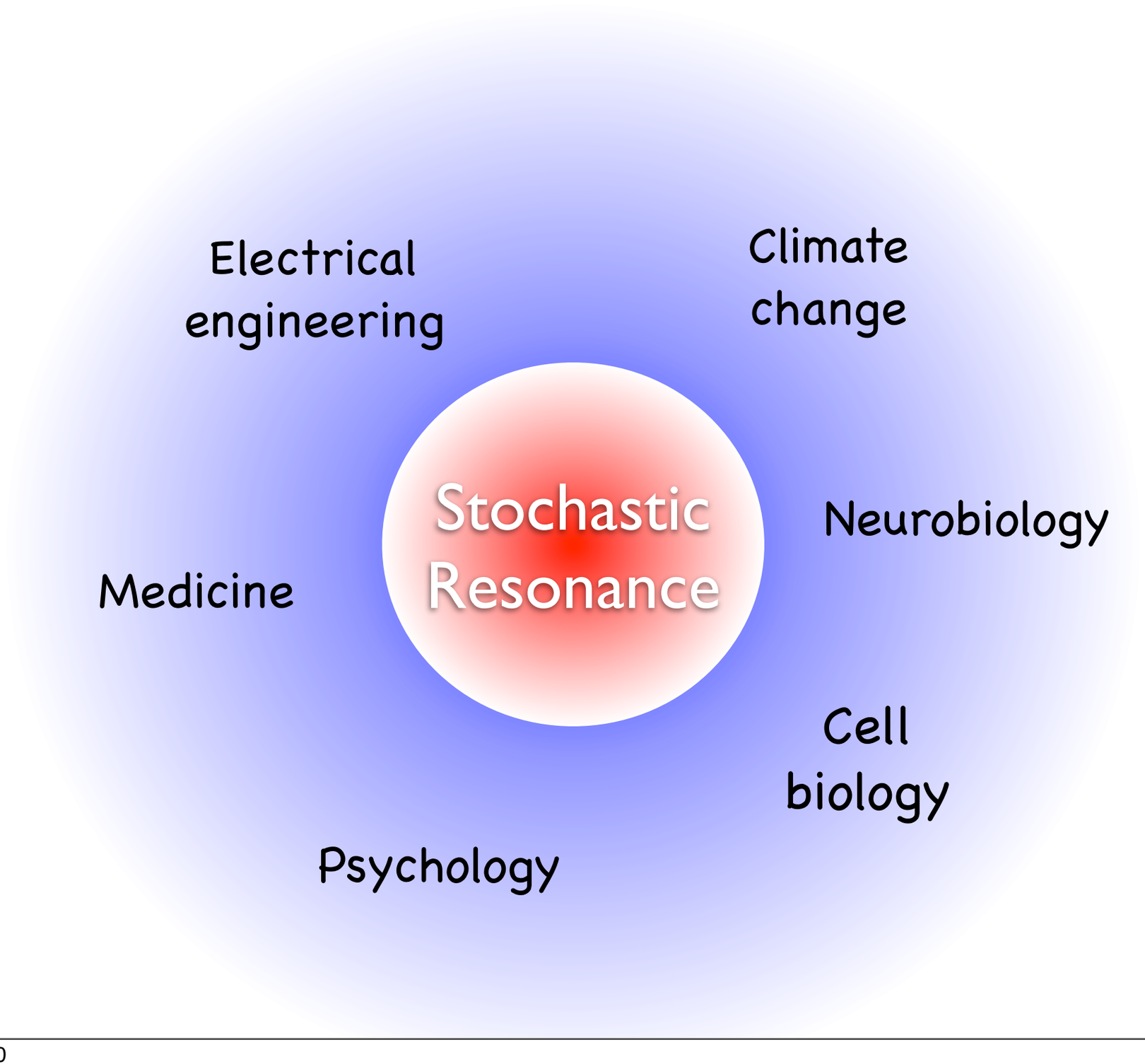
OHIO UNIVERSITY



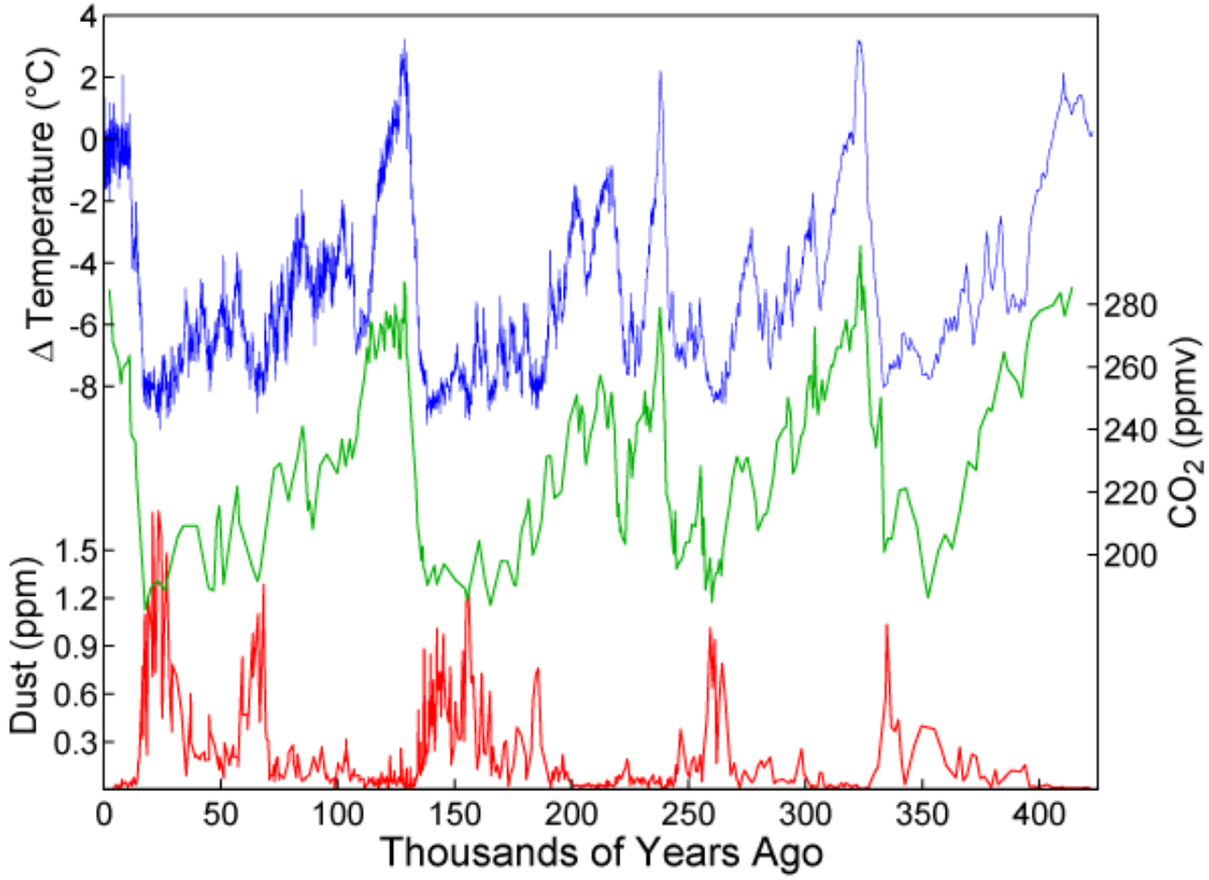
Ohio's only!

Stochastic Resonance:

