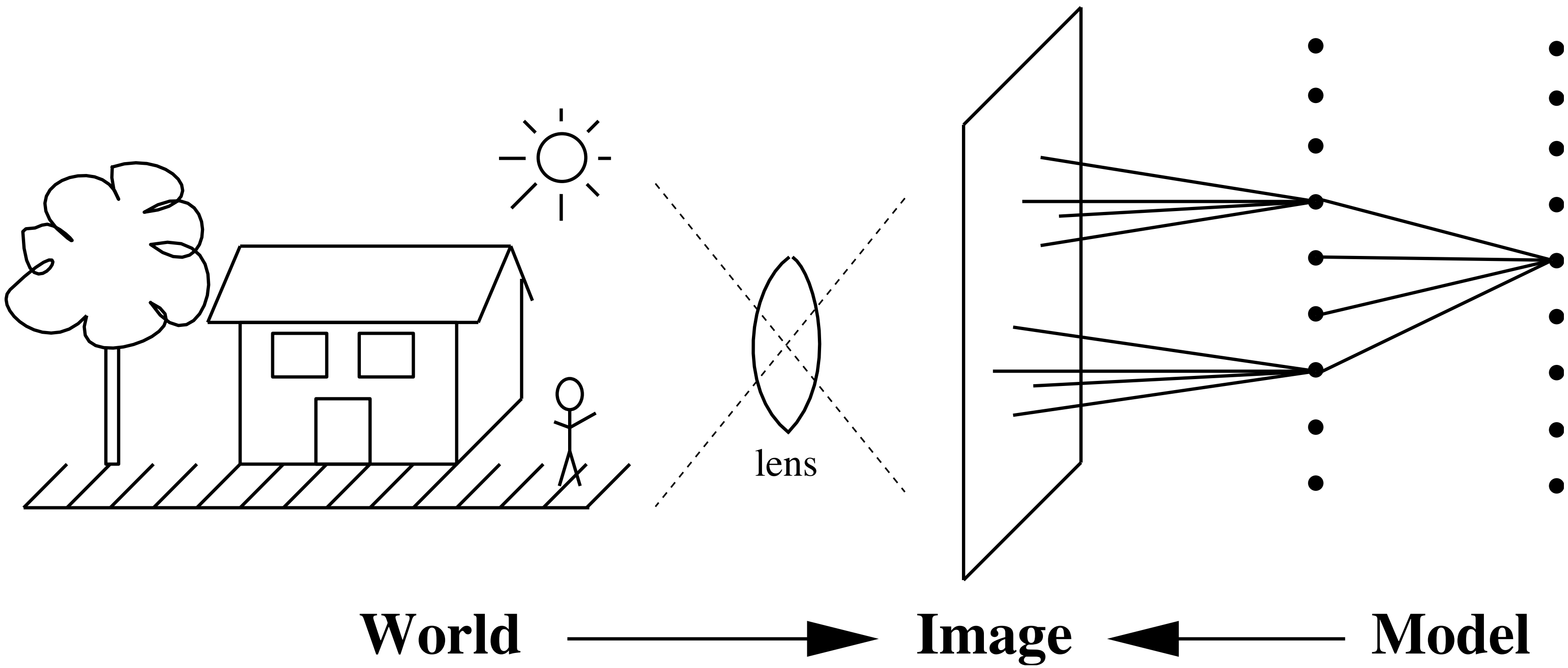
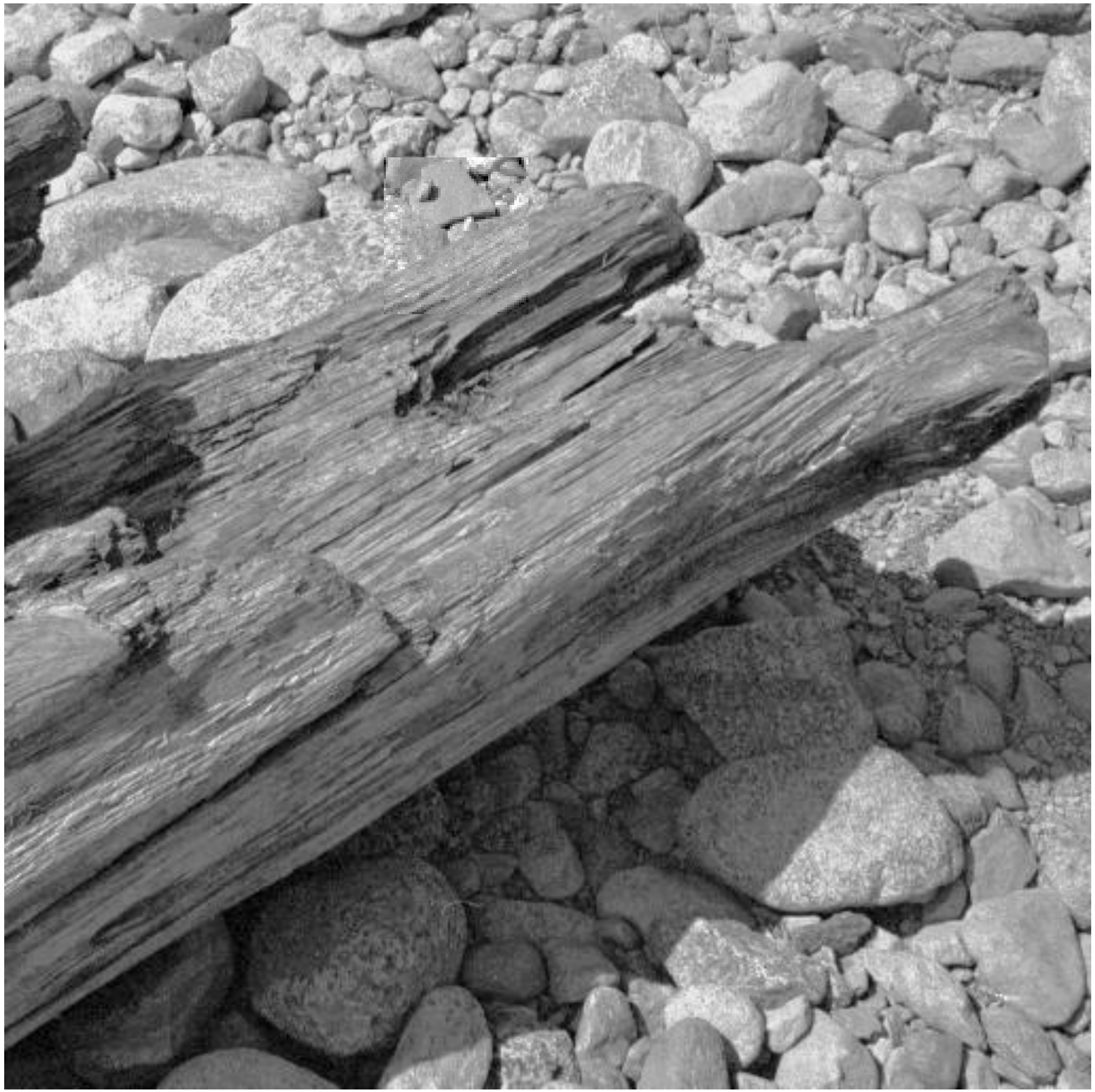
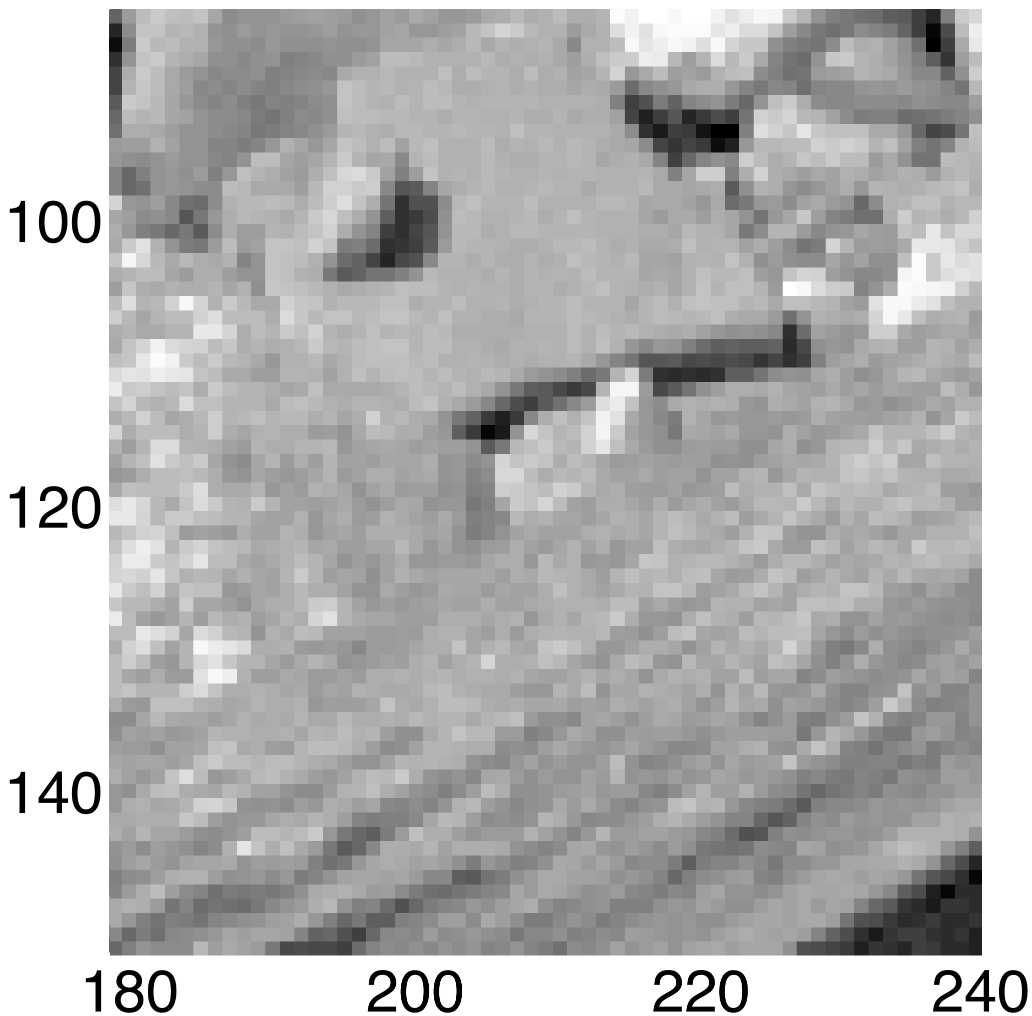
Perception as inference

