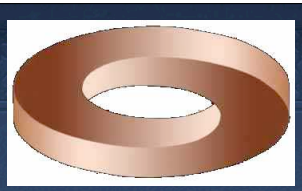
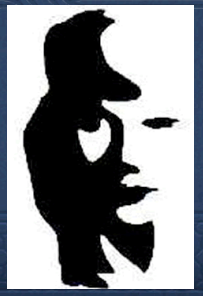
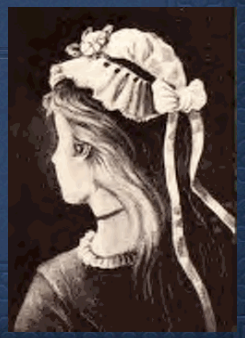


The Neuroscience of Vision III

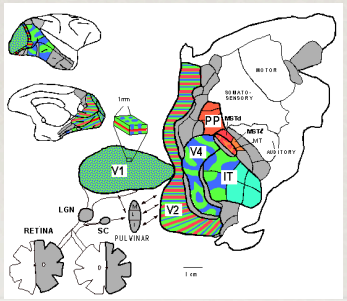


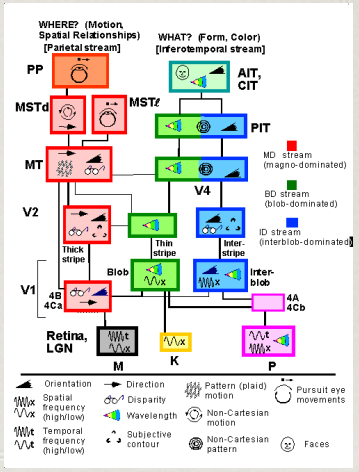


Mechanism for Visual Processing

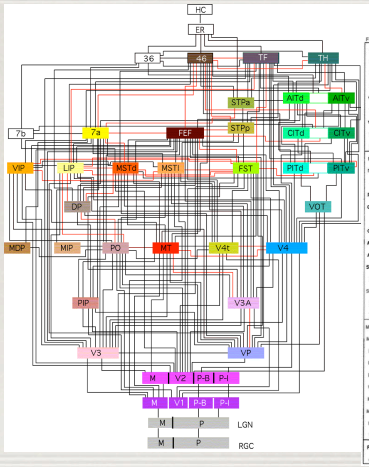
Van Essen: Schema of overall organization of visual processing

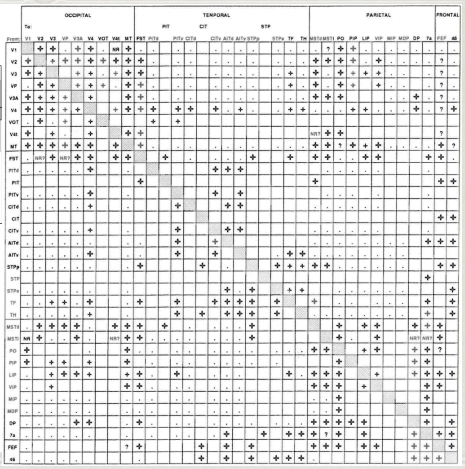
Represents the combined efforts of recording, lesion, stimulation





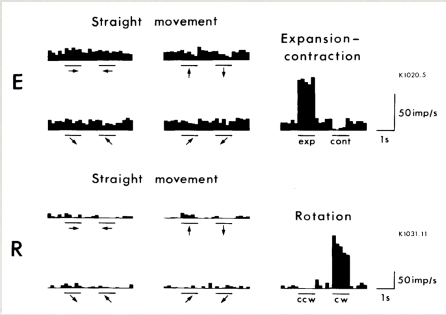
Visual System: A Hierarchical, Interconnected Network

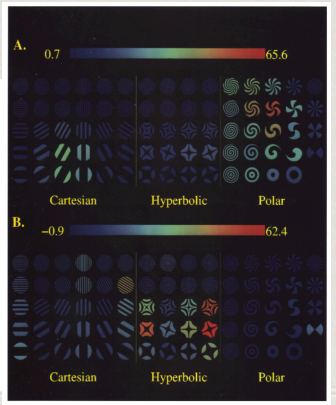




Finding Only What You Look For

- Looking for cells that respond to non-Cartesian movements and shapes, van Essen and Gallant found them in MSTd and V4
- What else should one look for?



