

# Lecture 11

## Space-time signal processing and filters

Network 3 (1992) 213–251. Printed in the UK

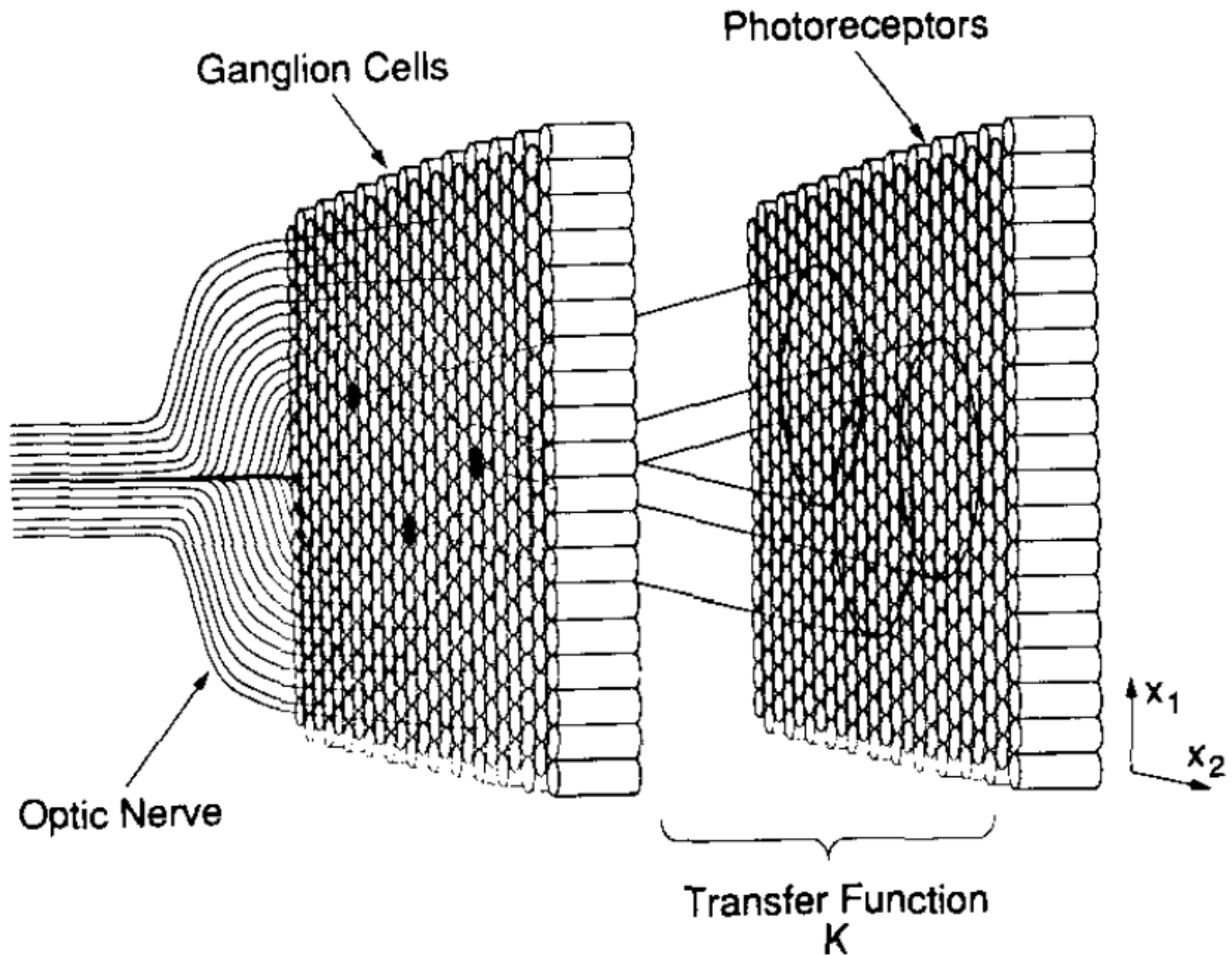
### REVIEW ARTICLE

## **Could information theory provide an ecological theory of sensory processing?**

Joseph J Atick†

School of Natural Sciences, Institute for Advanced Study, Princeton, NJ 08540, USA

# The retina as a black box processor



Natural scenes (as well as other environmental signals) are structured and highly redundant both in space and time

Scale-invariance in natural images (Field, '87)