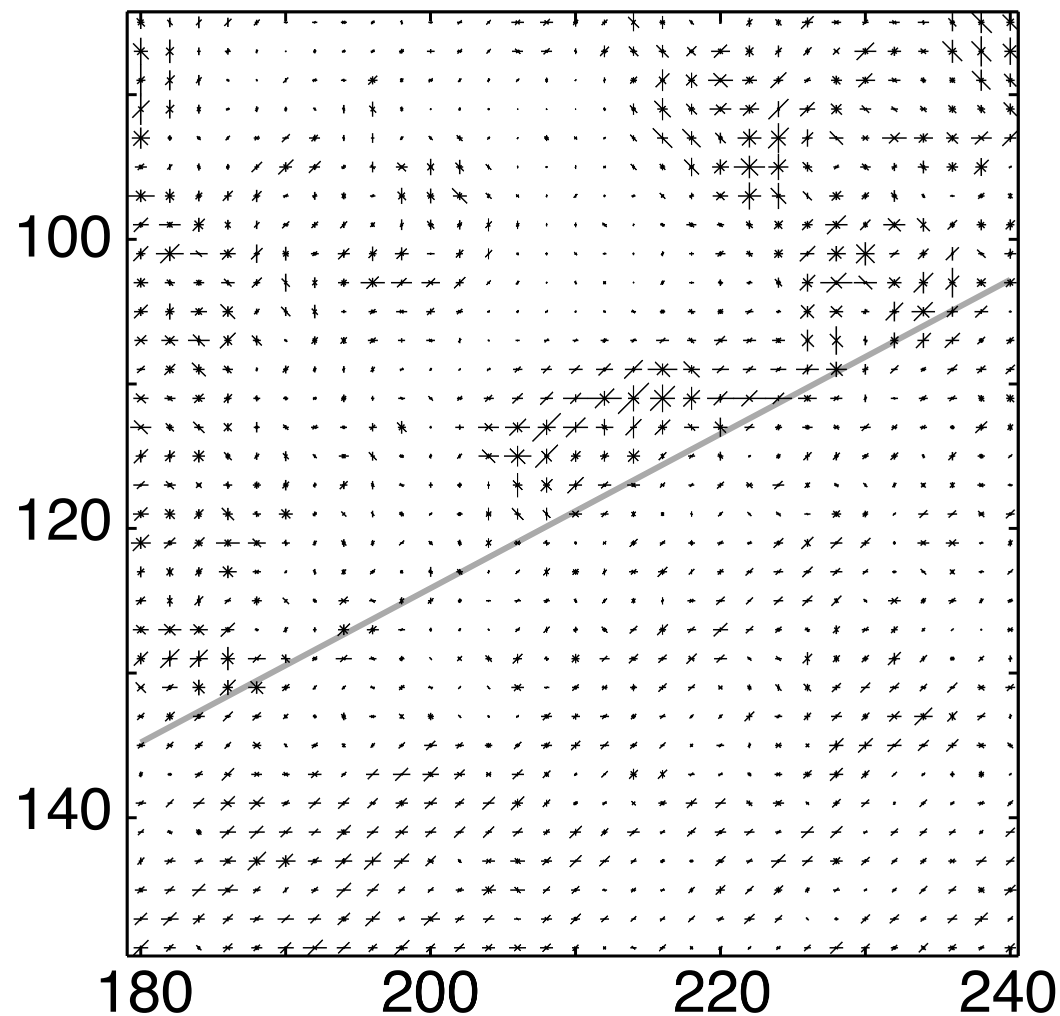


Natural scenes are full of ambiguity



Natural scenes are full of ambiguity





What do these edges mean?

