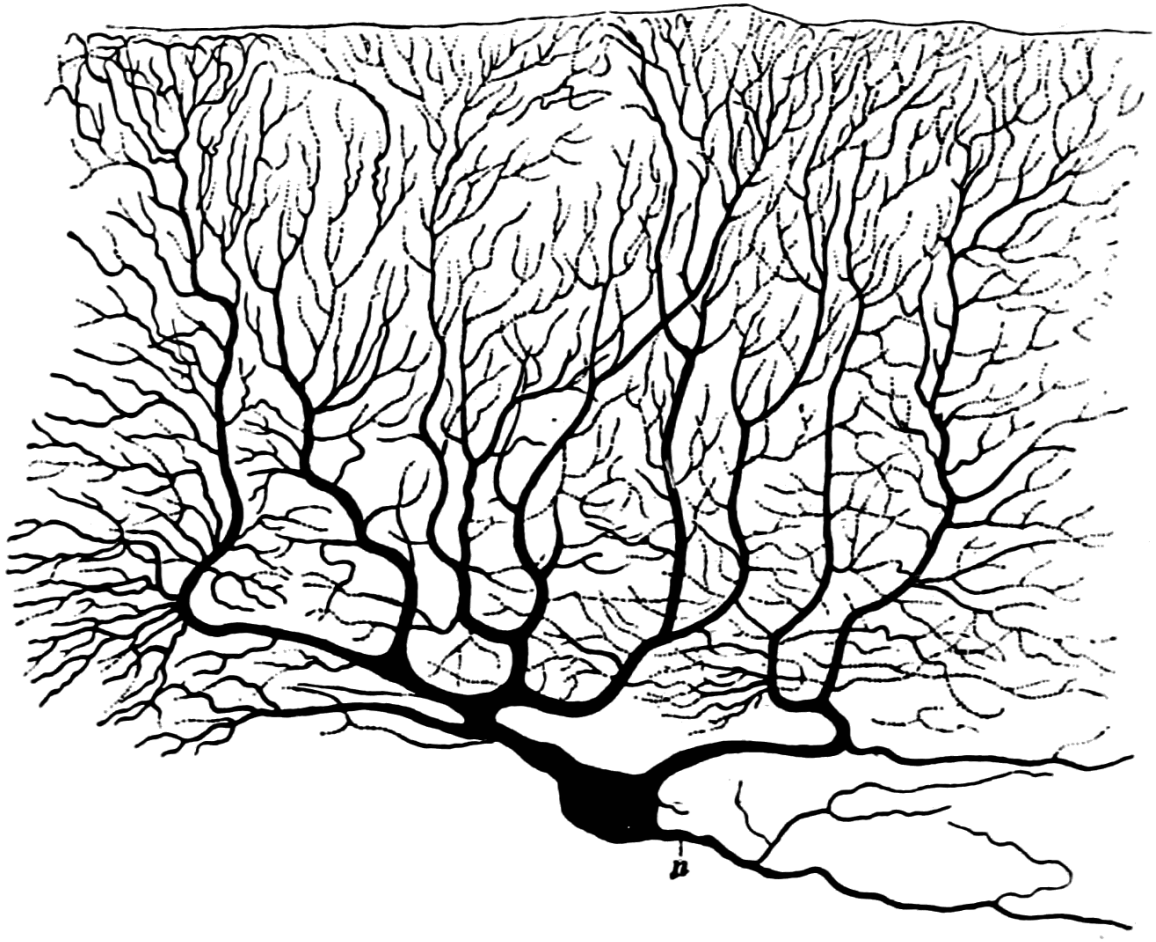
Information in the brain: information theory lecture 6