The evolution of a scientific paradigm

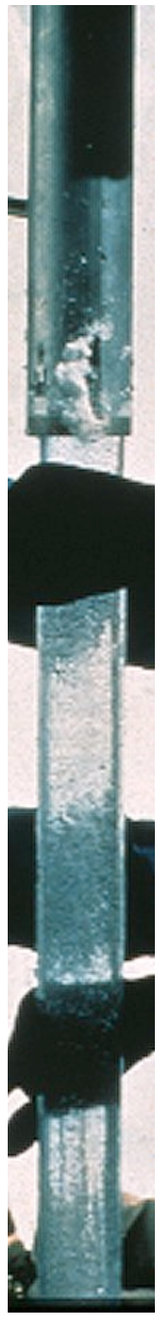


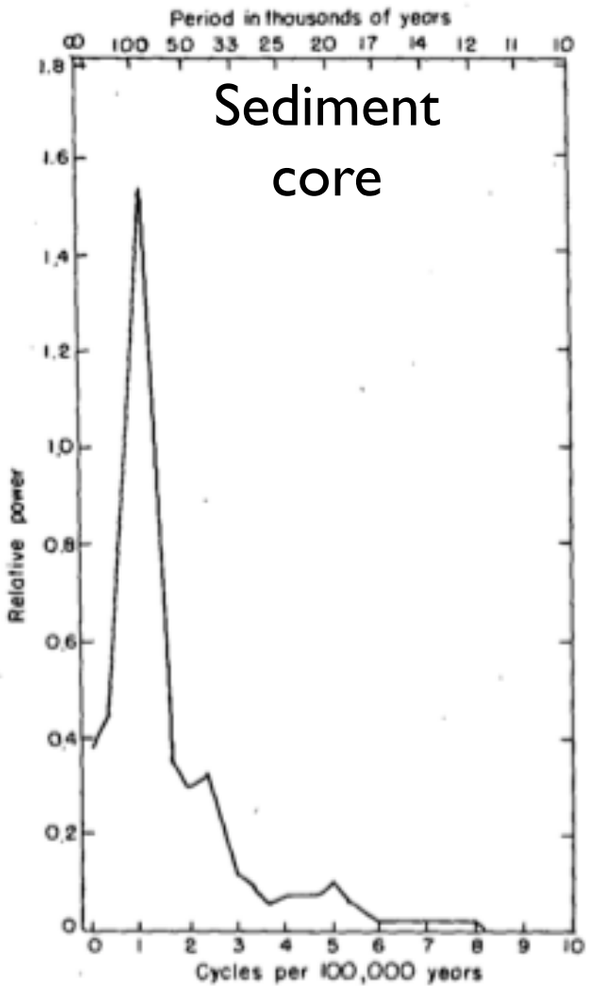
Climate change



Vostoc (antarctica) ice-core

NOAA National Oceanic and Atmospheric Administration



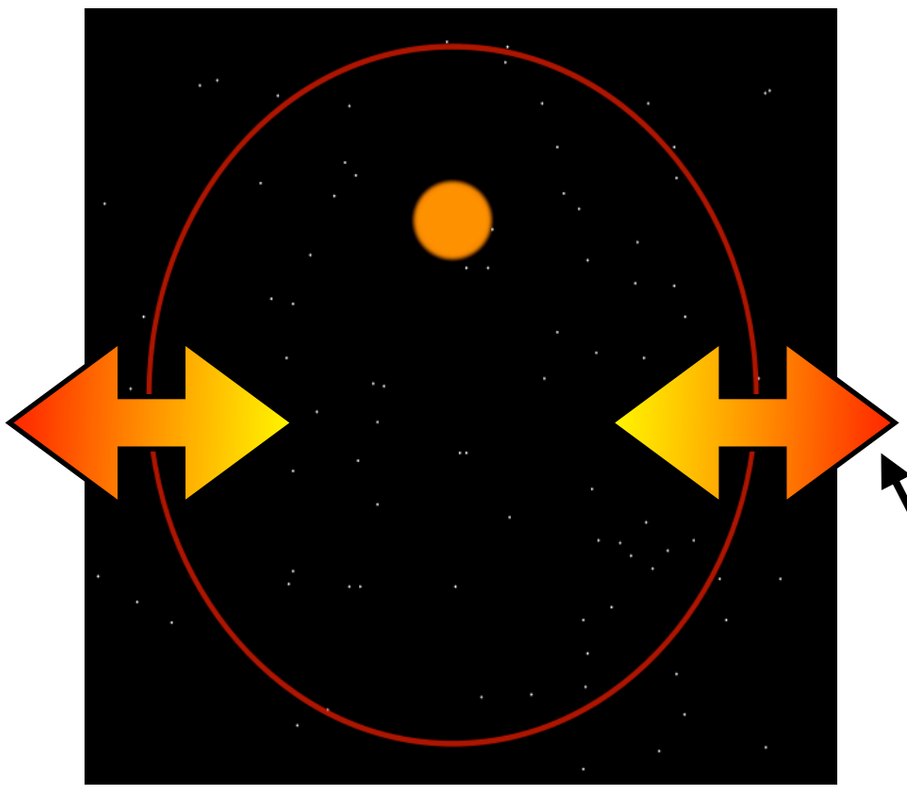


B.J. Mason, Quart. J. Roy. Meteor. Soc., 102 (1976)

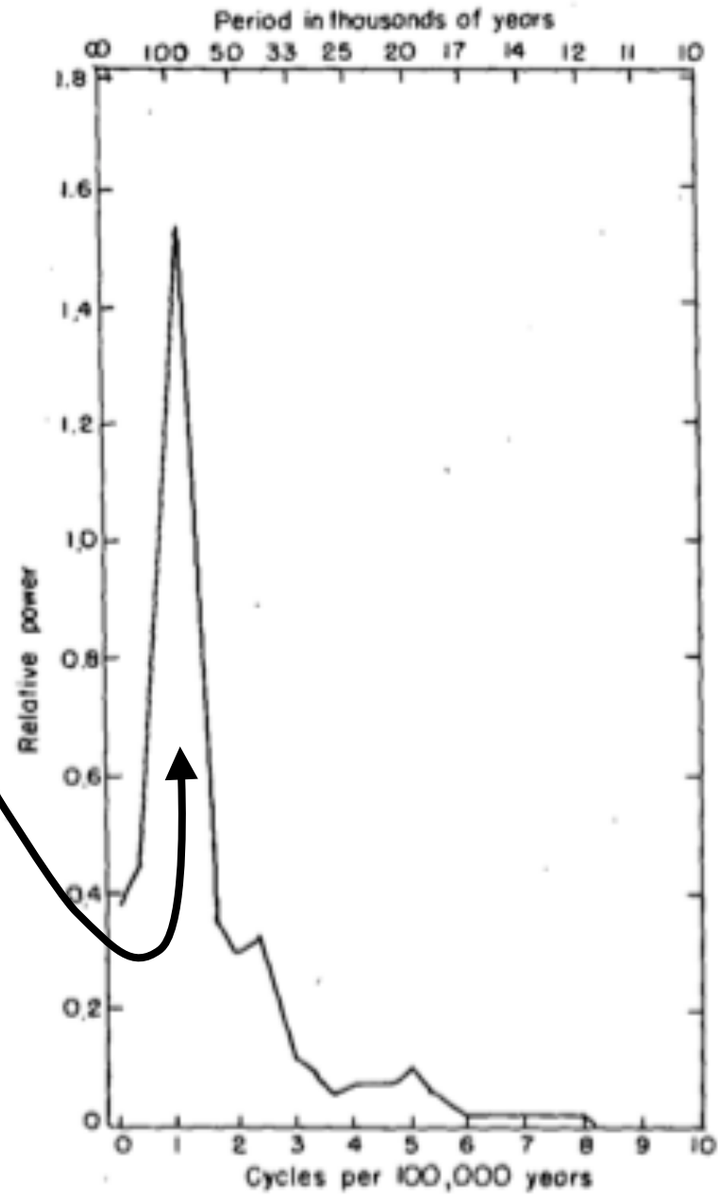
Why are the ice-ages so periodic ?

Milankowitch cycles:

Small changes in earth orbit eccentricity with 100k year periodicity



M. Milankowitch, Handbuch der Klimatologie I (1930)

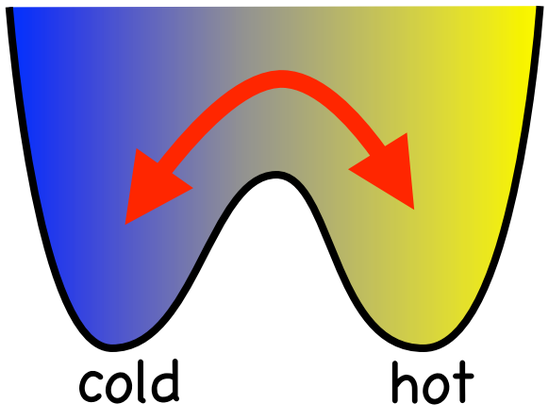


Changes are small! (<0.1% of solar constant)

What can amplify those small changes ?

Bistable Climate

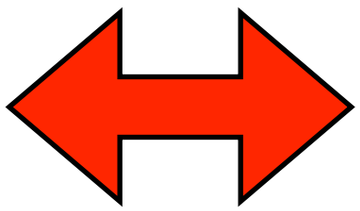
Budyko and Sellers (1969)