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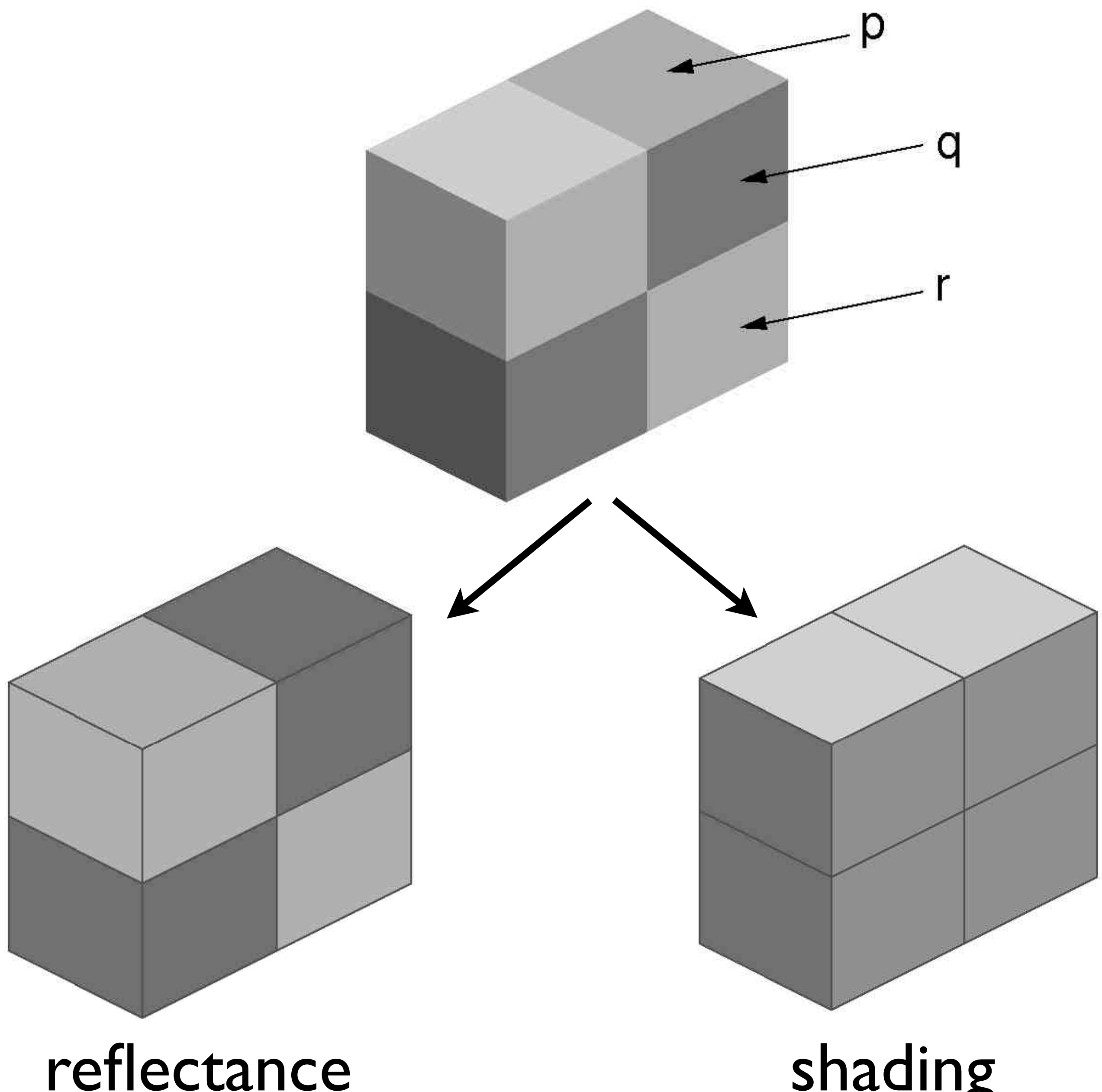
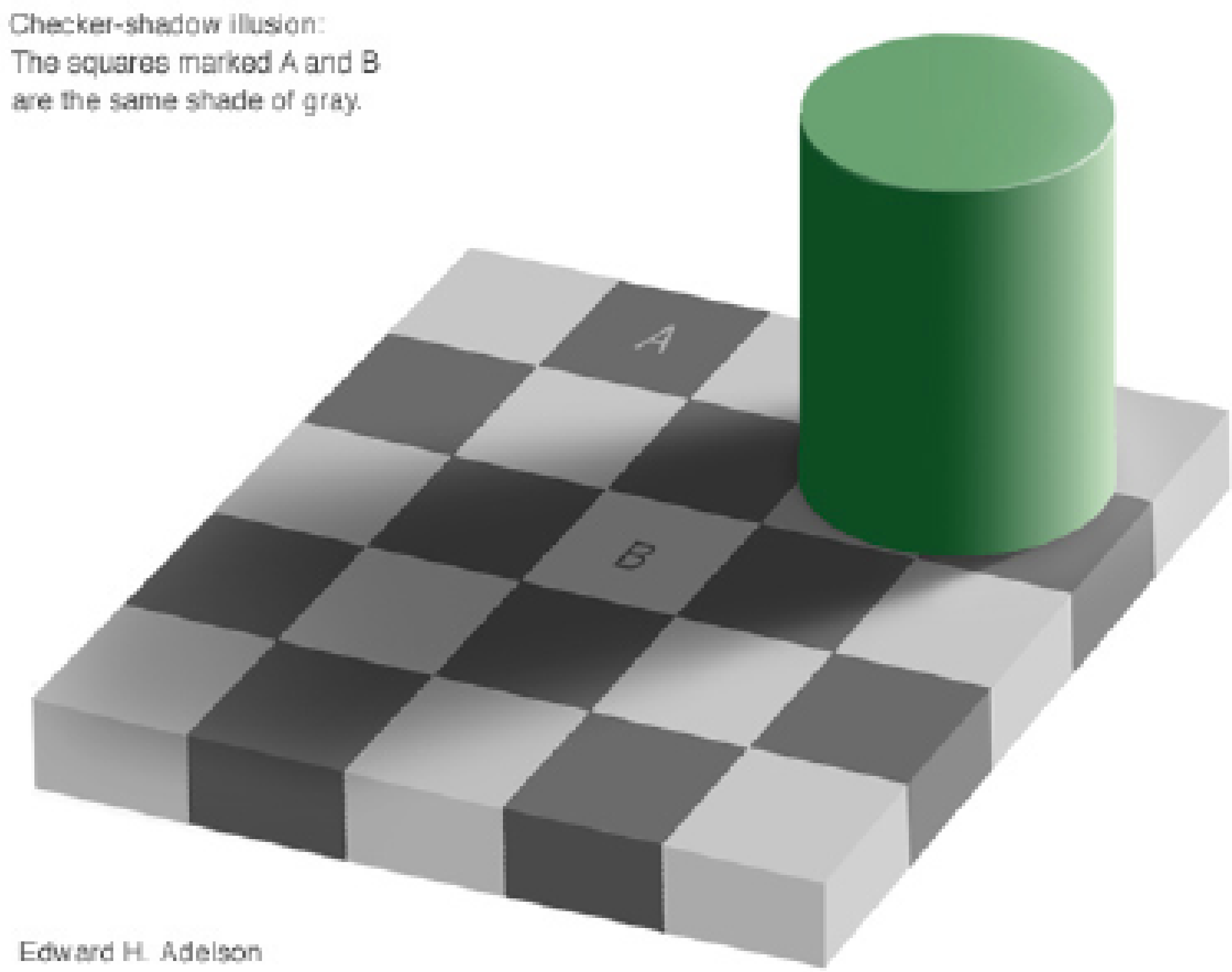
What is this?