COMSM0075 Information Processing and Brain

comsm0075.github.io

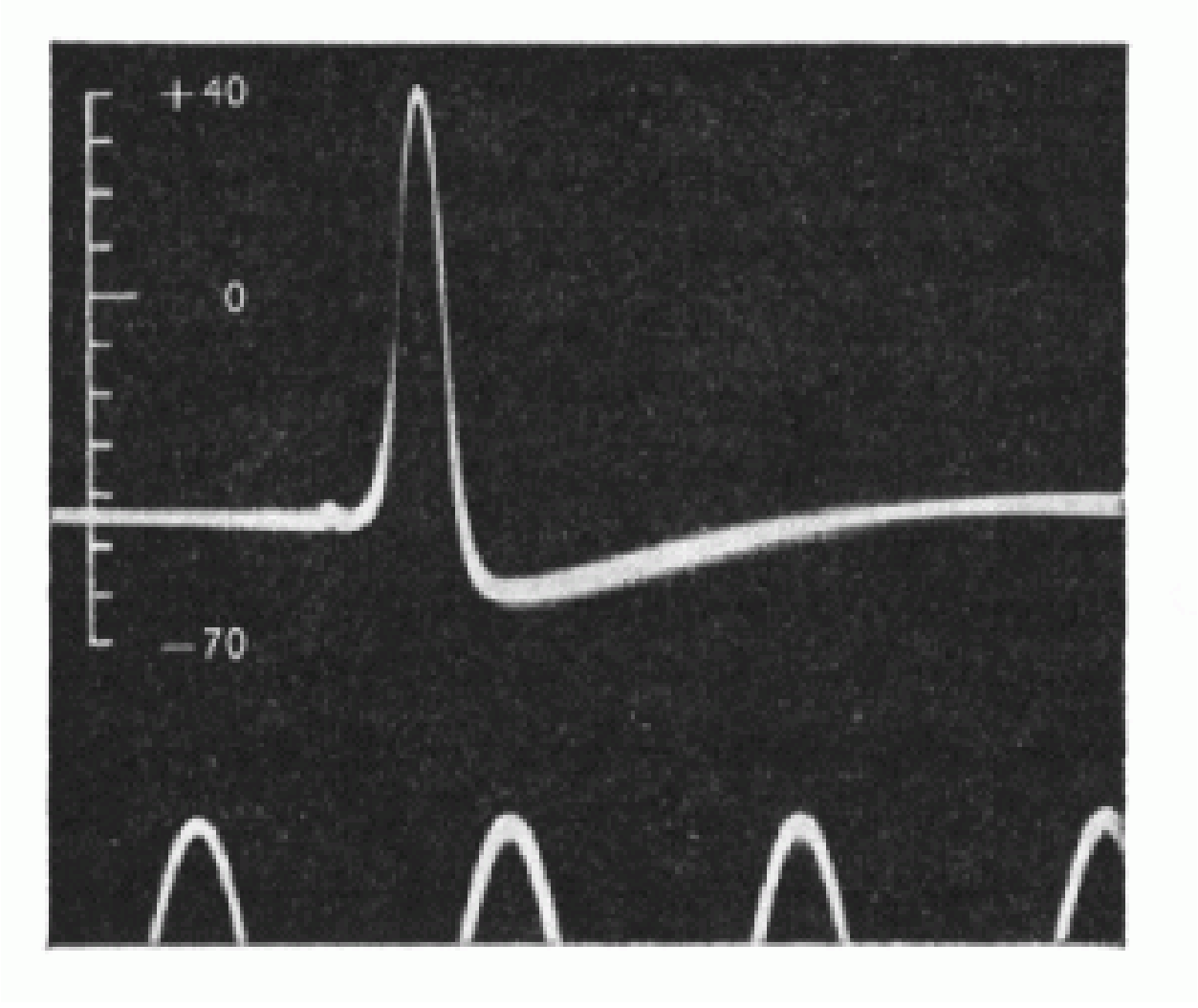
October 2020

Neurons



Picture from wikisource.