Ice

rock

cold --> ice
Most of the radiation reflected
ice does not melt



warm --> soil, rock
More radiation absorbed

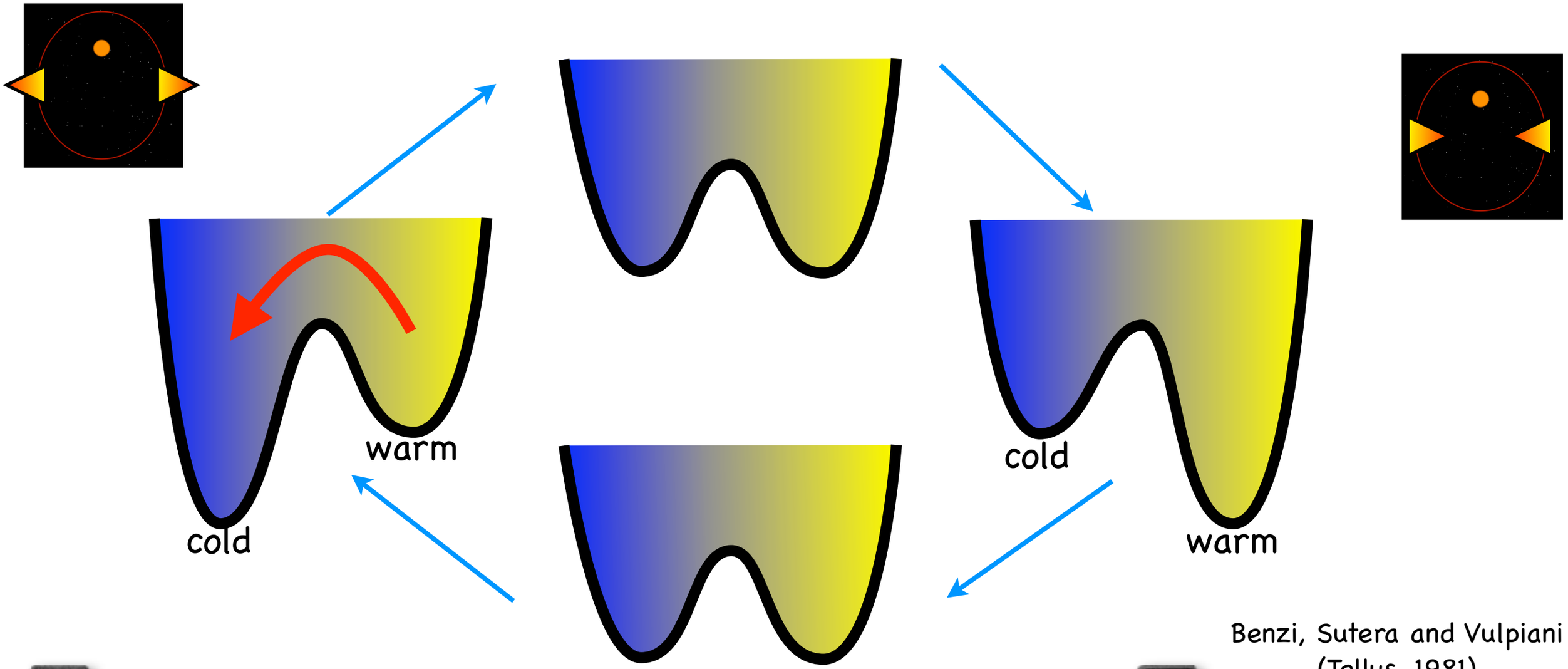
Extreme climatic events

cold reinforces cold !!

warm reinforces warm !!

Milankowitch Cycles and Bistability

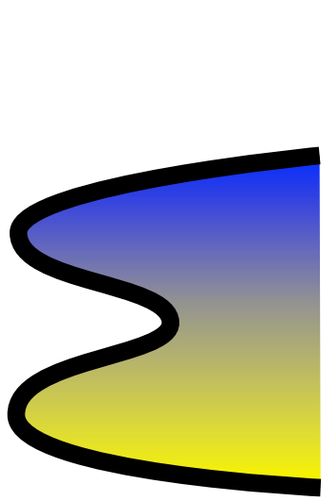
Climate "landscape"



- The 100ky cycles only bias the climate
- Fluctuations make climate switch
- small changes of conditions can have huge impact

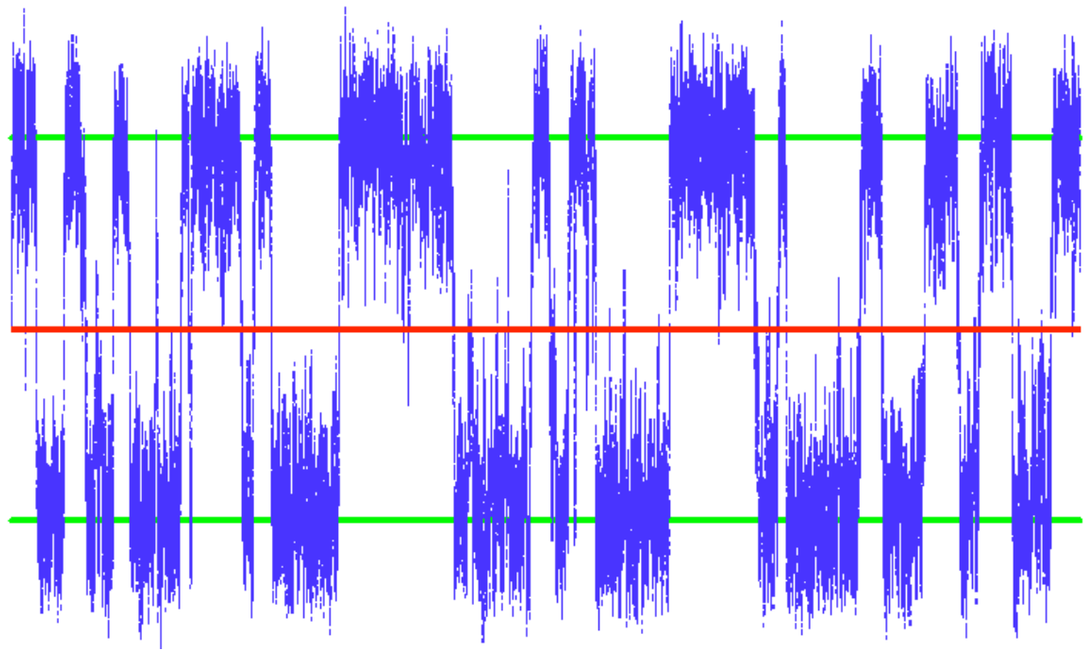
Benzi, Sutera and Vulpiani
(Tellus, 1981)
C. Nicolis and G. Nicoli
(Tellus, 1981)

A computer simulation

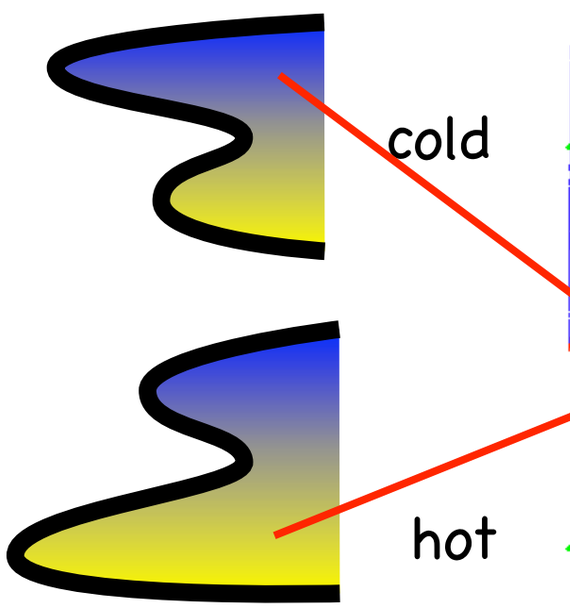


cold

hot

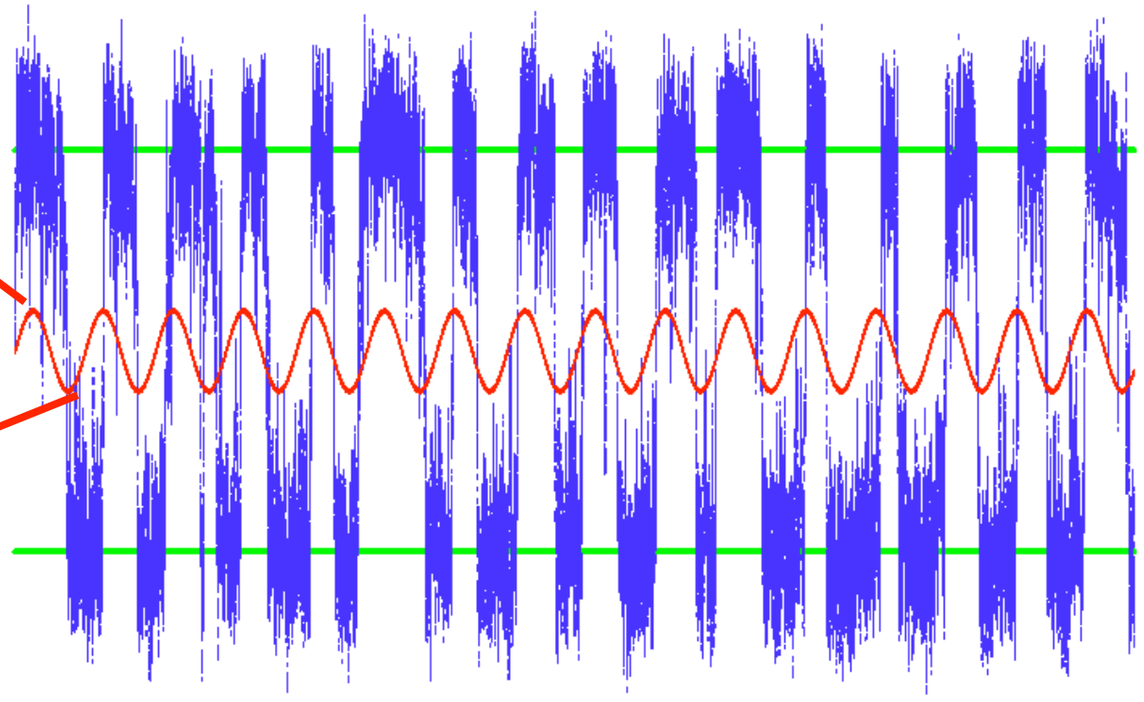


eccentricity
(no variations)