What do these edges mean?

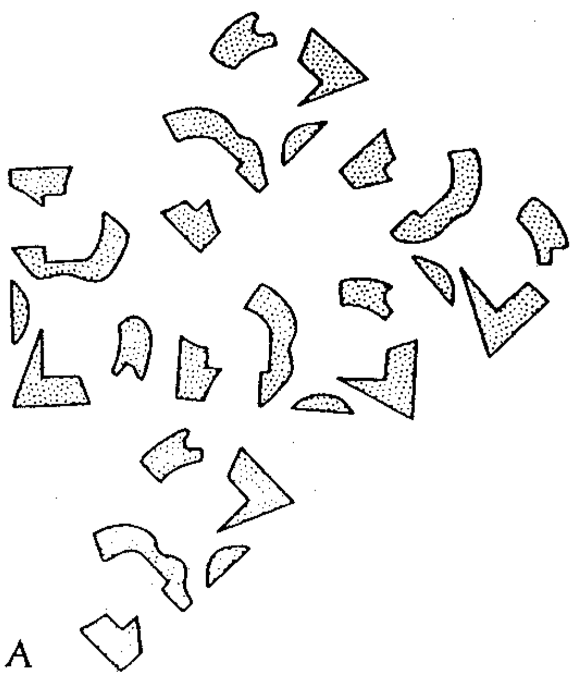


(Adelson, 2000)

Lightness perception depends on 3D scene layout

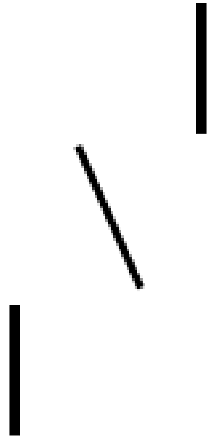


What are the letters?