Spikes

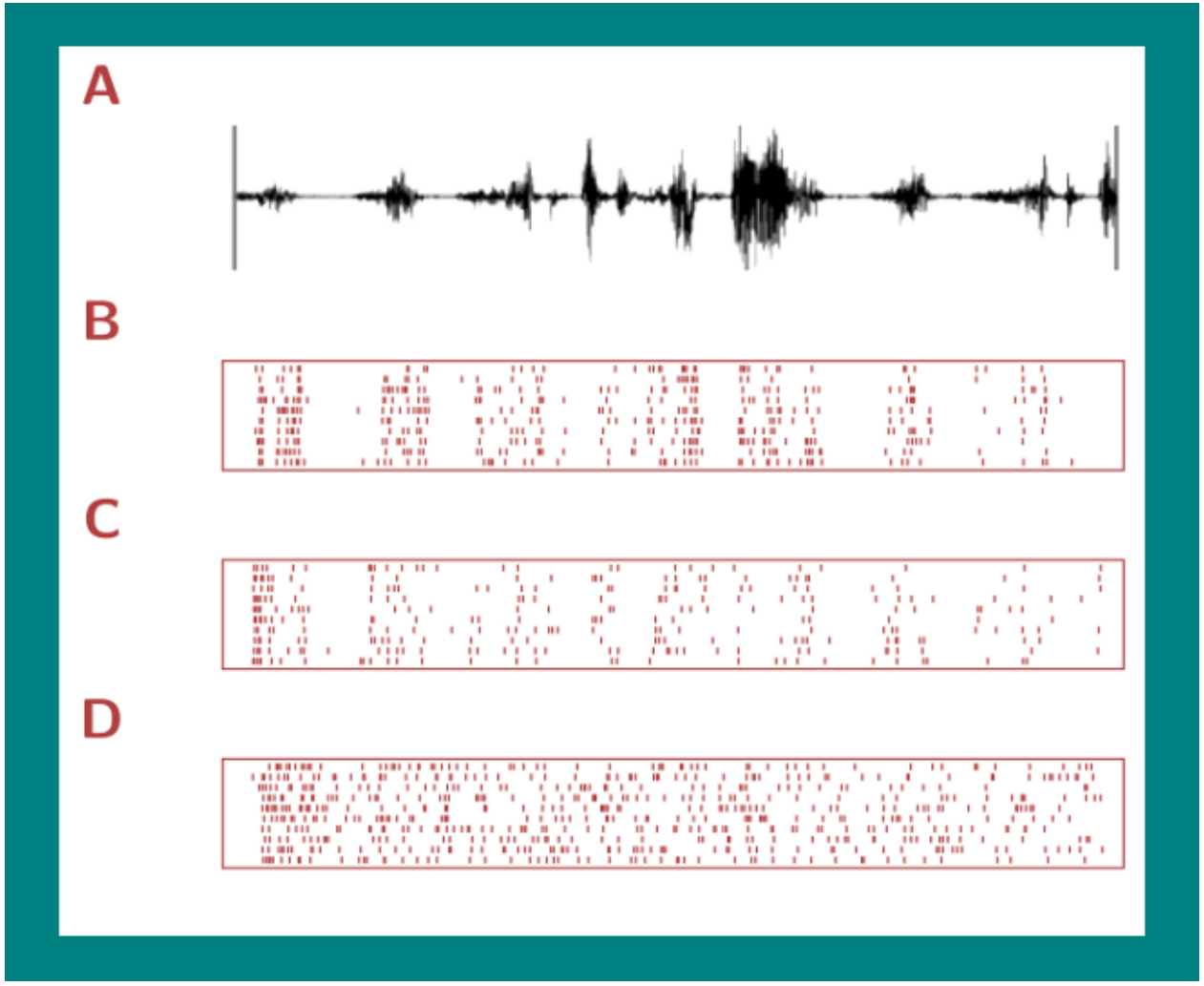


Picture from Hodgkin and Huxley, 1939.

Zebra finch

Picture from wikipedia.