cold

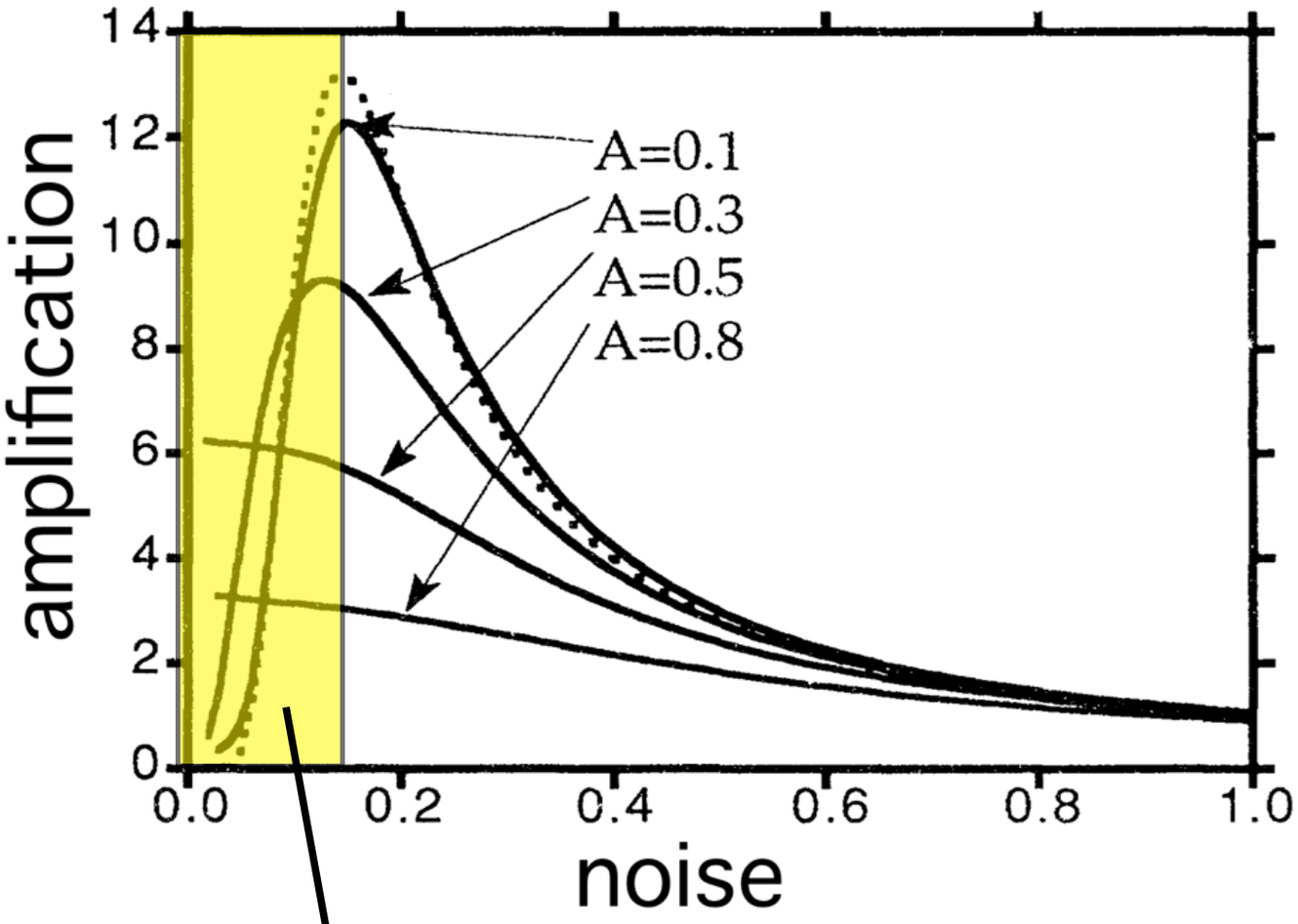
hot



eccentricity

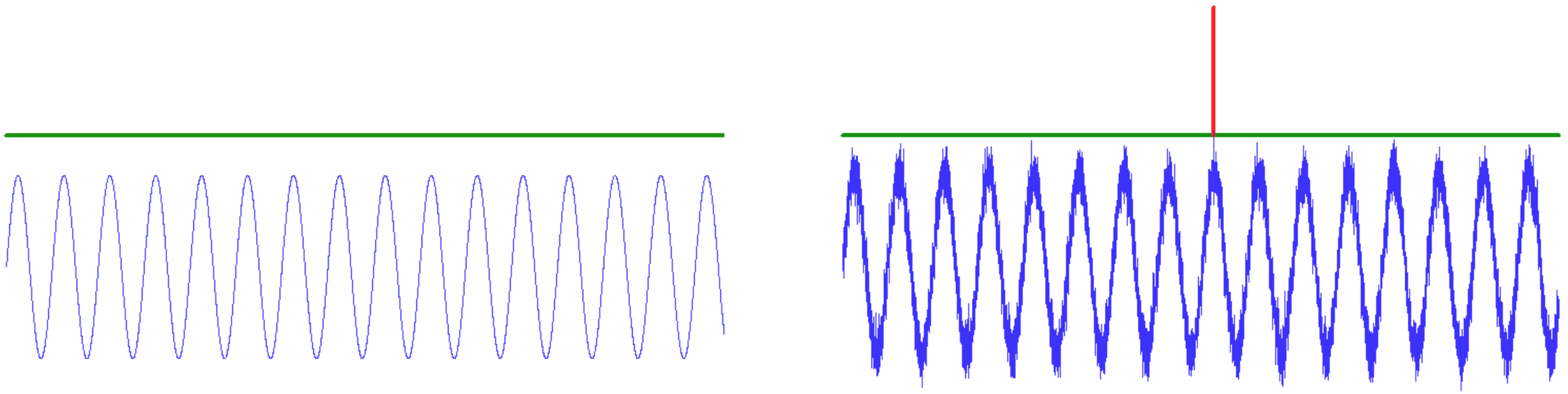
Amplification of small signals by noise

(P. Jung, P. Hänggi, Phys. Rev. A **44**, 8032 (1991))



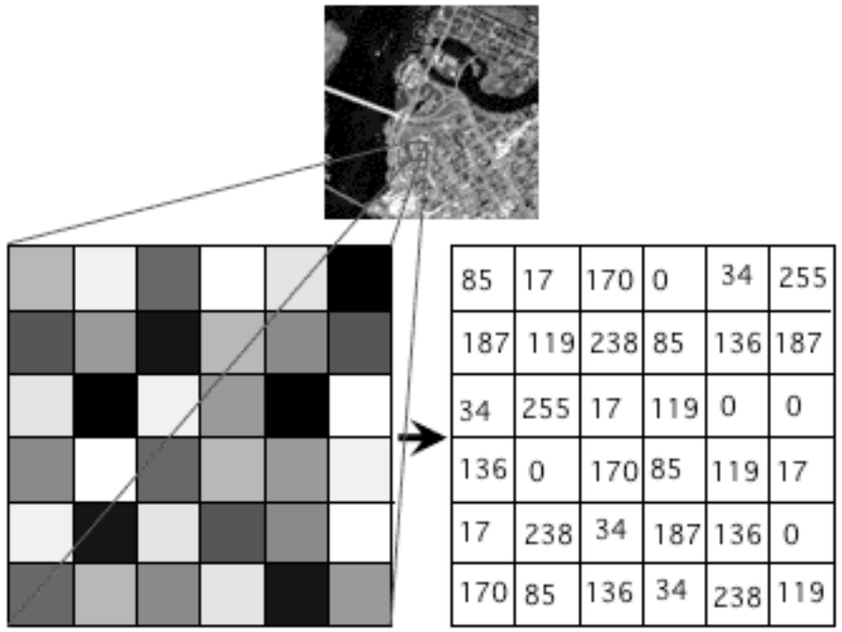
More noise , more signal !!

Thresholds and Stochastic Resonance



P. Jung, Phys. Rev. E50, 2513 (1994), F. Moss and L. Kiss, EPL, 29 (1995)

Visual Demonstration



85	17	170	0	34	255
187	119	238	85	136	187
34	255	17	119	0	0
136	0	170	85	119	17
17	238	34	187	136	0
170	85	136	34	238	119