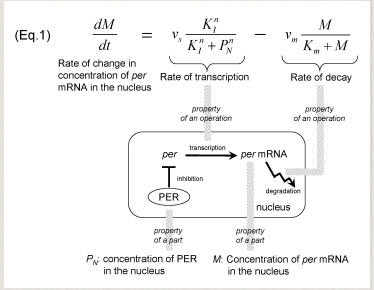


Making Sense of the Visual Mechanism

- The research strategies on which we have focused have primarily been directed at decomposing the mechanism of visual perception to identify its parts and the operations they perform
- But to understand how they carry out the task of seeing, researchers need to recompose the system
- One can recompose a mechanism in a diagram that traces the flow of activity
  - But a diagram is static and fails to reveal how the components will interact
  - Animation is helpful in showing how we think components interact, but their activity is not generated from the components
- Mathematical models can show what happens as the components each perform their operations

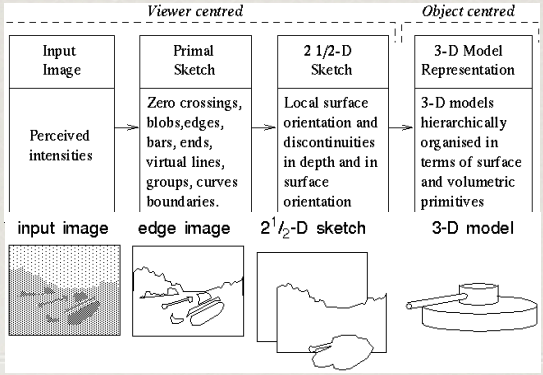
Mathematical Models

- Represent the components of the mechanism as variables
- Write difference or differential equations to specify how each component affects others
  - With parameters specifying the degree of effect
- Solve the equations analytically when possible
  - More commonly, simulate their solution by applying the equations iteratively on a computer



Marr's Algorithmic Account

- "Vision can be understood as an information processing task which converts a numerical image representation into a symbolic shape-oriented representation."

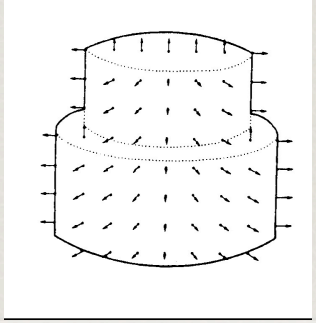


From Image to Primal Sketch

- Extract information regarding edges and intensity changes
  - Zero-crossings
  - Blobs
  - Edge segments
  - Boundaries

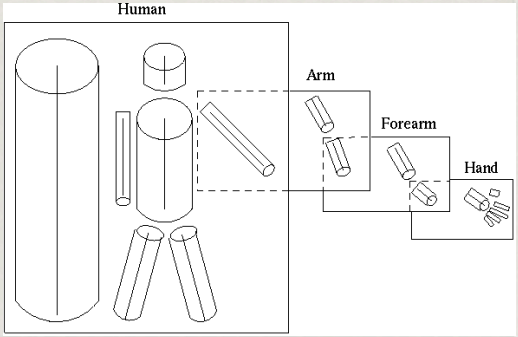
2½D Sketch

- Explicitly represent surfaces, their orientation and rough depth and the contours of discontinuities in a viewer—centered coordinate systems
  - Not a complete 3D representation, but estimate of location of objects relative to the viewer
- Infer depth from binocular disparity, texture gradients, occlusion, convergence, and relative sizes
- Typically, the 2½D sketch captures surfaces as we are aware of them



3D Representation of Objects

- Describes shapes and their spatial organization in an object-centered coordinate system
  - Modular hierarchical representation
- Corresponds more to our *understanding* than our *perceptual awareness*



Marr's Levels

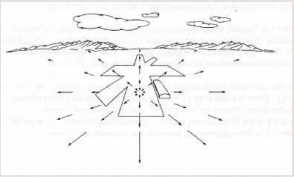
- Reacting to perceived stagnation in understanding the brain based on studying individual neurons or writing programs to describe how they work together, David Marr (1982) argued:
  - "there must exist an additional level of understanding at which the character of the information-processing tasks carried out during perception are analyzed and understood in a way that is independent of the particular mechanisms and structures that implement them in our heads.This was what was missing – the analysis of the problem as an information-processing task. Such analysis does not usurp an understanding at the other levels, of neurons or of computer programs – but is a necessary complement to them, since without it there can be no real understanding of the function of all those neurons."

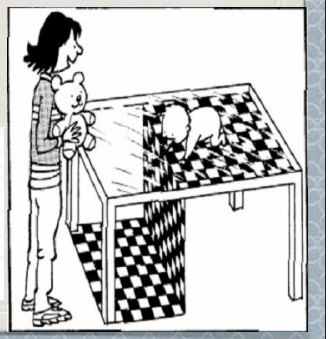
Marr's Levels

- Proposed that understanding had to proceed at three levels of analysis
  - **Computational theory**
    - What is the goal of the computation?
    - Why is it appropriate?
    - What is the logic of the strategy by which it can be carried out?
  - **Representation and algorithm**
    - How can this computational theory be implemented?
    - In particular, what is the representation for the input and output?
    - Why is the algorithm for the transformation?
  - **Hardware implementation**
    - How can the representation and algorithm be realized physically?