Spike trains

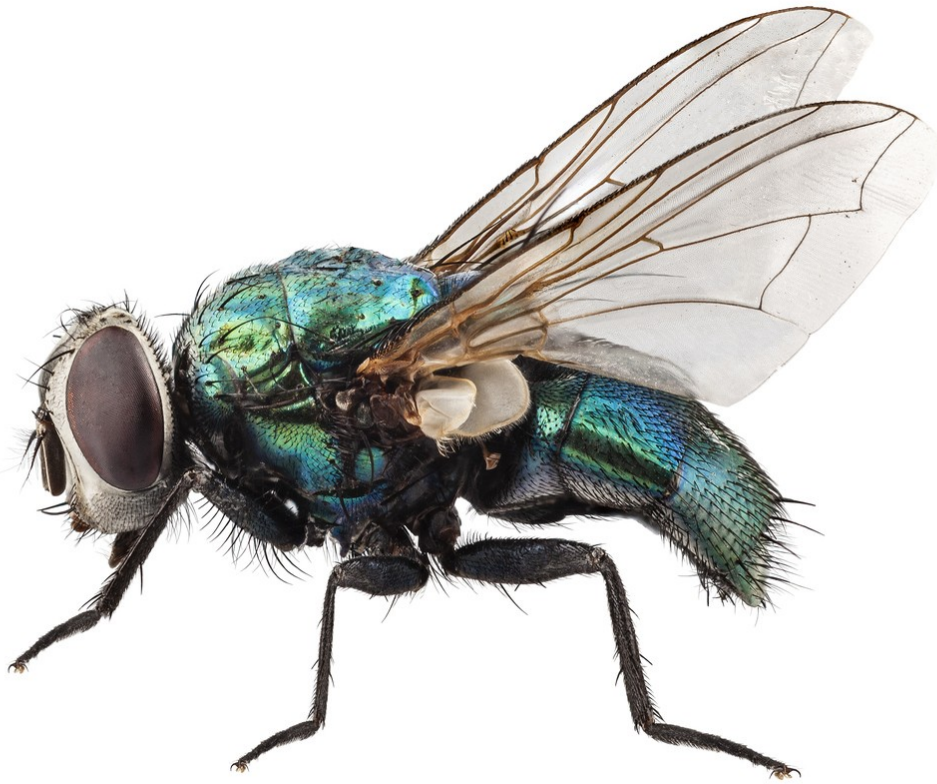


Shannon's entropy

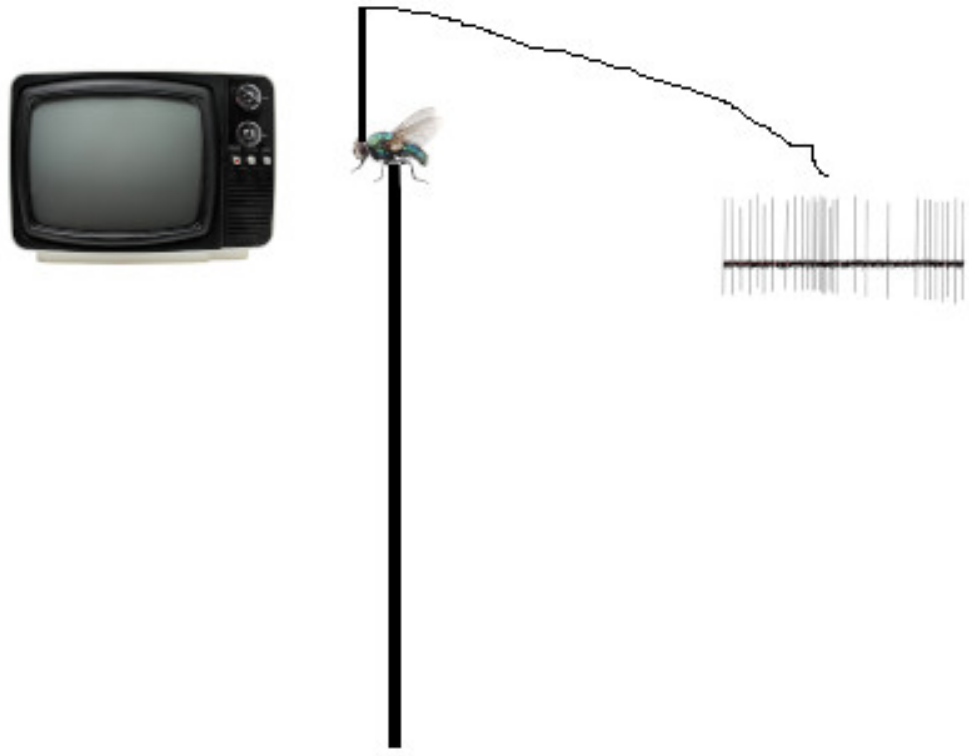
$$H(X) = -\sum_i p_X(x_i) \log_2 p_X(x_i)$$