A



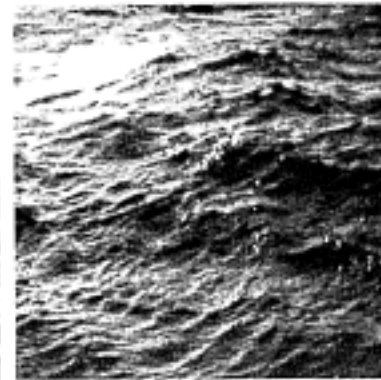
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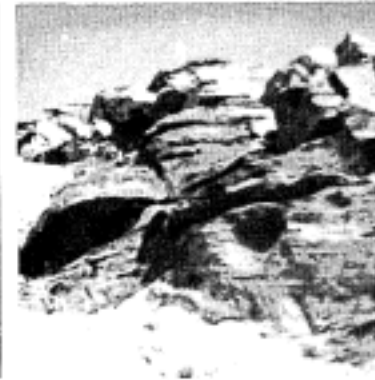
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D



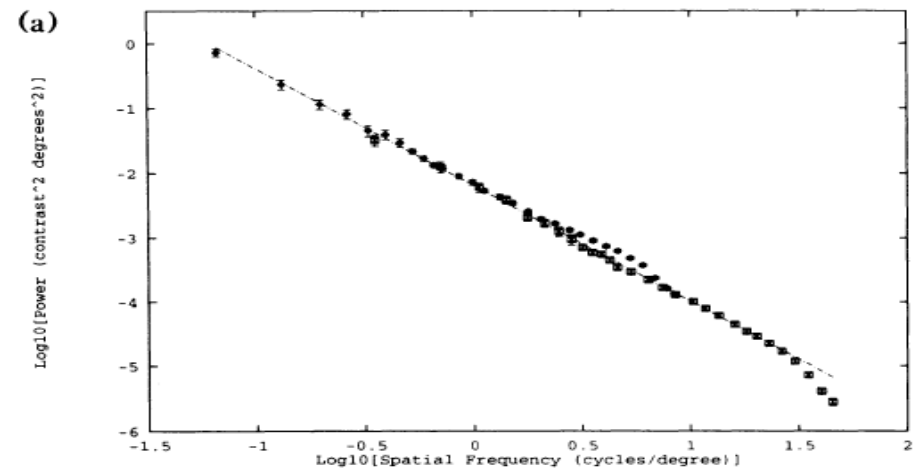
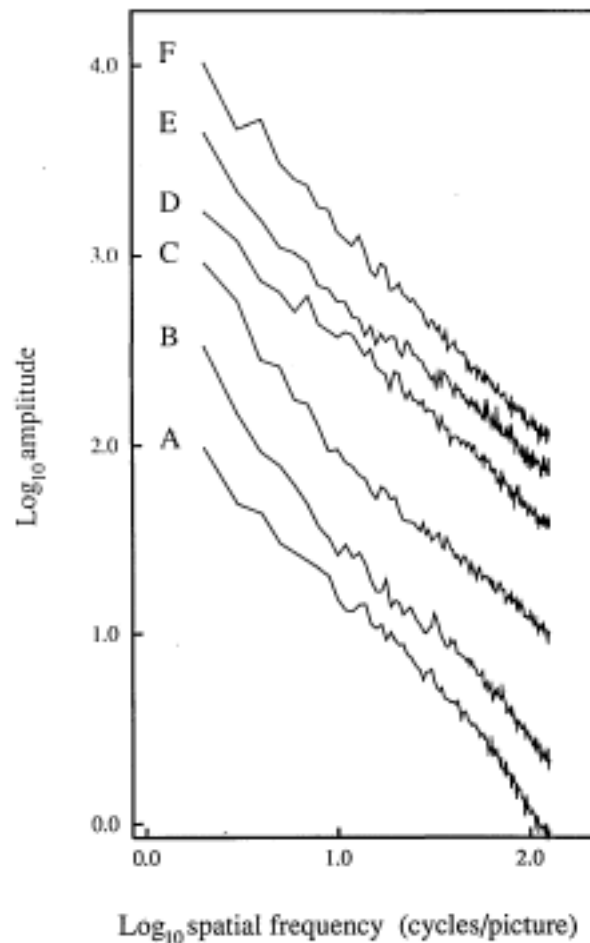
E



F

Natural scenes (as well as other environmental signals) are structured and thus highly redundant both in space and time

Scale-invariance in natural images (Field, '87)