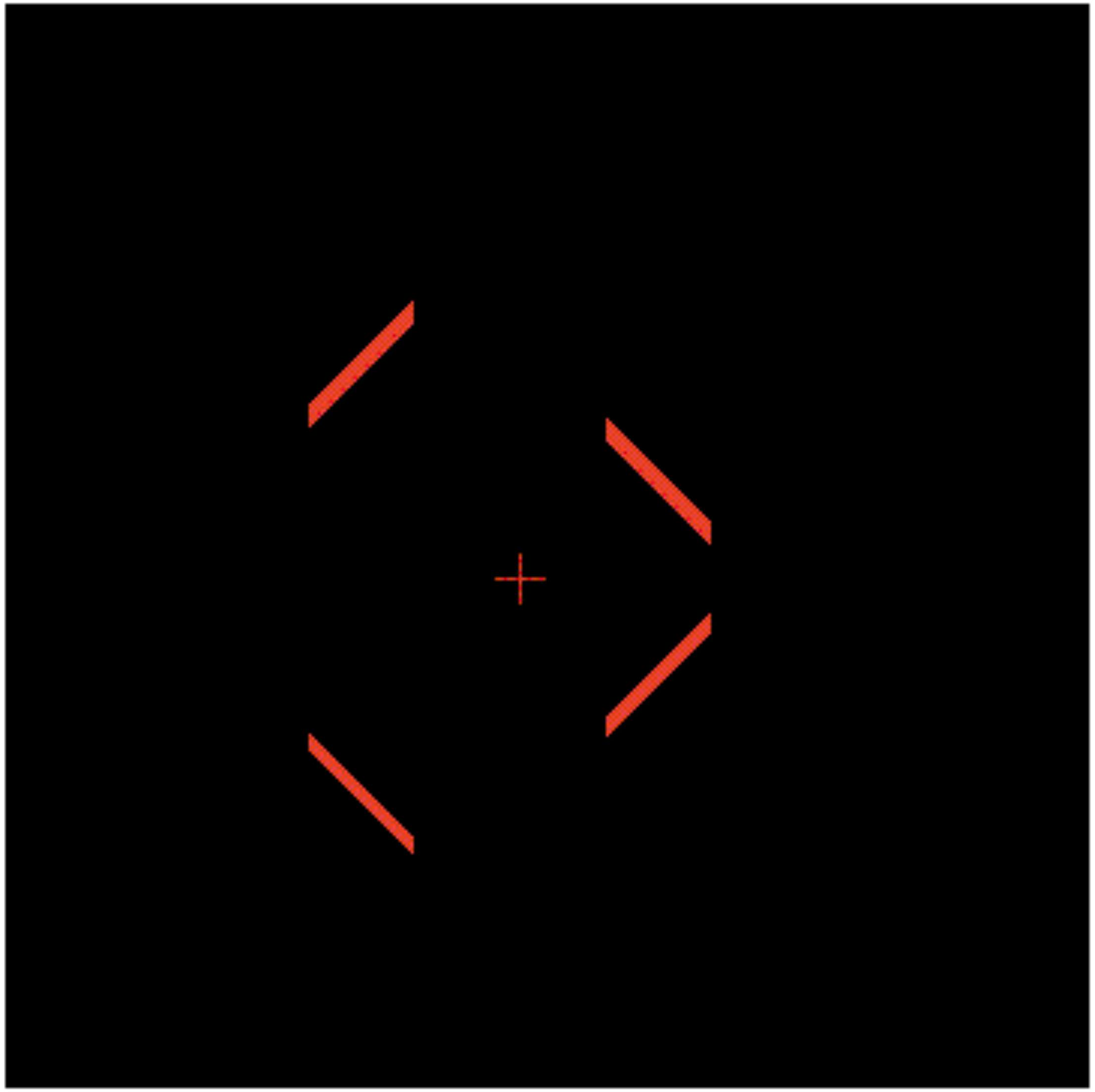


A

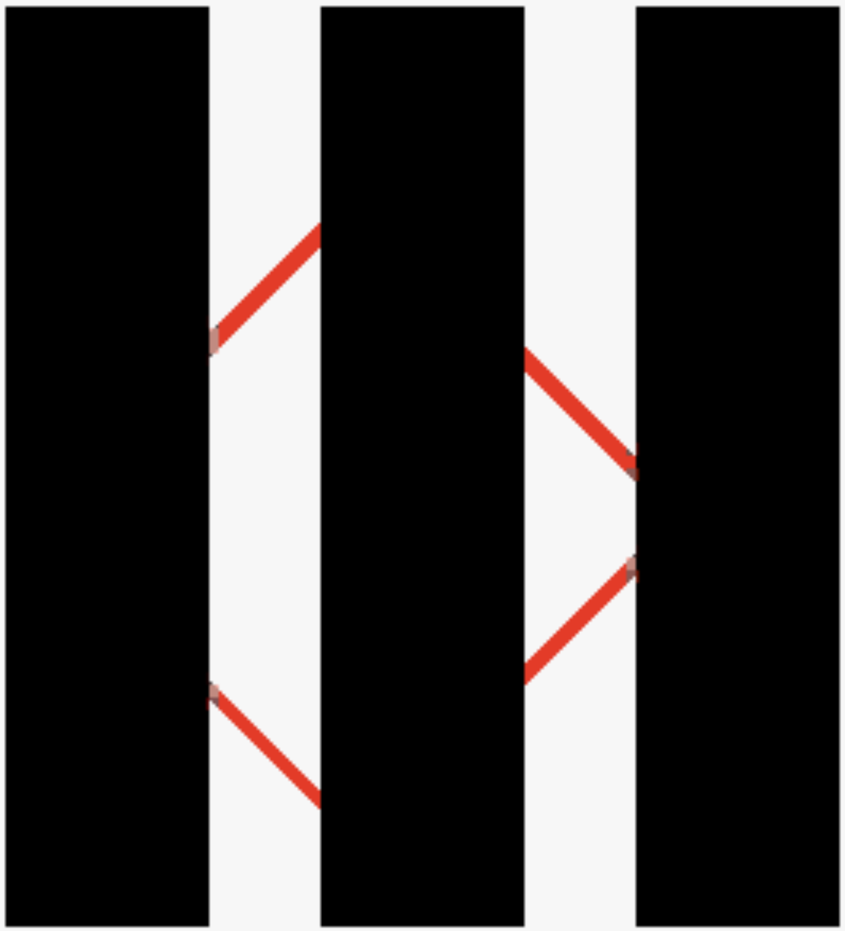
What letter is this?



What is this?

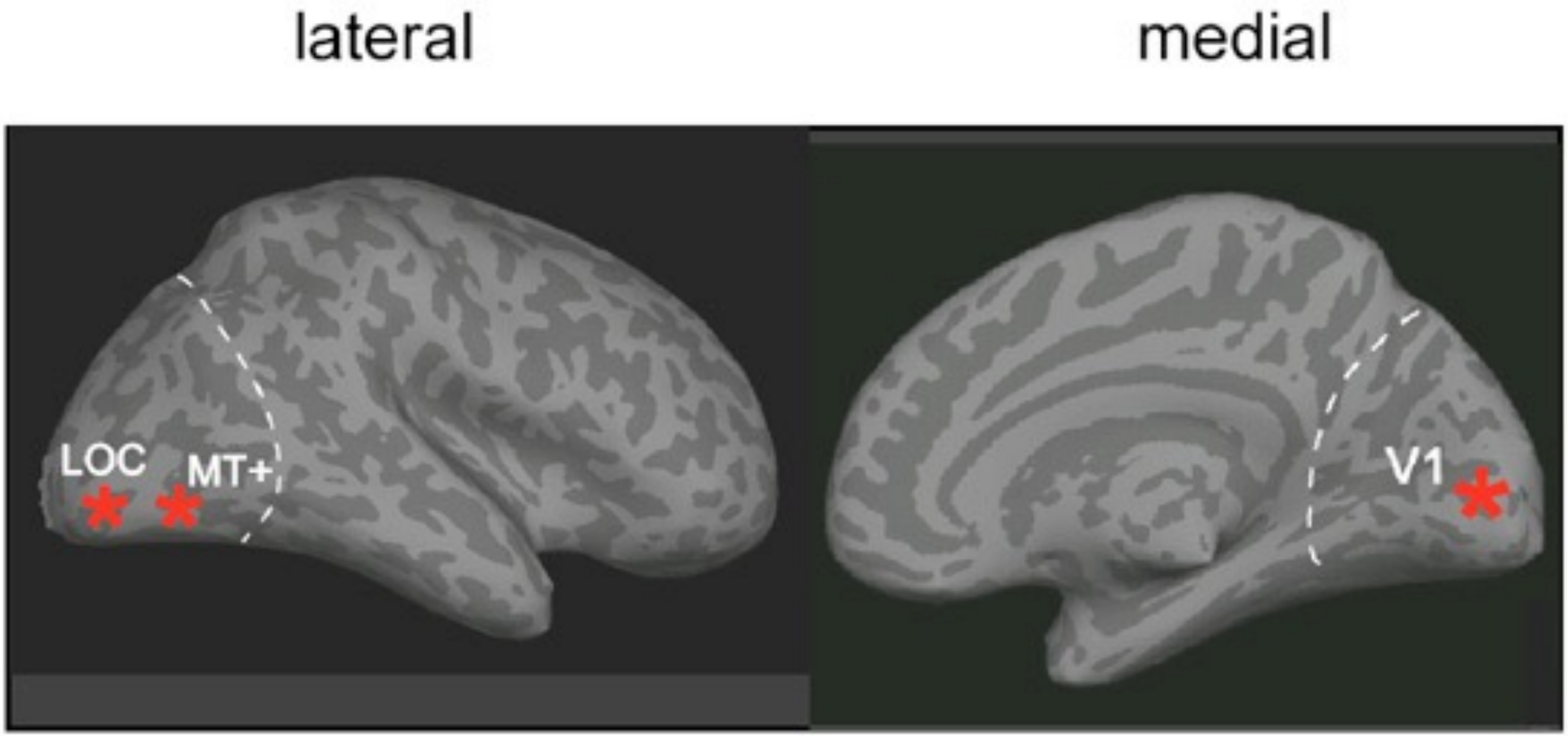


What is this?