Fly

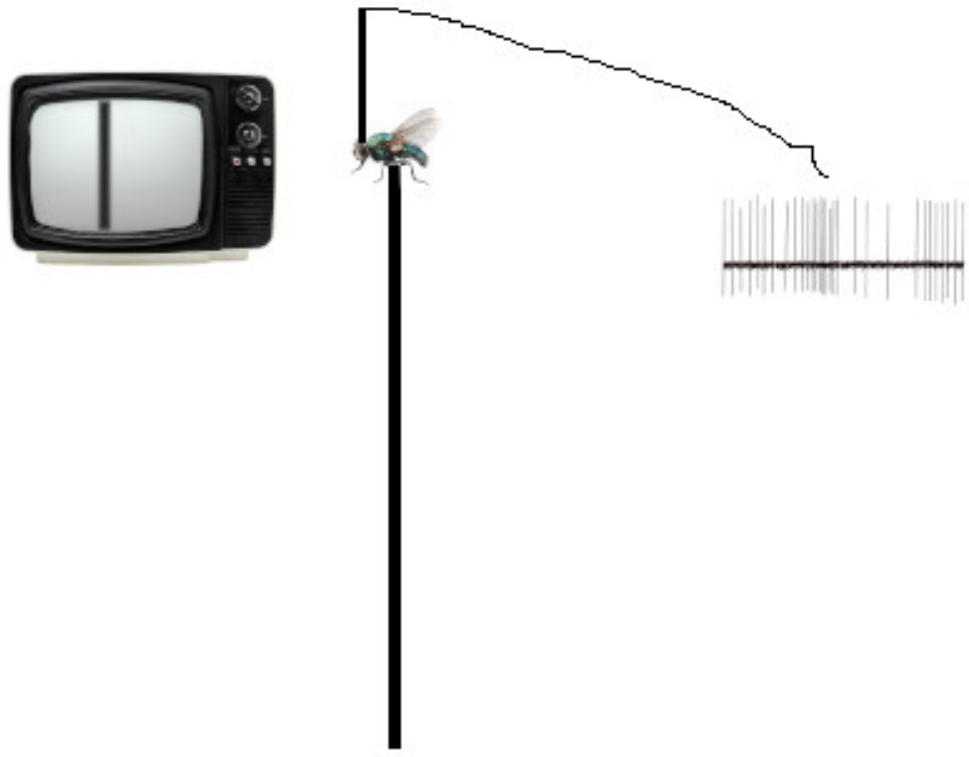
Experiment by Bialek and coworkers



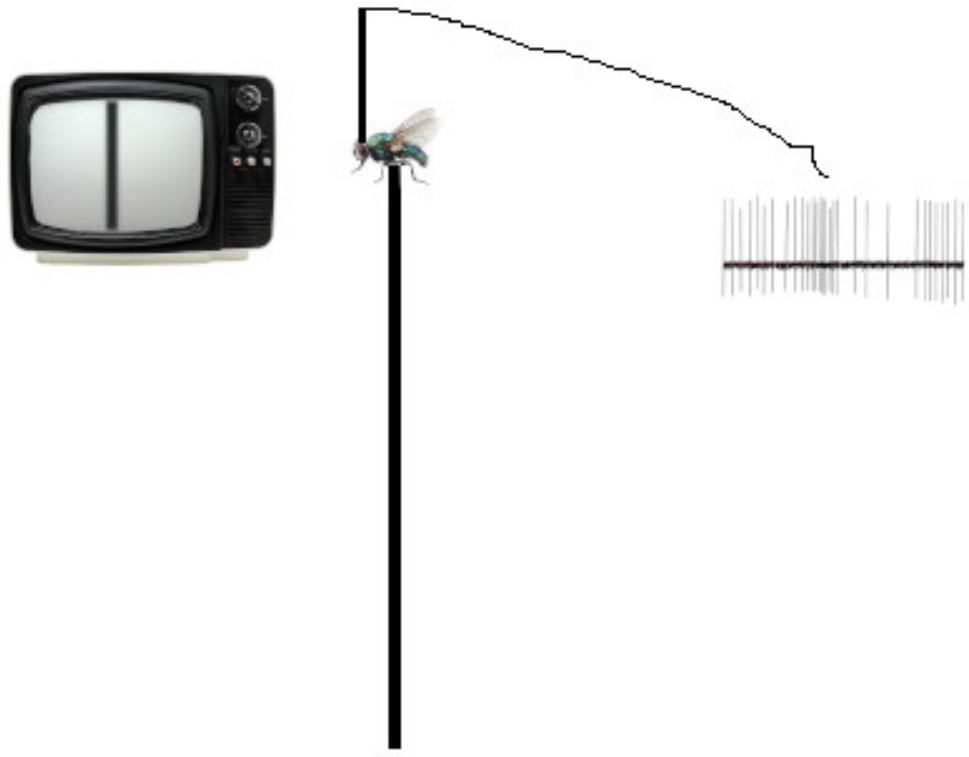
Experiment by Bialek and coworkers



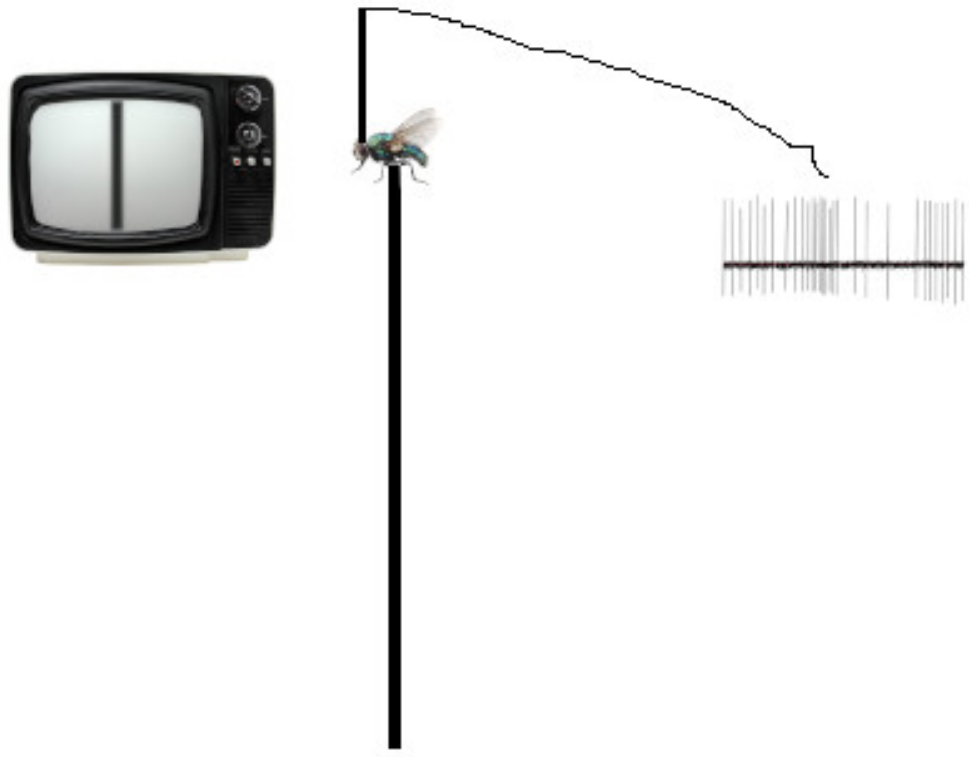