# What is the response of the system?

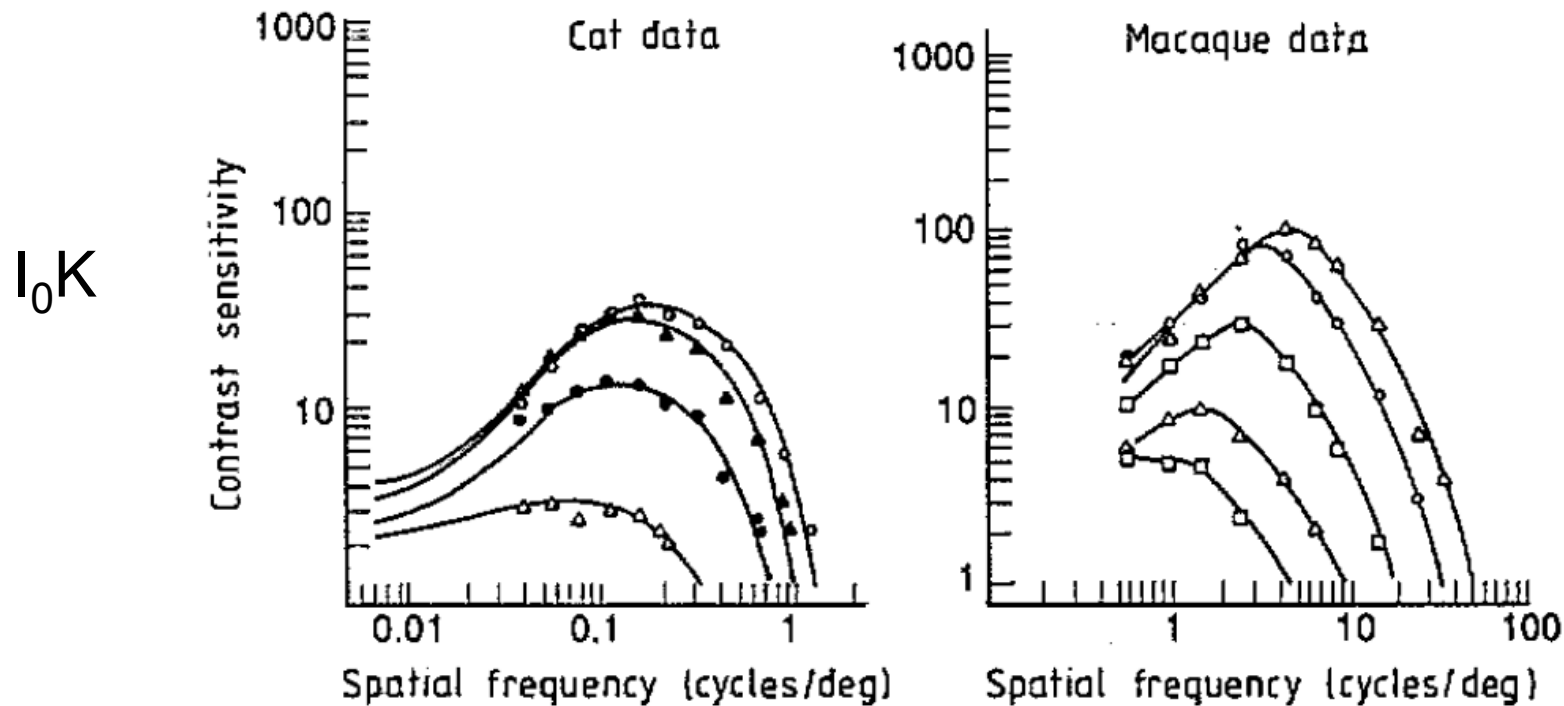
Luminosity grating  $L = I_0 [1 + m \cos(kx) \cos(\omega t)]$

is presented after adaptation and the minimum contrast  $m(I_0, \omega, k)$  needed to elicit a response level  $r_0$  is measured