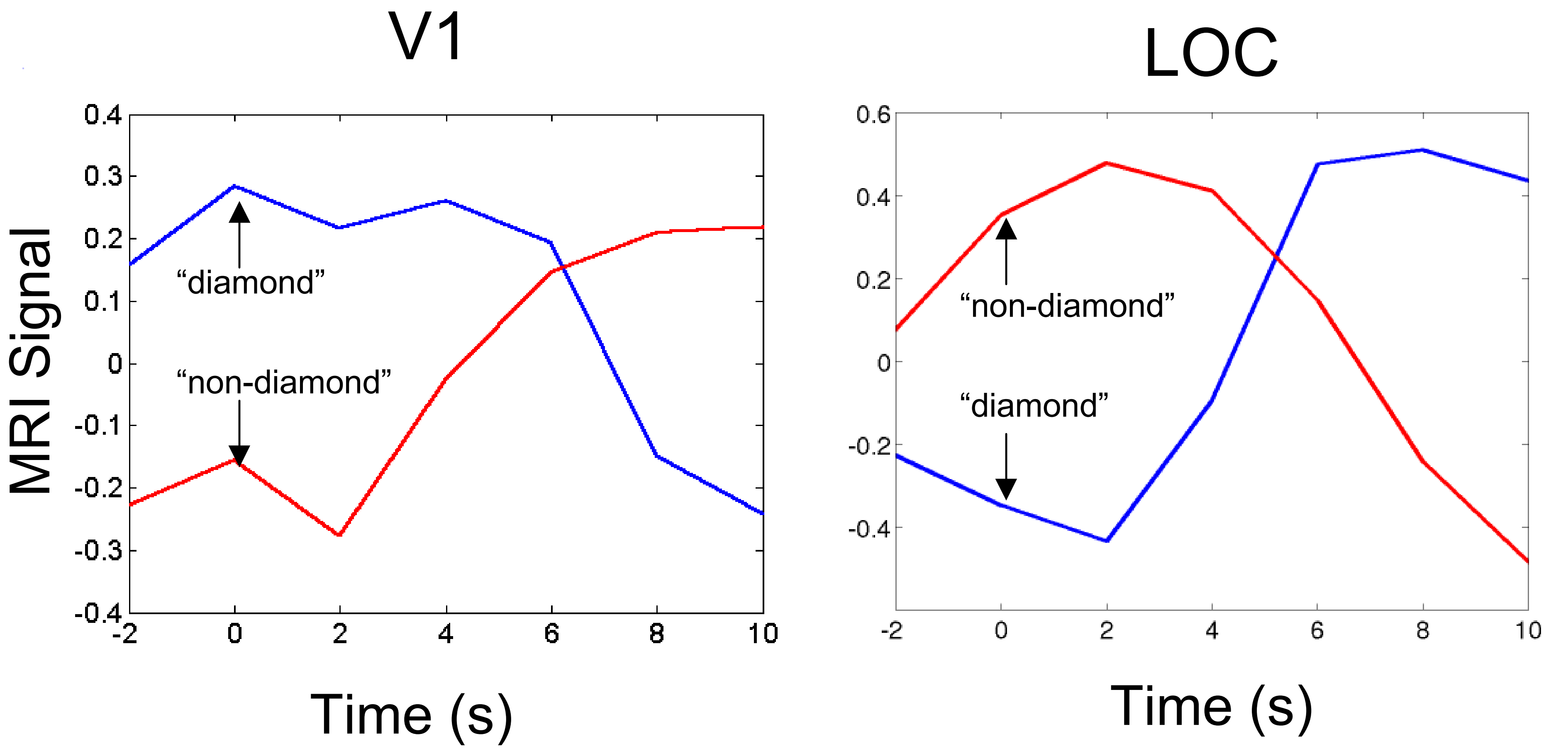


How are these different percepts represented in cortex?

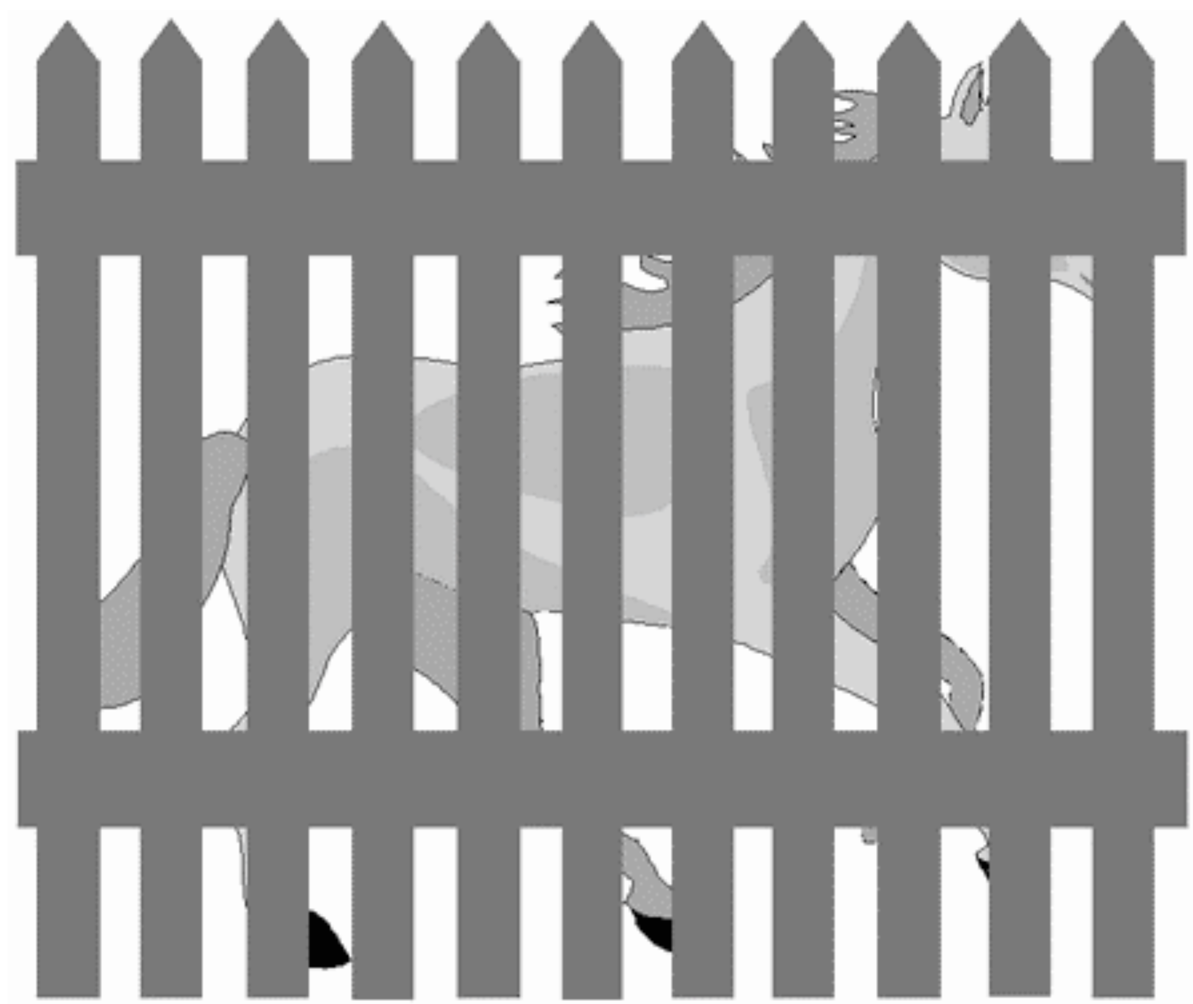
(Scott Murray - Ph.D. thesis)