Marr vs. Gibson

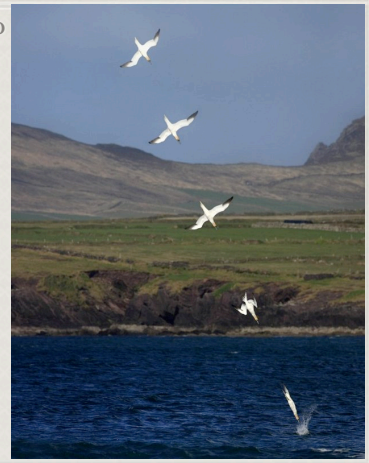
- Marr contended that the process of vision was one of inference—inferring what one is seeing from minimal cues
- Gibson contended that there is rich information "in the light"
  - Specify affordances: possibilities of action
  - And where the agent is and how it is moving in the environment





Information in the Light

- How does the gannet know when to fold its wings when diving into water to catch a fish?
  - Too soon and it is a missile with no guidance system
  - Too late and it is wingless
- David Lee showed that they are sensitive to a simple measure--the rate of expansion of the target in their visual field
- Note: on Van Essen's account neurons in MSTd do exactly this

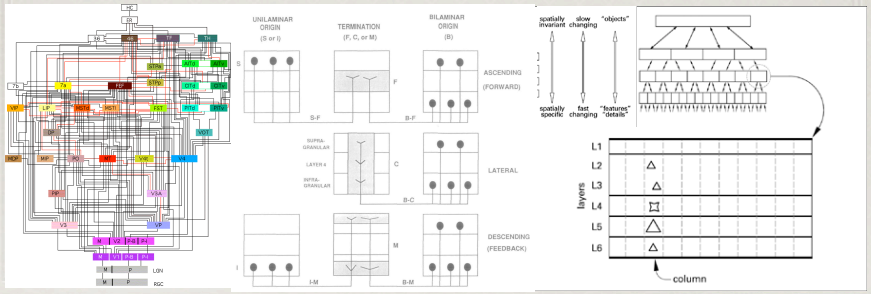


Inferential/computational (Marr) vs. Ecological Perception (Gibson)

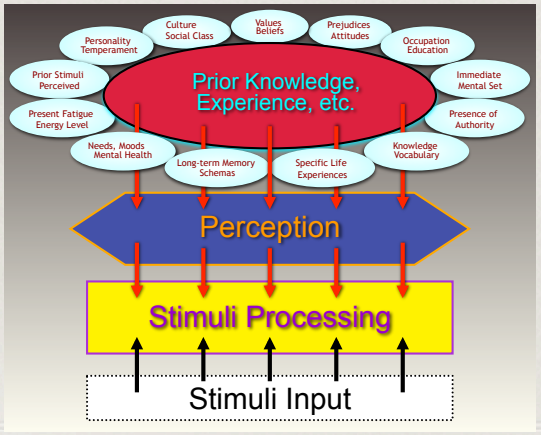
- Marr viewed Gibson as a competitor
  - Gibson spoke of "directly perceiving" information in the light and rejected the idea of vision as making inferences/ computations
- But can they be reconciled?
  - Gibson as providing insight into Marr's computational theory--the account of the goal and appropriateness of perception
  - And perhaps showing that some things don't have to be computed (e.g., a complete, internal representation of the world and our place in it) since the world is always there to give further information as needed

Top Down/Recurrent Connections

- Most of the connections in van Essen's diagram involve both upwards and downwards projections
  - Areas local in the hierarchy have smaller receptive fields whereas those higher cover more of the visual field
  - Fan in going up, fan out going down

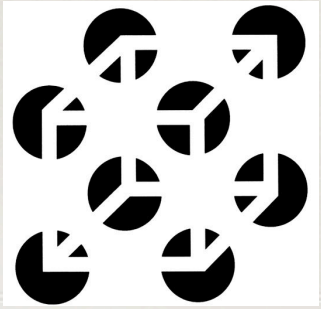


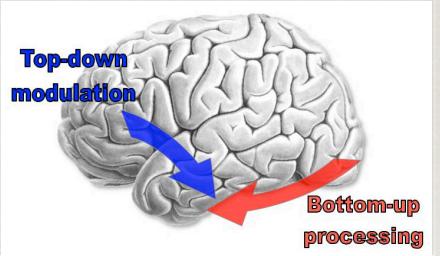
Top-Down and Bottom-Up Interact



Top-Down/Recurrent Connections: What Do They Do?

- The figure below can be seen either as a cube floating in front of 8 discs or as a cube seen through eight holes. Only in the first case do illusory contours appear
- The fact that how the figure appears shifts with how the individual chooses to view it illustrates top-down control





Richard Gregory on Top-Down Perception

Learning to See

- Top-down processes can change how the more basic processes operate so that one can learn to see things one hasn't seen before

Top-Down Processing: Nuisance or Useful Strategy?

- Top down processes can easily lead to misperception
  - Seeing what one wants to see rather than what is there
- So why does the brain employ top down processes?

- Helps to resolve ambiguity in sensory input
  - Instantaneous input can be interpreted in many ways
  - Previous context narrows the range of possibilities
- Provides a basis for learning
  - We are constantly predicting how the world will appear next
  - When it fails to fulfill out expectations, the network can adjust so as to predict better in the future