Linearity of the response  $I_0 K_{I_0}(|k|, \omega) = \frac{r_0}{m}$

Excellent reading: D. Hubel's online book Eye, Brain and Vision

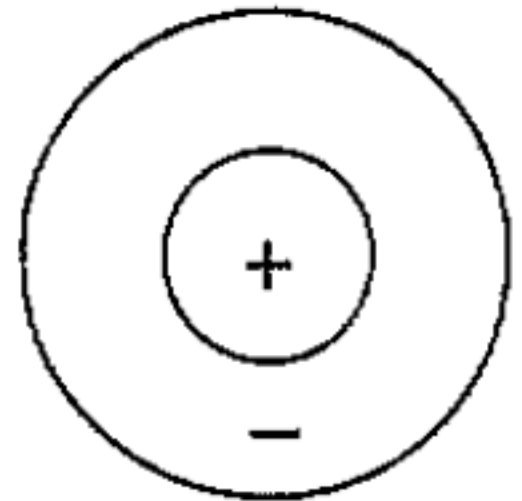
# Experimental filters (in Fourier)



**Figure 4** Measured contrast sensitivity. The data in the left figure are reproduced from Enroth-Cugell and Robson (1966), while that on the right are from De Valois *et al* (1974). In both cases, the luminance level  $I_0$  decreases by one log unit each time we go to a lower curve.