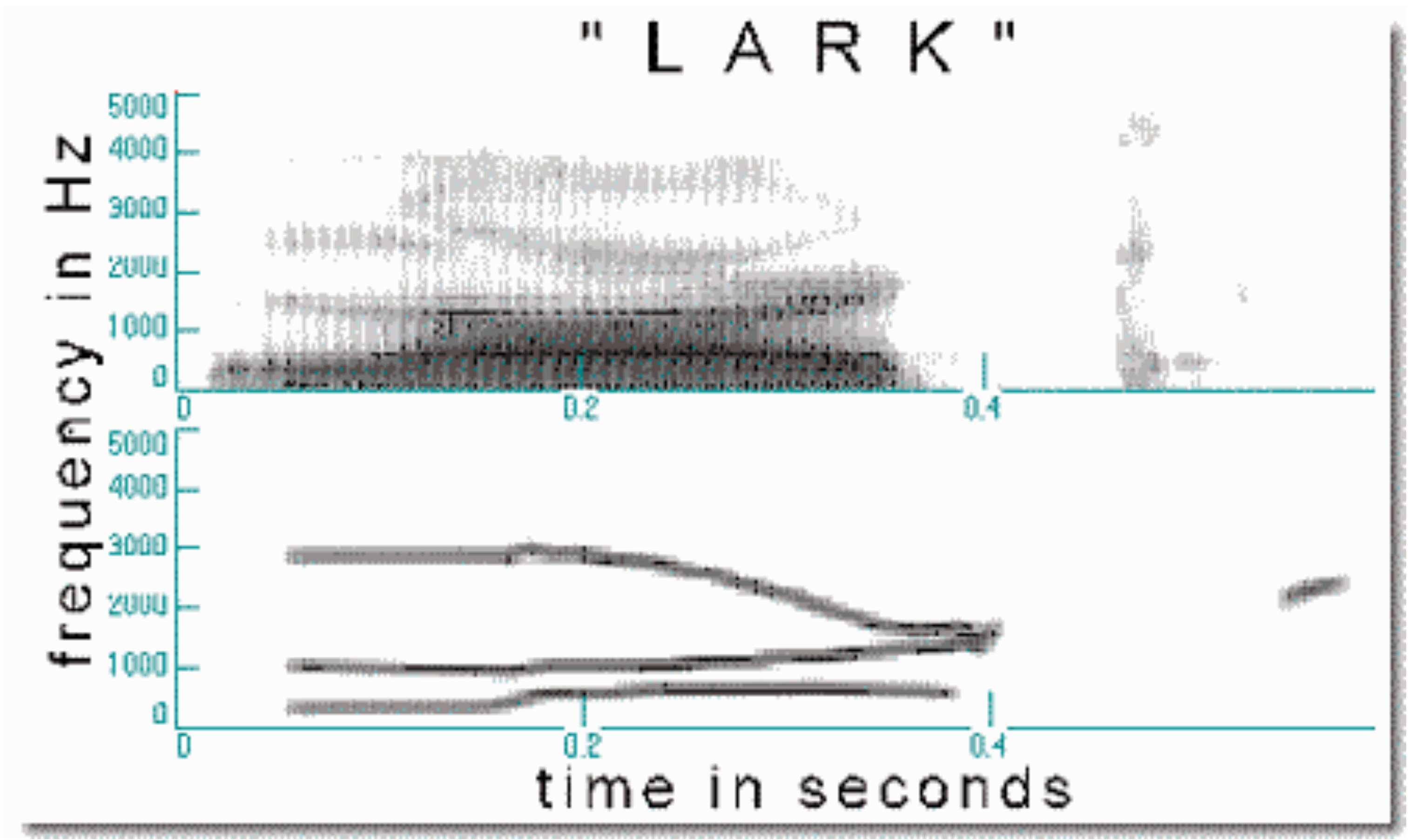
BOLD signal: LOC vs. V1



Picket-fence effect with speech
(from Bregman 'Auditory Scene Analysis')



Sinewave speech



Sinewave speech

Please say what this word is

sill
shook
rust
wed
pass
lark
jaw
coop
beak

Bayes' rule

$$P(E|D) \propto \underbrace{P(D|E)}_{\substack{\text{how data is} \\ \text{generated by} \\ \text{the environment}}} \times \underbrace{P(E)}_{\substack{\text{prior beliefs} \\ \text{about the} \\ \text{environment}}}$$

$$\begin{aligned} E &= \text{the actual state of the environment} \\ D &= \text{data about the environment} \end{aligned}$$

Simple example

$$y = x + n$$

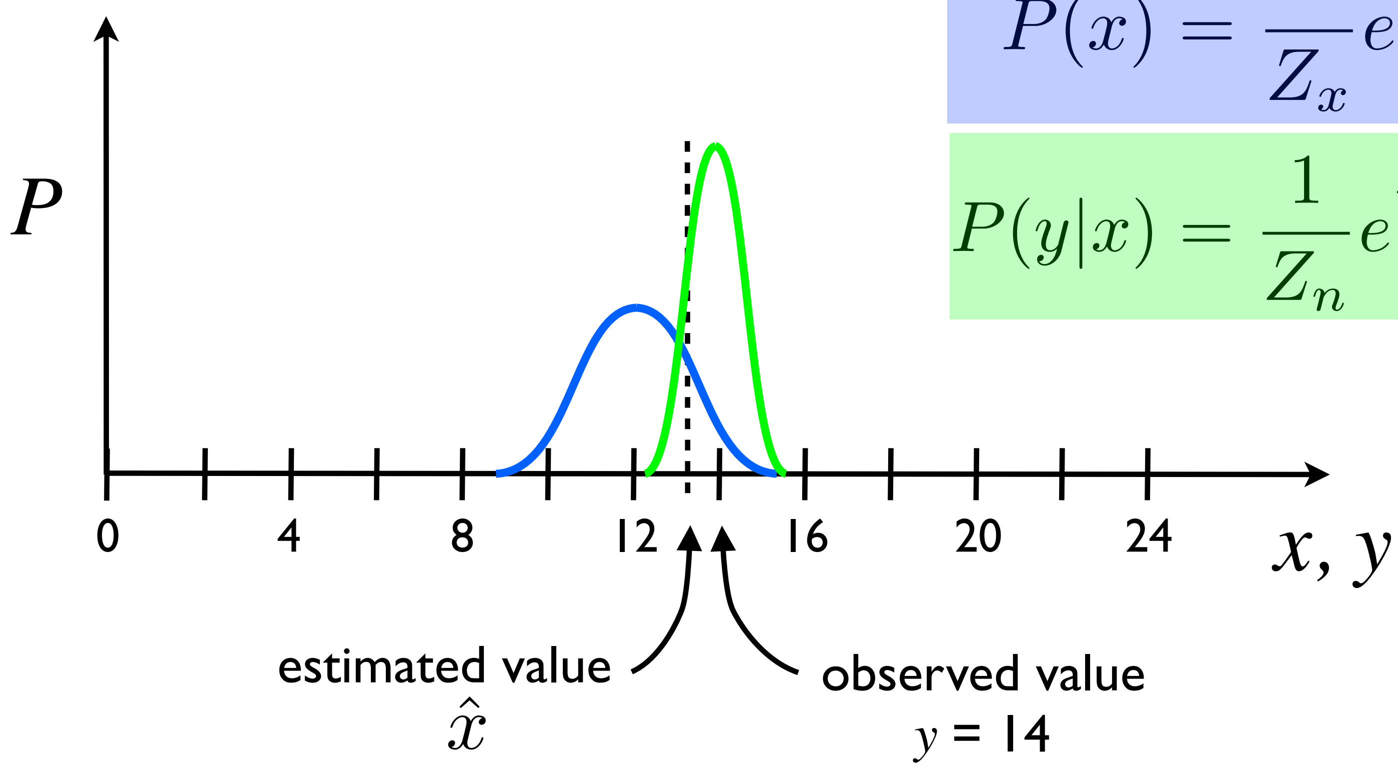
You observe *y*, what is *x*?