Experiment by Bialek and coworkers



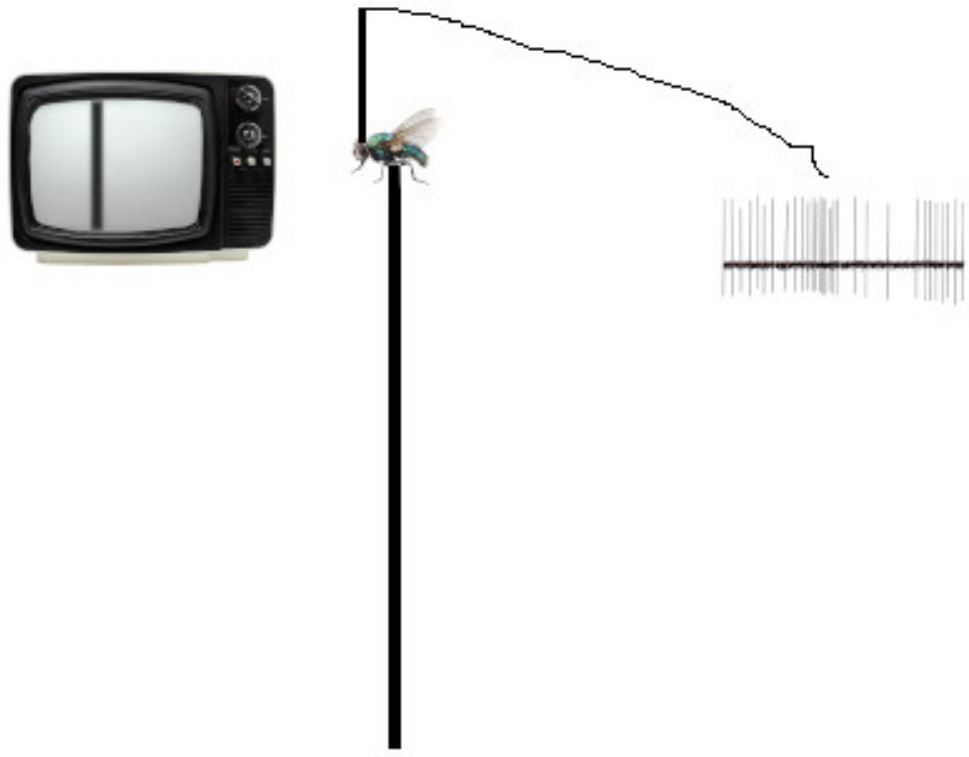
Experiment by Bialek and coworkers



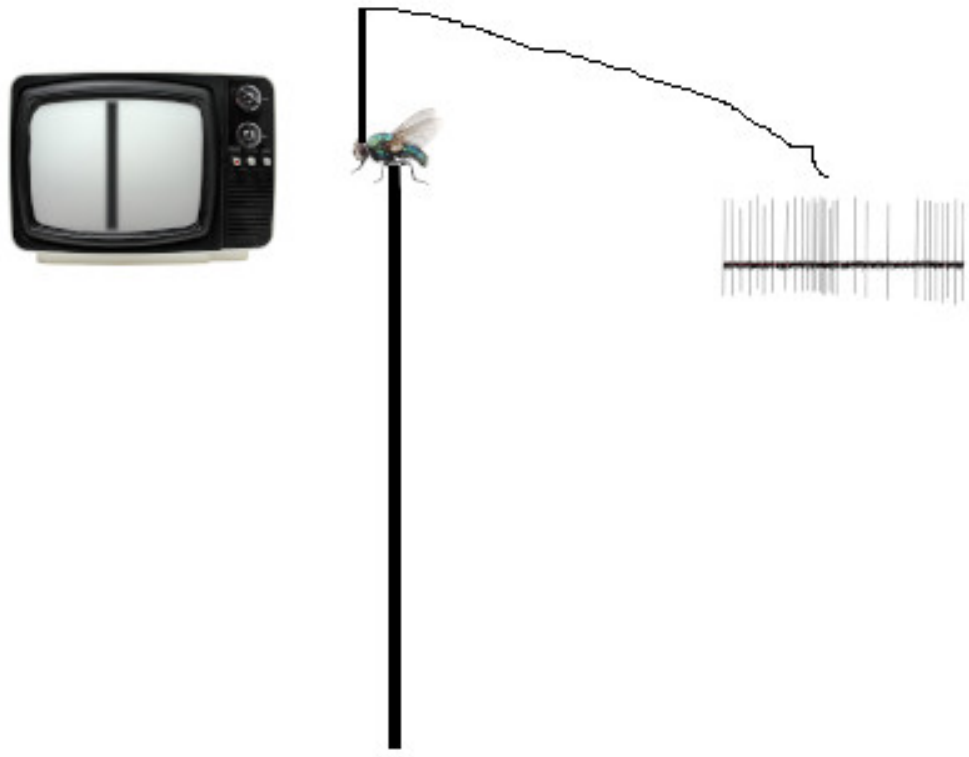
Experiment by Bialek and coworkers



Experiment by Bialek and coworkers