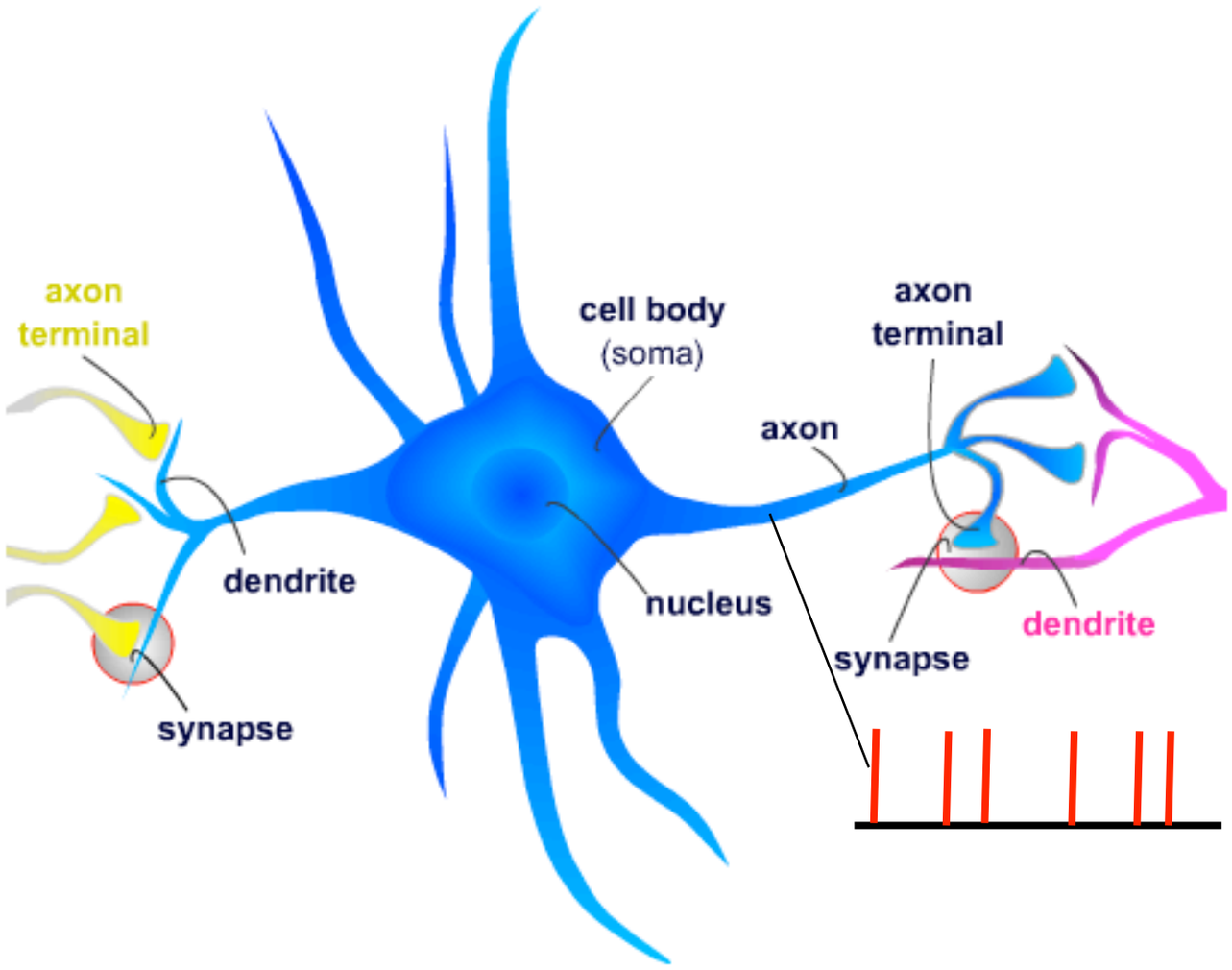
Threshold filter: Show only pixels with a grayscale above threshold

Add noise: Each pixel is added noise

noise →

Simmonotto et al. Phys. Rev. Lett. 78, 1186 (1997)

Stochastic Resonance in Neurobiology



source: Consortium on Cognitive Science Instruction (CCSI)

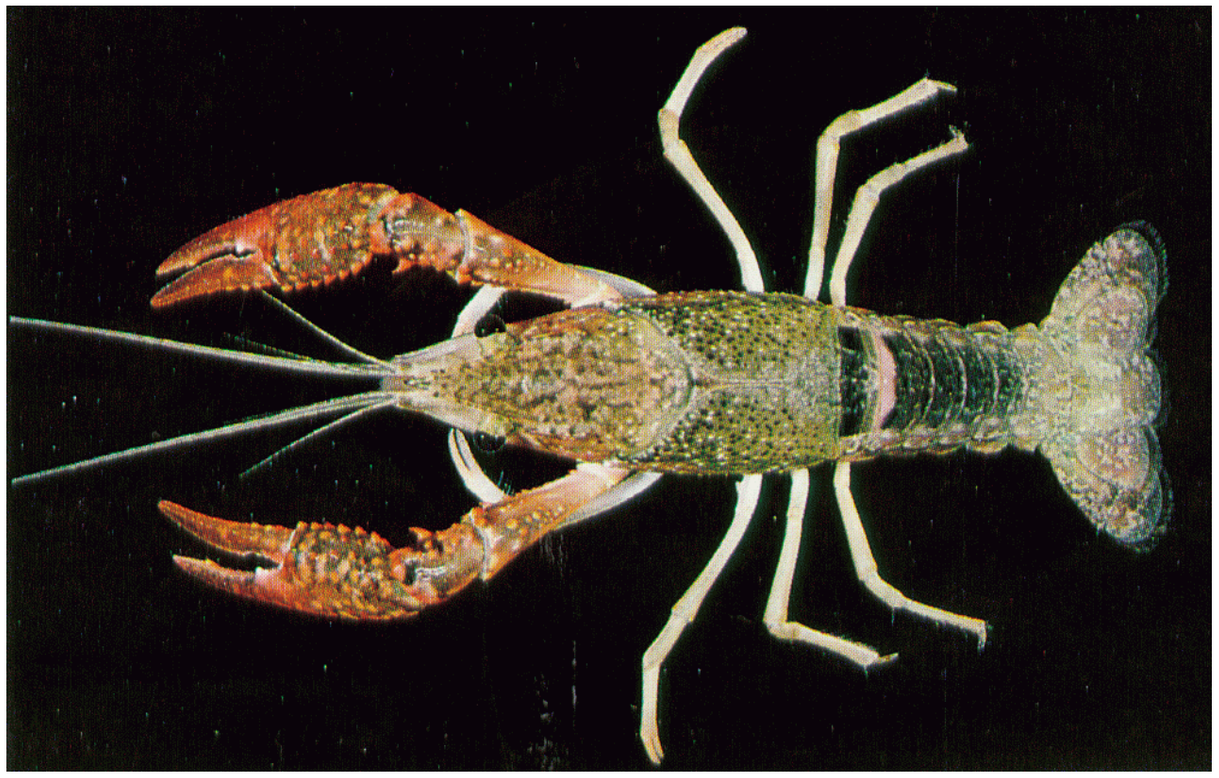
Input: currents at synapses

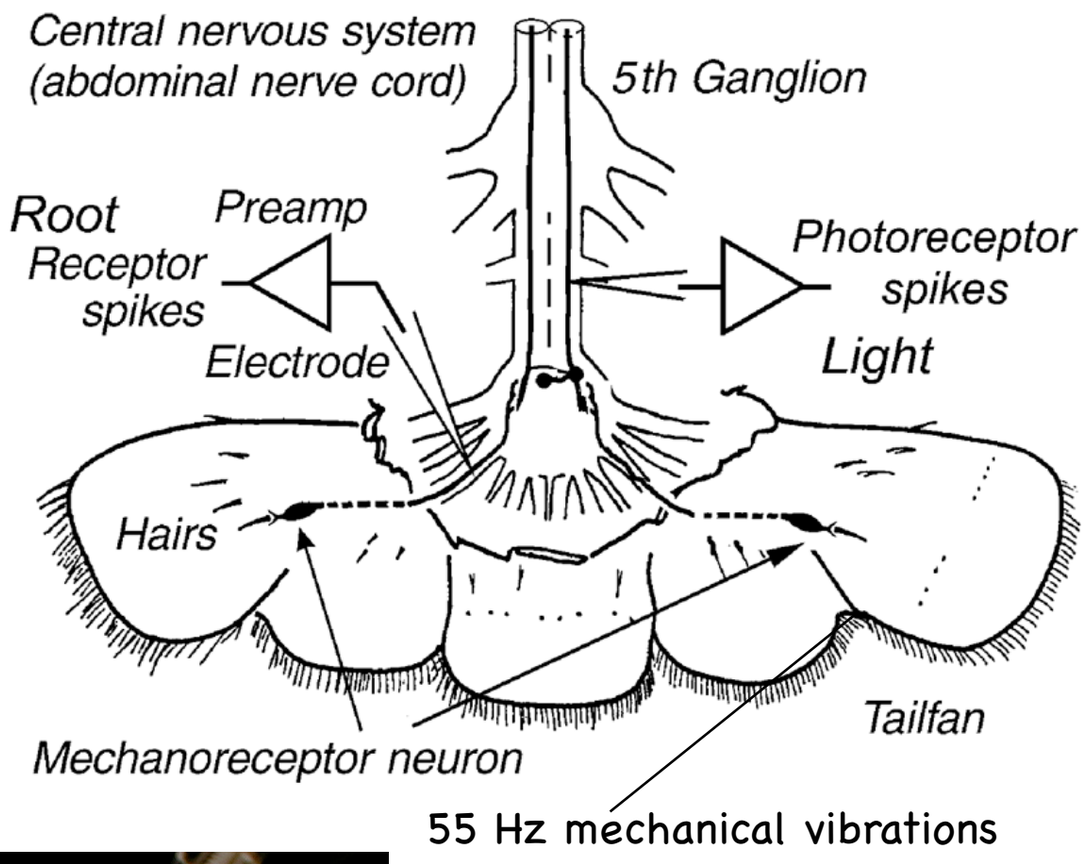
Processing: action potential if the sum of currents exceeds threshold