$$P(x|y) \propto P(y|x)\,P(x)$$

likelihood prior

$$P(x) = \frac{1}{Z_x} e^{-\frac{(x-\mu_x)^2}{2\sigma_x^2}}$$

$$P(y|x) = \frac{1}{Z_n} e^{-\frac{(y-x)^2}{2\sigma_n^2}}$$



How to compute $\hat{x}$?

$$P(x|y) \propto P(y|x)\, P(x)$$

$$= \frac{1}{Z_n} e^{-\frac{(y-x)^2}{2\sigma_n^2}} \; \frac{1}{Z_x} e^{-\frac{(x-\mu_x)^2}{2\sigma_x^2}}$$

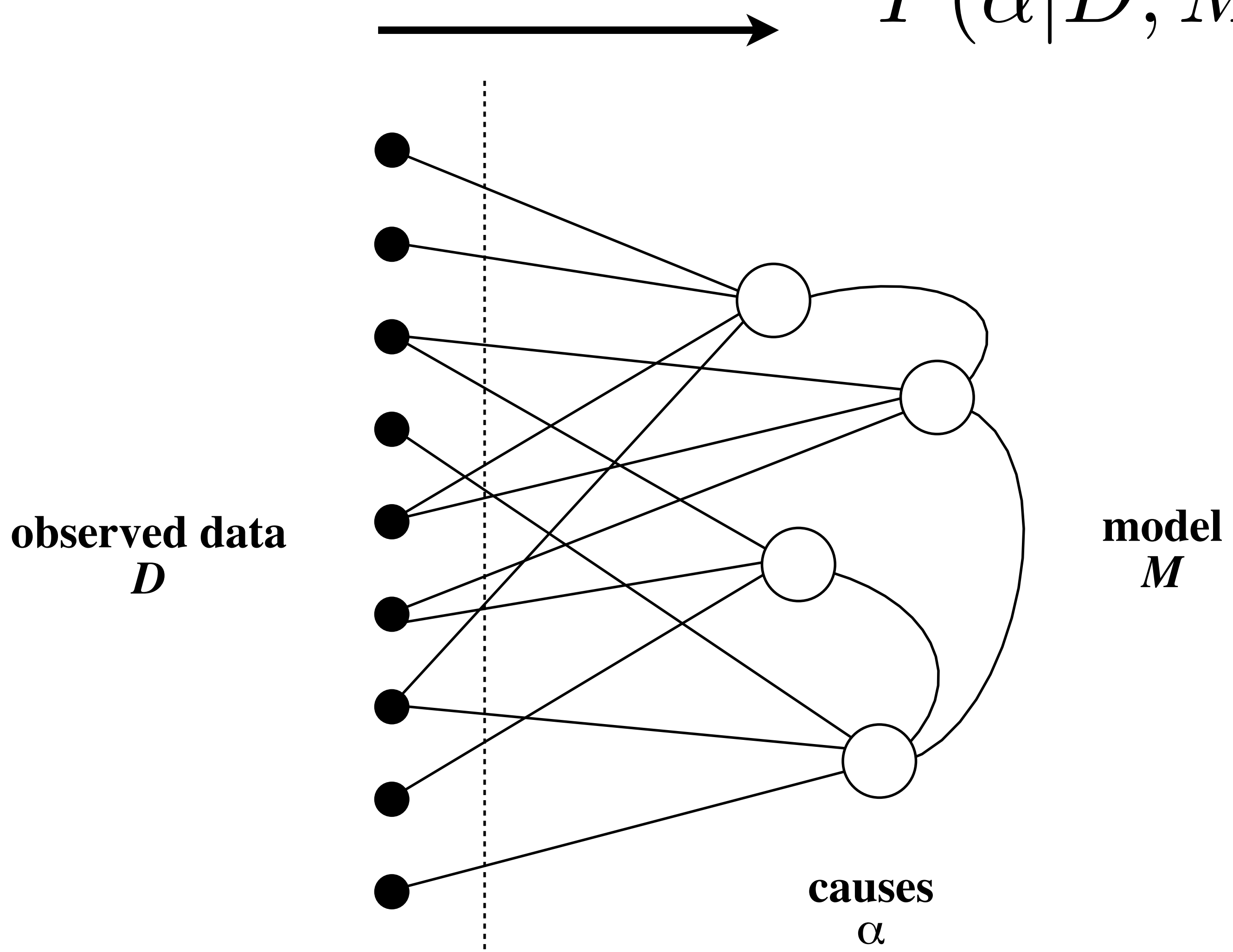
$$-\log P(x|y) = \frac{(y-x)^2}{2\sigma_n^2} + \frac{(x-\mu_x)^2}{2\sigma_x^2} + \text{const.}$$

$$-\frac{\partial}{\partial x} \log P(x|y) = -\frac{(y-x)}{\sigma_n^2} + \frac{(x-\mu_x)}{\sigma_x^2} = 0$$

$$\Rightarrow \boxed{\hat{x} = \frac{\sigma_x^2\, y + \sigma_n^2\, \mu_x}{\sigma_x^2 + \sigma_n^2}}$$

Generative models

inference $P(\alpha|D, M)$



$P(D|\alpha, M)$ explanation or prediction

Inference:

$$P(\alpha|D, M) \propto P(D|\alpha, M)\, P(\alpha|M)$$

Explanation or prediction:

$$P(D|\hat{\alpha}, M) \quad \text{with} \quad \hat{\alpha} = \arg\max_{\alpha} P(\alpha|D, M)$$

Objective for learning:

$$\hat{M} = \arg\max_{M} \langle \log P(D|M) \rangle$$

$$P(D|M) = \sum_{\alpha} P(D|\alpha, M)\, P(\alpha|M)$$