Experiment by Bialek and coworkers



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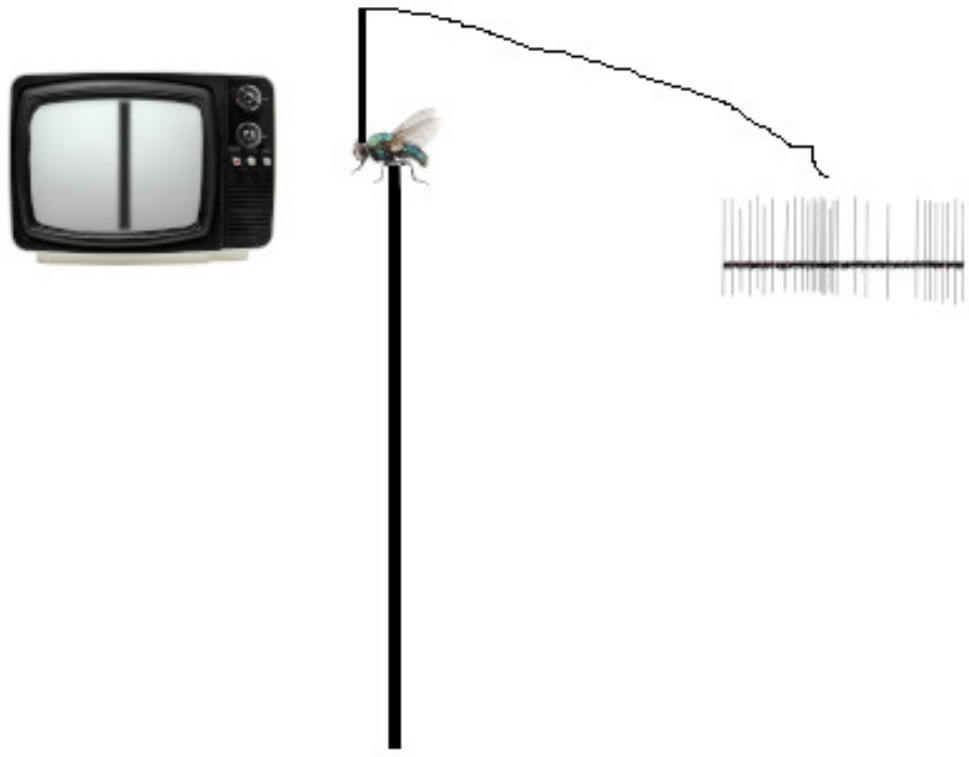
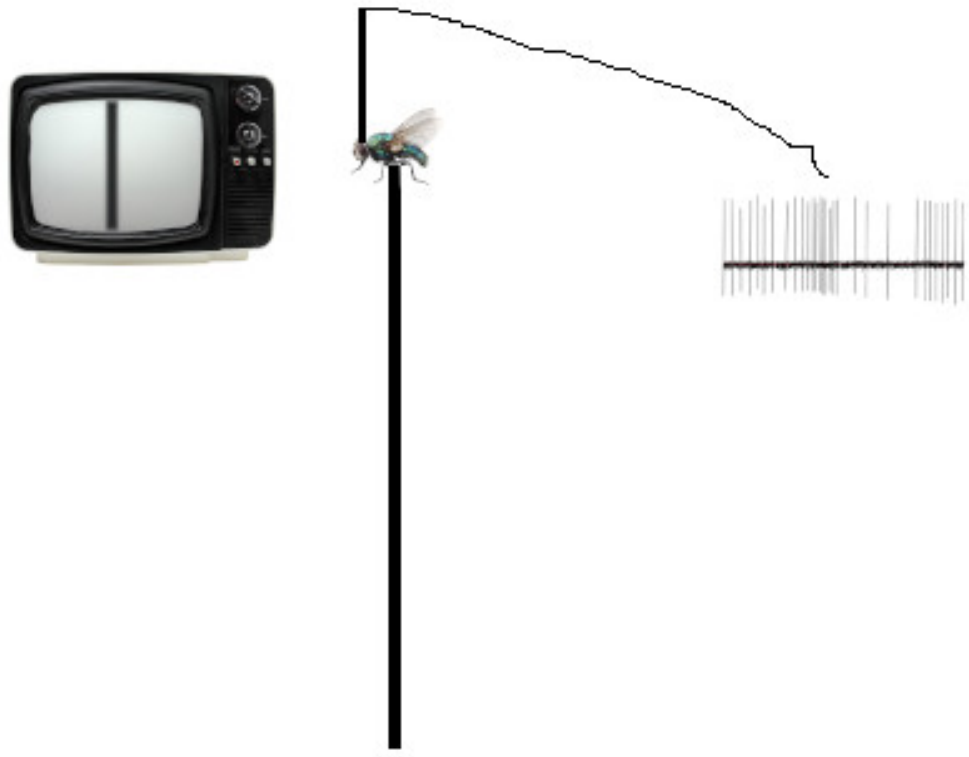
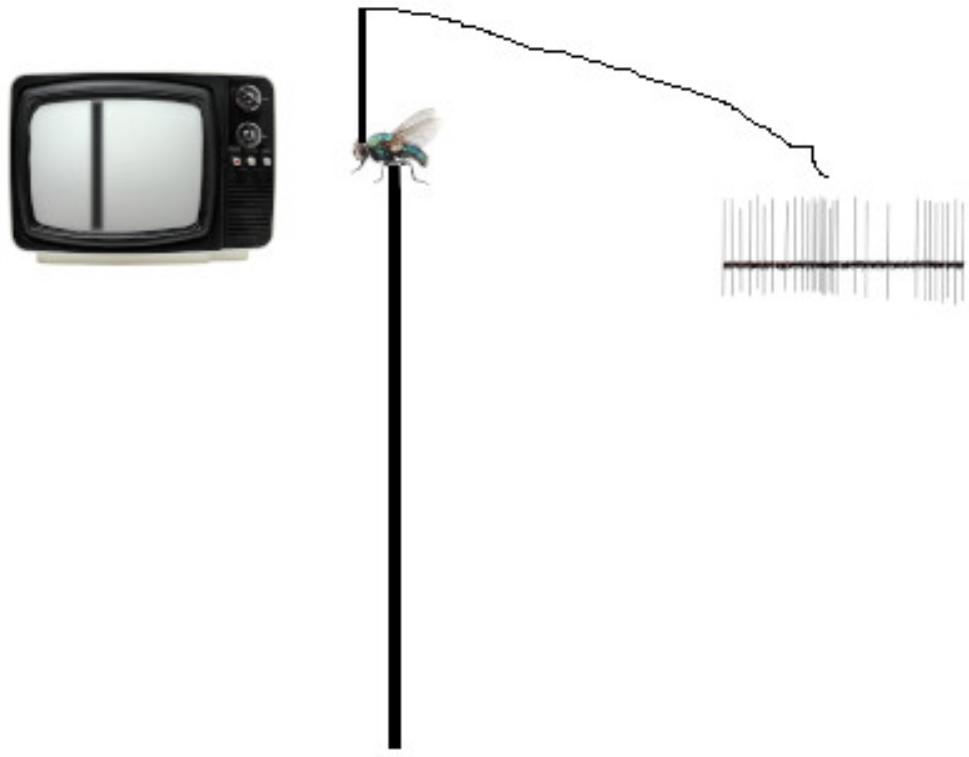