Output: electric pulses traveling down the axon

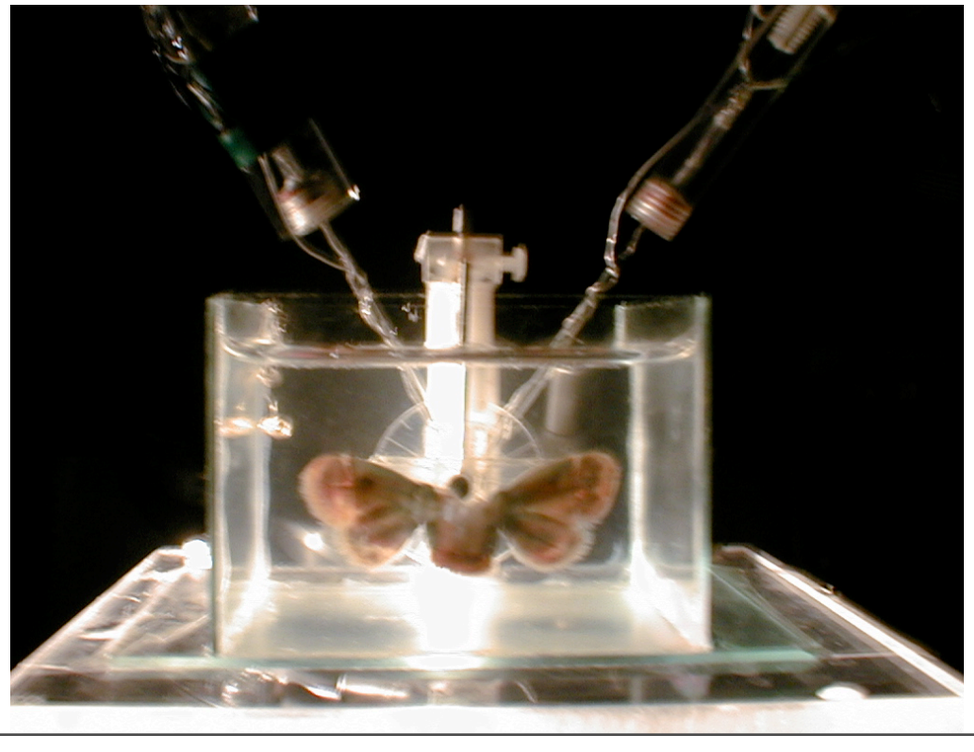
Basic idea: Signals below threshold can be detected in the presence of additional noise

SR in the Crayfish

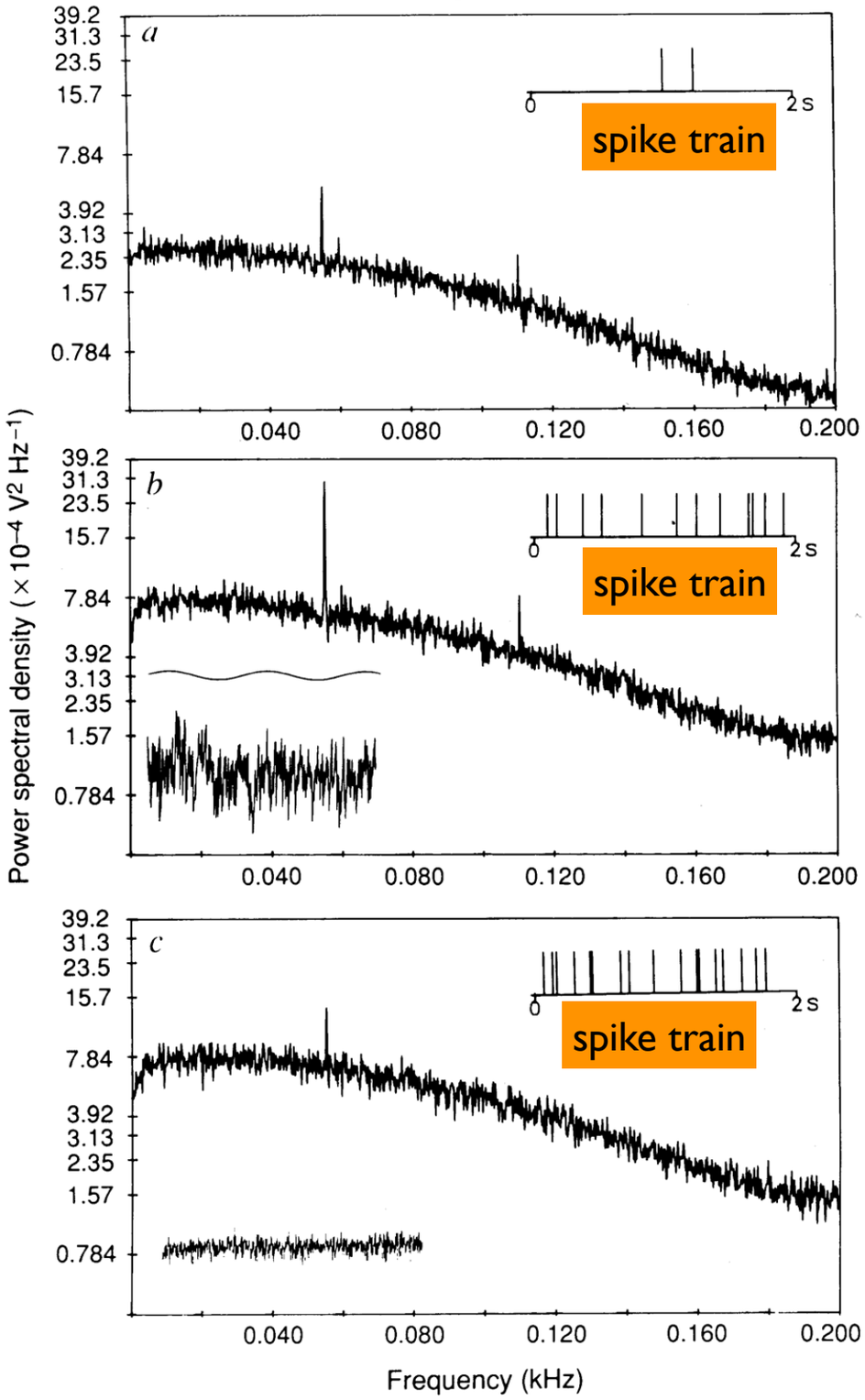




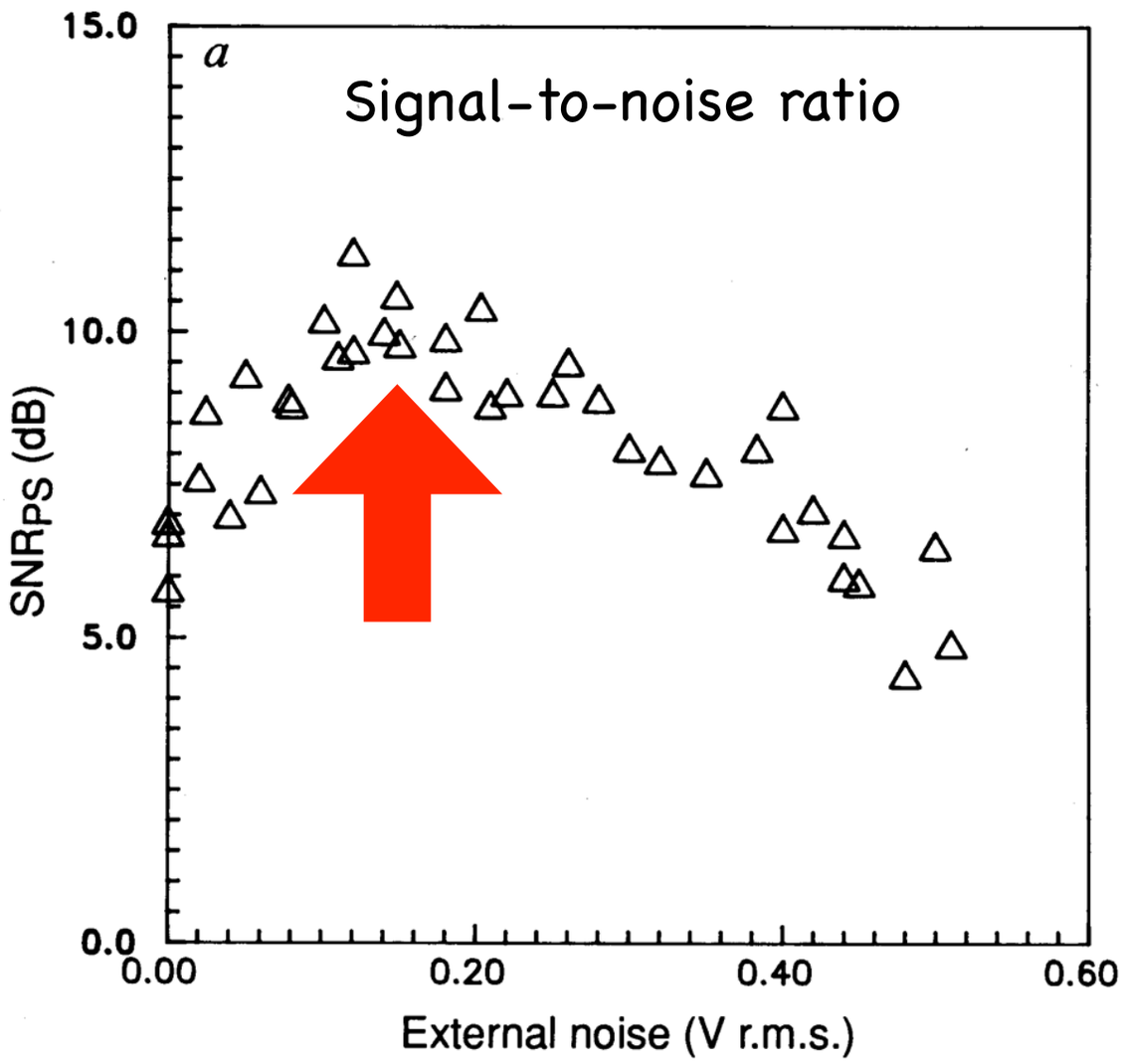
Credits:
Sonya Bahar & Frank Moss
University of Missouri
St. Louis