Note transition from band-pass to low-pass as

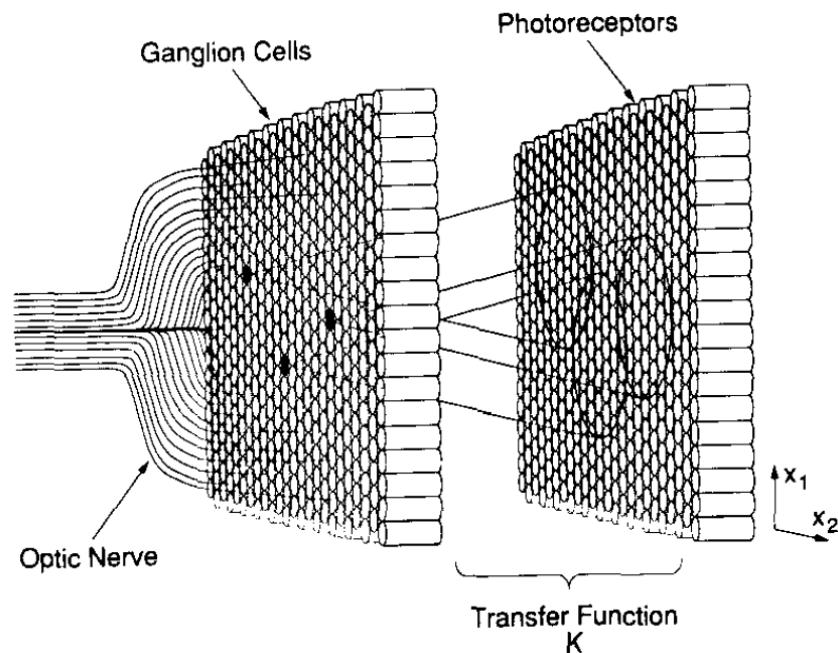
# On/Off-centre cells



Similar organization in the temporal domain

# Optimizing compression of sensed signals

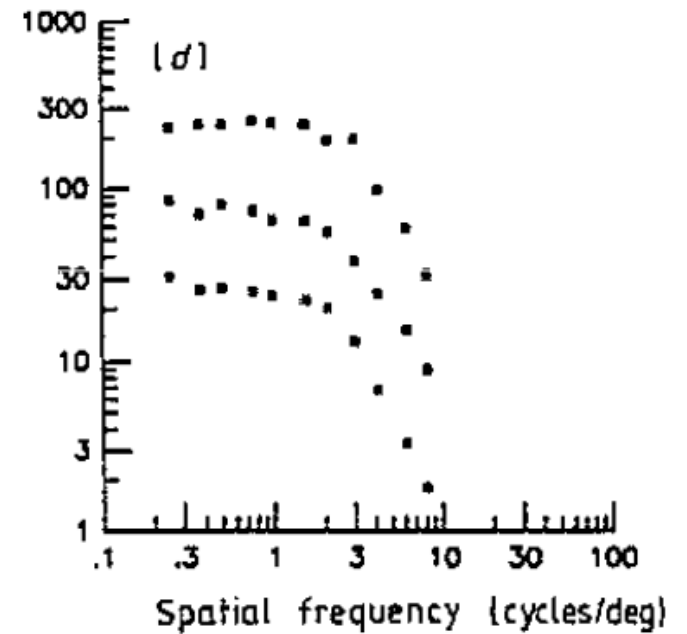
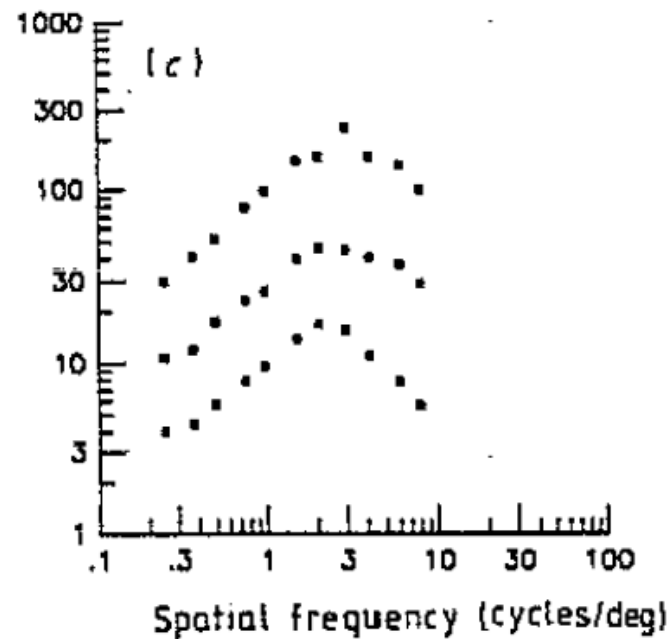
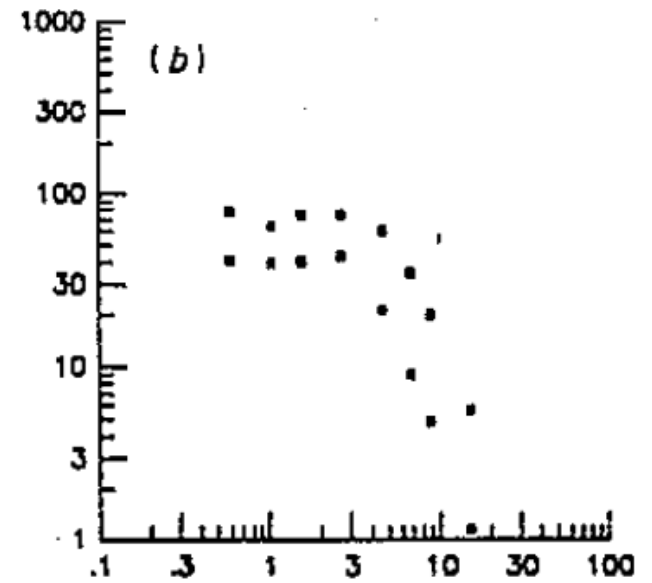
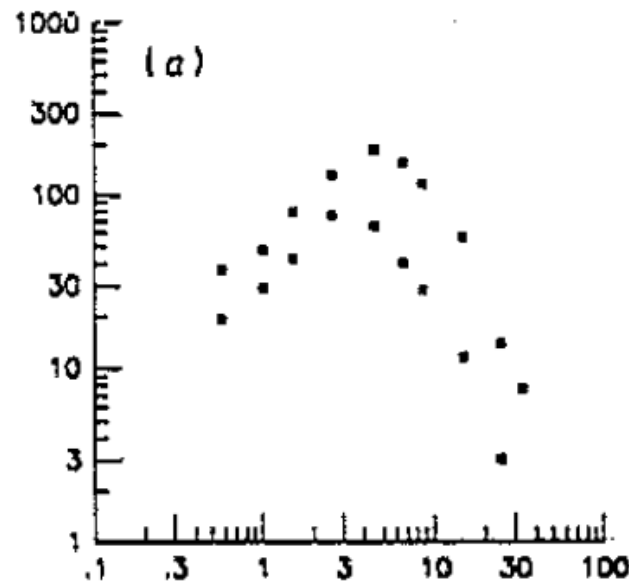
In section 3, we have given several reasons why a sensory pathway, such as the visual pathway, might recode incoming signals from the natural environment into a more efficient representation. In this section, we show how to use this idea to predict retinal processing in the spatial domain. We work with the hypothesis that the retina's main goal is to build a minimum entropy representation, i.e. a representation where the elements are statistically independent or decorrelated (the same procedure followed



i.e. the transfer function  $K$  has evolved to optimize the compression of the sensory signal sensed from the environment and sent to the visual cortex via the optic nerve



“Whitening” is confirmed by experimental data at low frequencies and high intensities



# In the presence of noise

Modulation transfer function