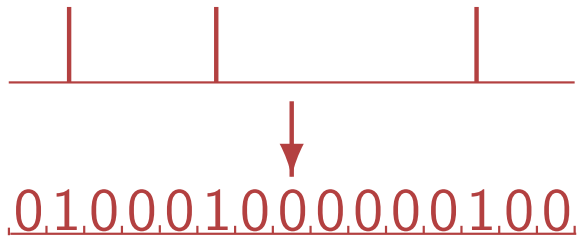
Experiment by Bialek and coworkers



Experiment by Bialek and coworkers



Discretize



Split into words

$$010001000000100 \rightarrow 01000, 10000, 00100$$

W

$$
\begin{aligned}
\mathbf{w}_0 &= (0,0,0,0,0) \\
\mathbf{w}_1 &= (0,0,0,0,1) \\
\mathbf{w}_2 &= (0,0,0,1,0) \\
\mathbf{w}_3 &= (0,0,0,1,1) \\
&\ldots
\end{aligned}
$$

W

$$
\begin{aligned}
\mathbf{w}_0 &= (0,0,0,0,0) \\
\mathbf{w}_1 &= (0,0,0,0,1) \\
\mathbf{w}_2 &= (0,0,0,1,0) \\
\mathbf{w}_3 &= (0,0,0,1,1) \\
&\dots
\end{aligned}
$$

and

$$
p(\mathrm{w}_0) \approx \frac{\#(\text{occurance of } \mathrm{w}_0)}{\#(\text{trials})}
$$

$H(W)$

$$01000, 10000, 00100, 10000, 01000, 01100, 00011, 00110, 01000, \ldots$$

$H(W|S)$

s_1	s_2	s_3	s_4	...
01000	10000	00100	10100	...
00100	11000	00001	01000	...
01010	00000	00100	00010	...
01000	01000	10100	10010	...
01100	10010	01100	00100	...

$H(W|S)$

s_1	s_2	s_3	s_4	...
01000	10000	00100	10100	...
00100	11000	00001	01000	...
01010	00000	00100	00010	...
01000	11000	10100	10010	...
01100	10010	01100	00100	...

$$p(W = 11000|S = s_2) \approx \frac{\#(11000)}{\#(\text{trials})} = \frac{2}{5}$$

$I(W, S)$

$$I(W, S) = H(W) - H(W|S)$$

or

information about S in W= total information in W- noise

discretization size

One question is how to decide how small to make the discretization time and how long to make the words. It is argued that the blowfly responds very quickly to attempts to swat it, so the information coming from H1 is being interpreted by other brain areas over a time scale of 30 ms.

result

$\delta t = 3$ ms gives 78 ± 5 bits per second or 1.8 ± 0.1 bits per spike.

Strong et al. 1998

too many words

30 ms words with 3 ms letters:

$$2^{10} = 1024$$

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30 ms words with 3 ms letters:

$$2^{10} = 1024$$

If six seconds of data are used for the repeating stimulus, that is 100 different stimuli, then even for a three hour recording, there are 1800 trails for each stimulus, not a huge amount for estimating 1024 probabilities.