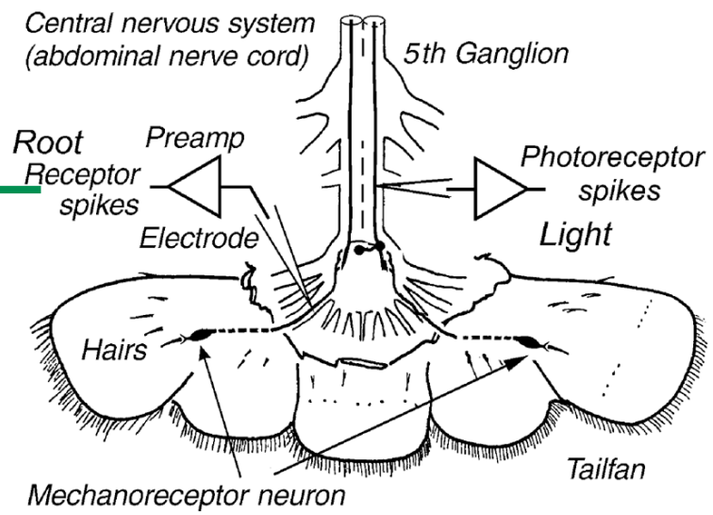
Douglass, Wilkins, Pantazelou and Moss, Nature 365 (1993)



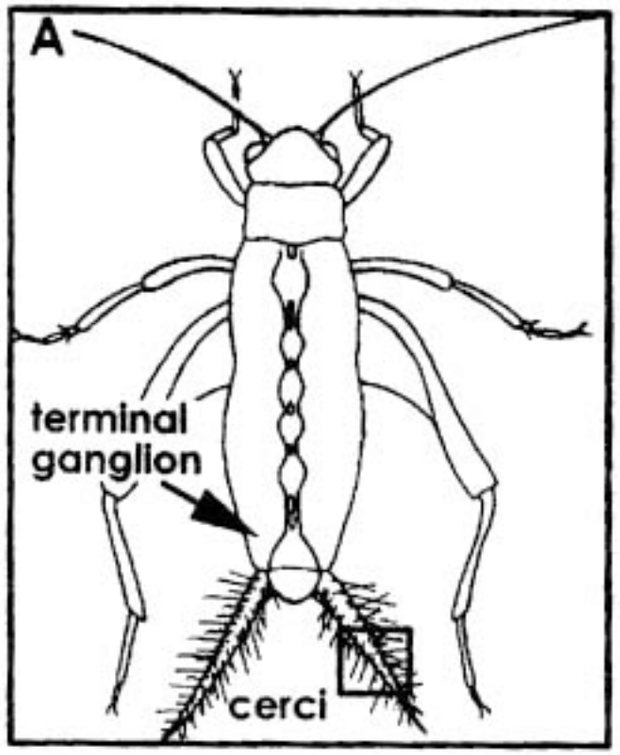
Power spectra of recorded spike train



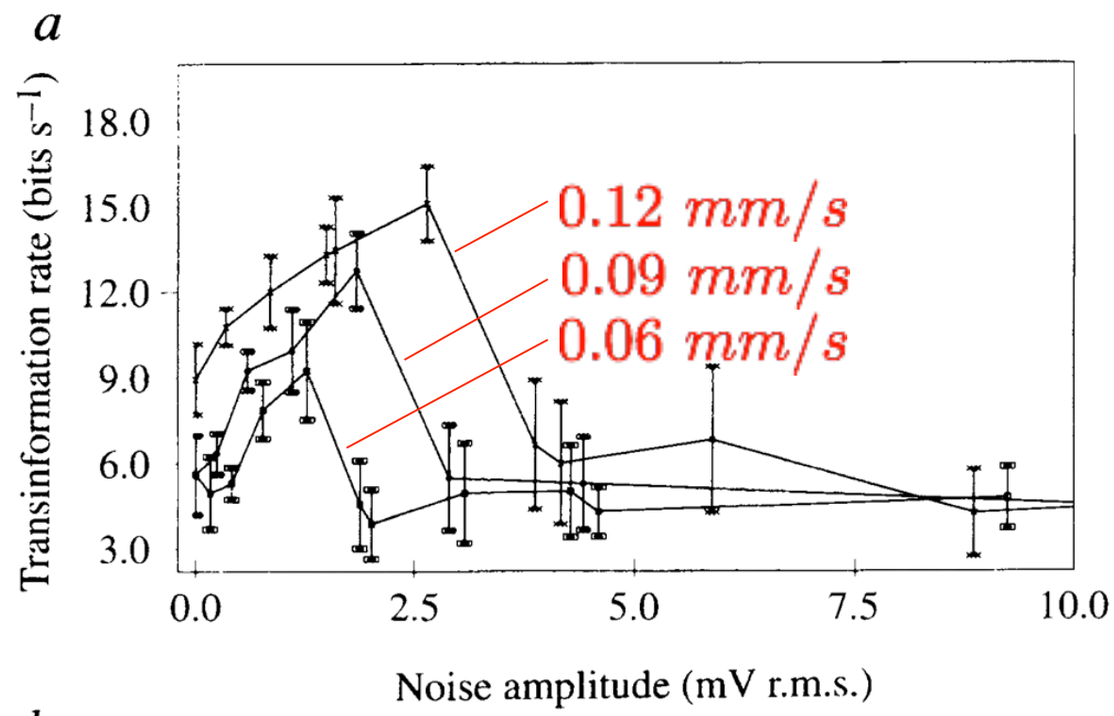
spike train

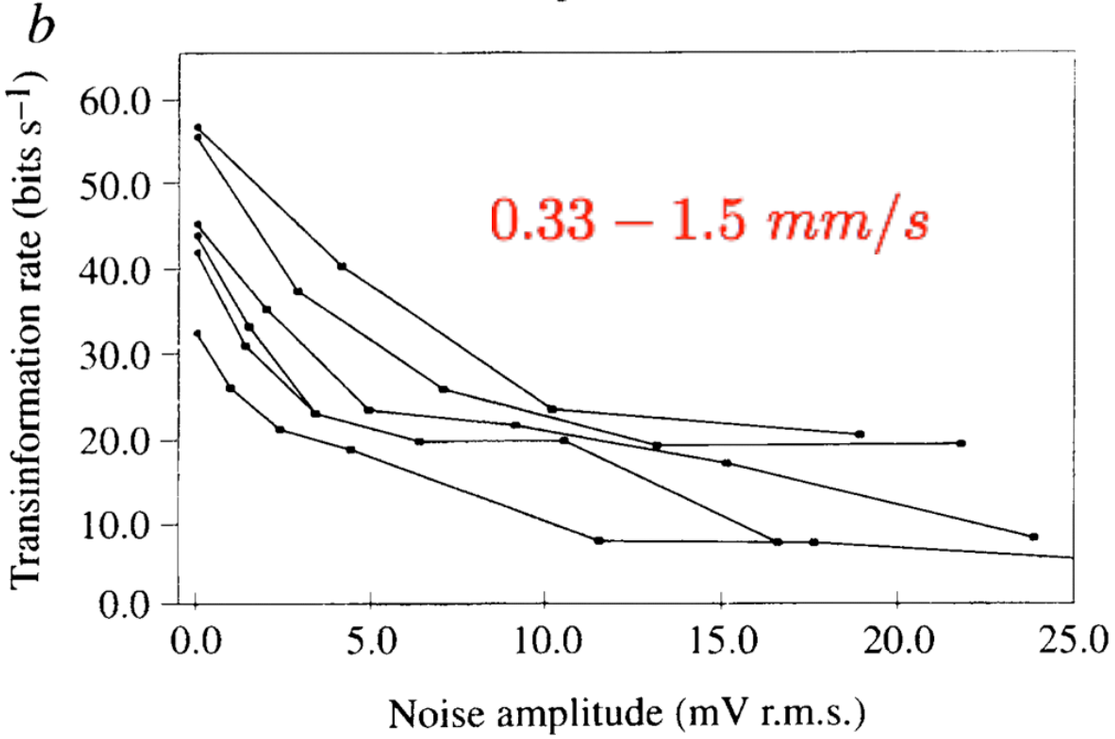


SR in a Cricket



detect air movement (approaching wasp)





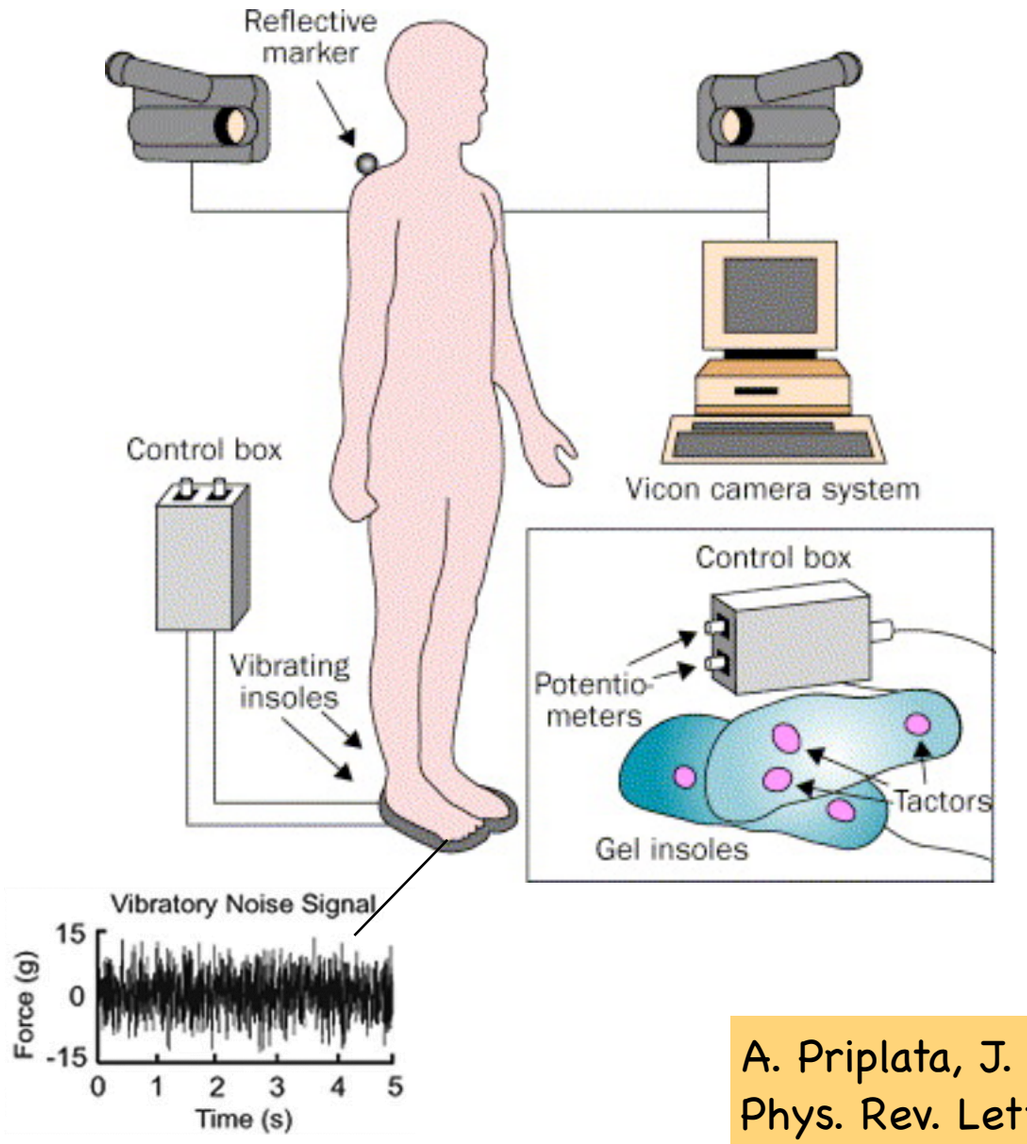
signal: broadband air flow
wasp: < 1mm/s

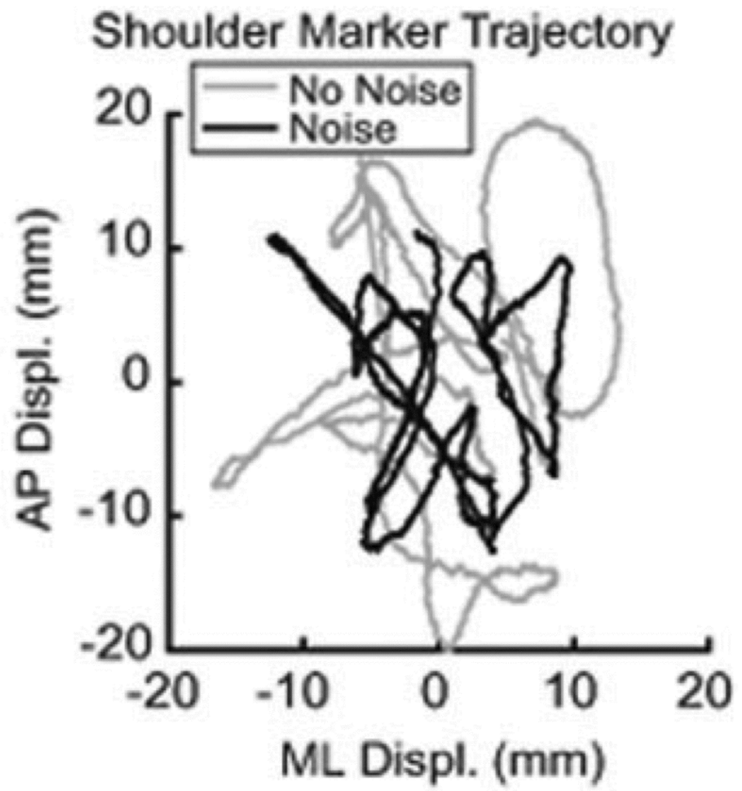
noise: random broadband airflow

output: spike trains at terminal ganglion

SR and human posture control

Somatosensory function declines with age and in diabetic patients. Can additional noise help restore function?

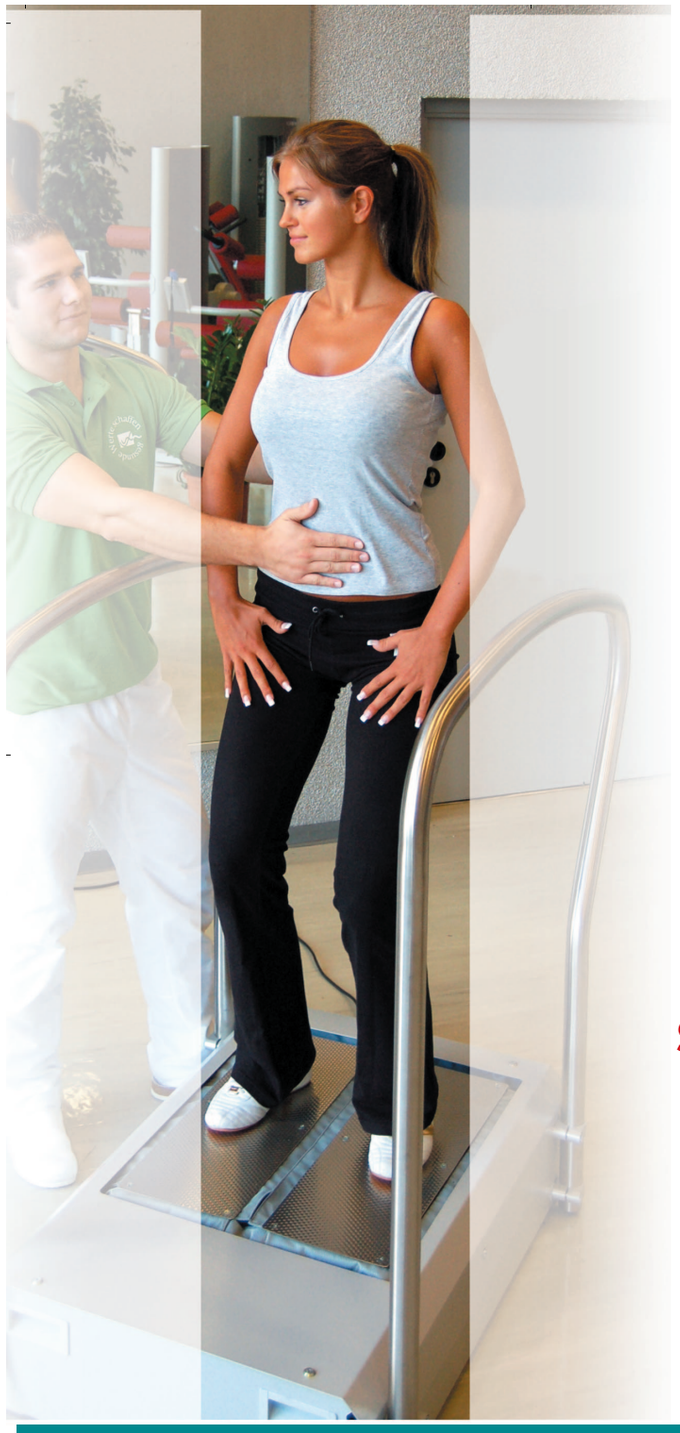




Reduction in sway of person

A. Priplata, J. Niemi, M. Salen, J. Harry, L.A. Lipsitz and J.J. Collins Phys. Rev. Lett. 89 (2002)

Stochastic Resonance Therapy



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- Schlaganfall
- Schädel-Hirn-Trauma
- Inkomplette Querschnittlähmung/spinale Läsionen
- Depression
- Harn-Inkontinenz
- Orthopädische Läsionen (z.B. Bandrupturen, Frakturen)
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- Neuropathie/Diabetes
- Schmerz

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Summary

The Stochastic Resonance paradigm is transformative

It has changed the way scientists interpret the role of fluctuations in many disciplines