A Recap of Proof Planning and "Hawkins Neuroscience 101"

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Working with:

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What You Will See

- Part 1 (the “boring stuff” by Matt):
  - Very brief recap of proof planning
  - What came of the original plan
  - An intro to Hawkins neuroscience
- Part 2 (the “interesting stuff” by Brendan):
  - Relating brain function to proof planning
  - A link to “understanding”
  - A bit about CONSCS

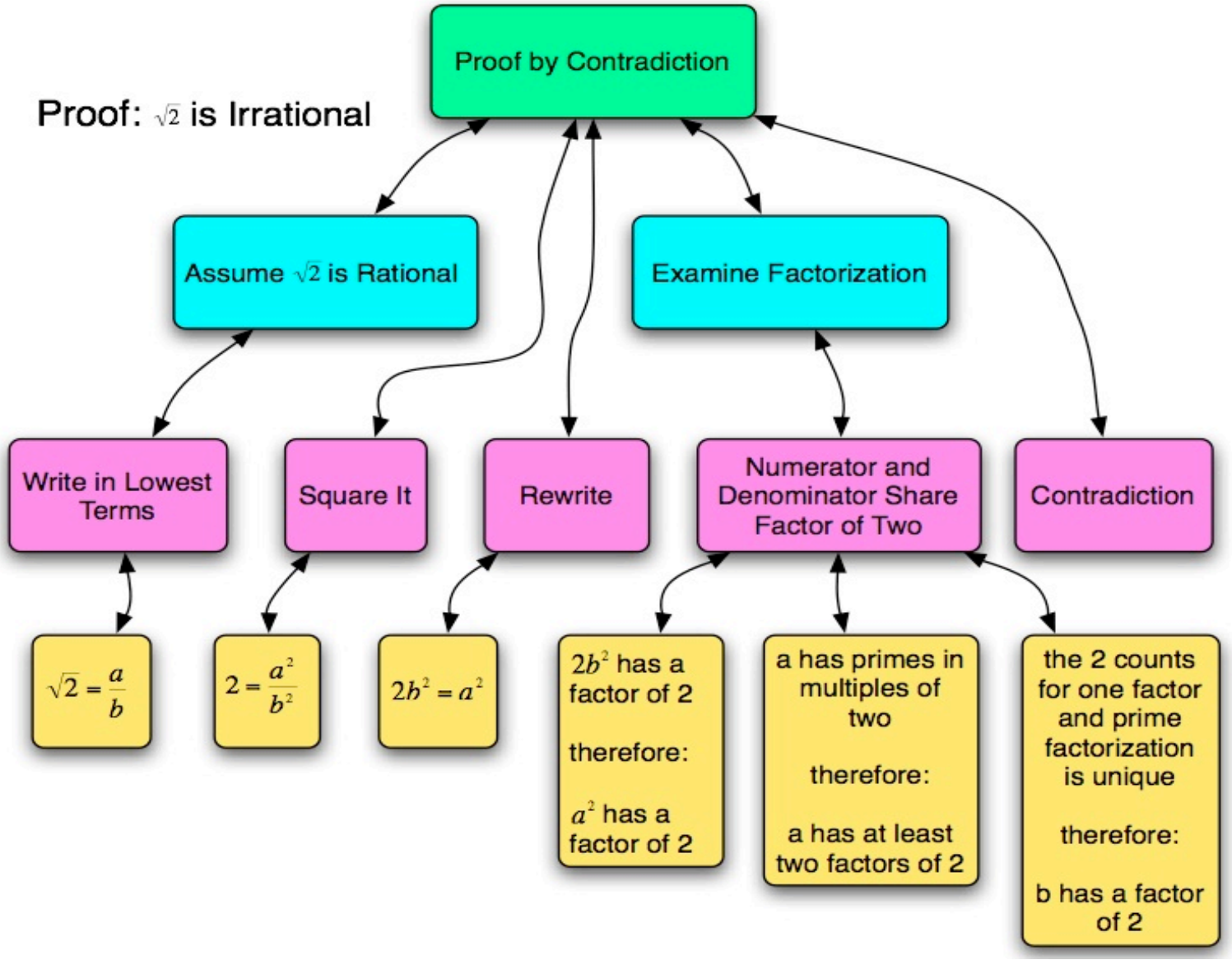
And now to quickly recap…

An ‘elevator talk’ about proof planning

What is a proof plan?

- Anything that guides a proof search
  - Should narrow the search space
  - Should give some idea of what will happen
  - Can be formal or informal, detailed or not
    - “Proof by contradiction”
    - “Use rule A, B, then C some number of times”

A More Concrete Example



Proof Clustering

- The idea
  - Cluster similar proofs together
  - Analyze similarity between the proofs
  - Generalize a rule, technique, or strategy
- Useful in proof planning as the rules are reused for proofs of new theorems
- New rules are more tools on your belt

Our Goal

- Implement automatic proof clustering for the Ωmega theorem prover
  - This implied working with extended regular expressions
  - [a,a,b,c], [a, b, d], [a, a, a, b, c] = (a*)b(c|d)
  - Wanted the smallest sparse regular expression that generated the cluster

The Outcome

- Generating these regular expressions was not easy to do
- Regular expressions were arbitrary
- Were they even appropriate?
- Instead, we looked for some real inspiration…
  - …and so the brain was found

Welcome Class…

to “Hawkins Neuroscience 101”

Who is Jeff Hawkins anyway?

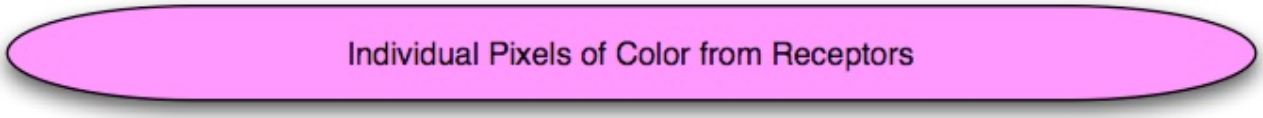
- Founder: Palm Computing, Handspring
- Deep interest in the brain all his life
- Redwood Neuroscience Institute
- “On Intelligence”
  - Variety of neuroscience research as input
  - Includes his own ideas, theories, guesses
  - Increasingly accepted view of the brain

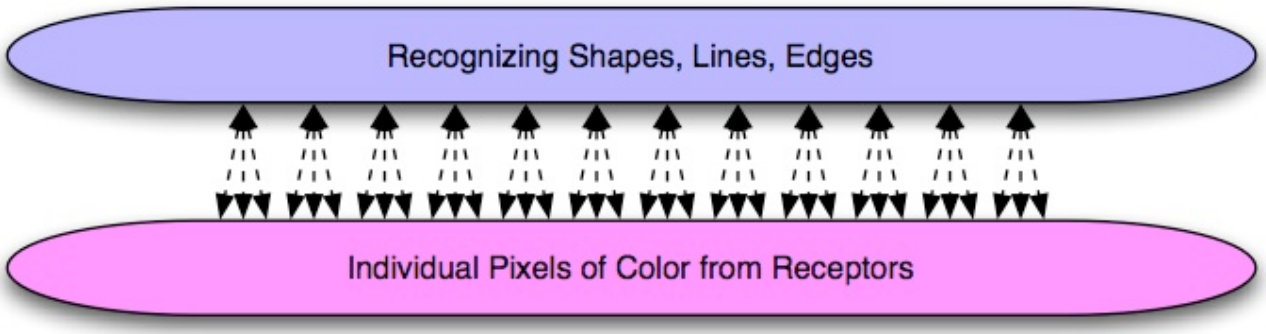
The Cortex

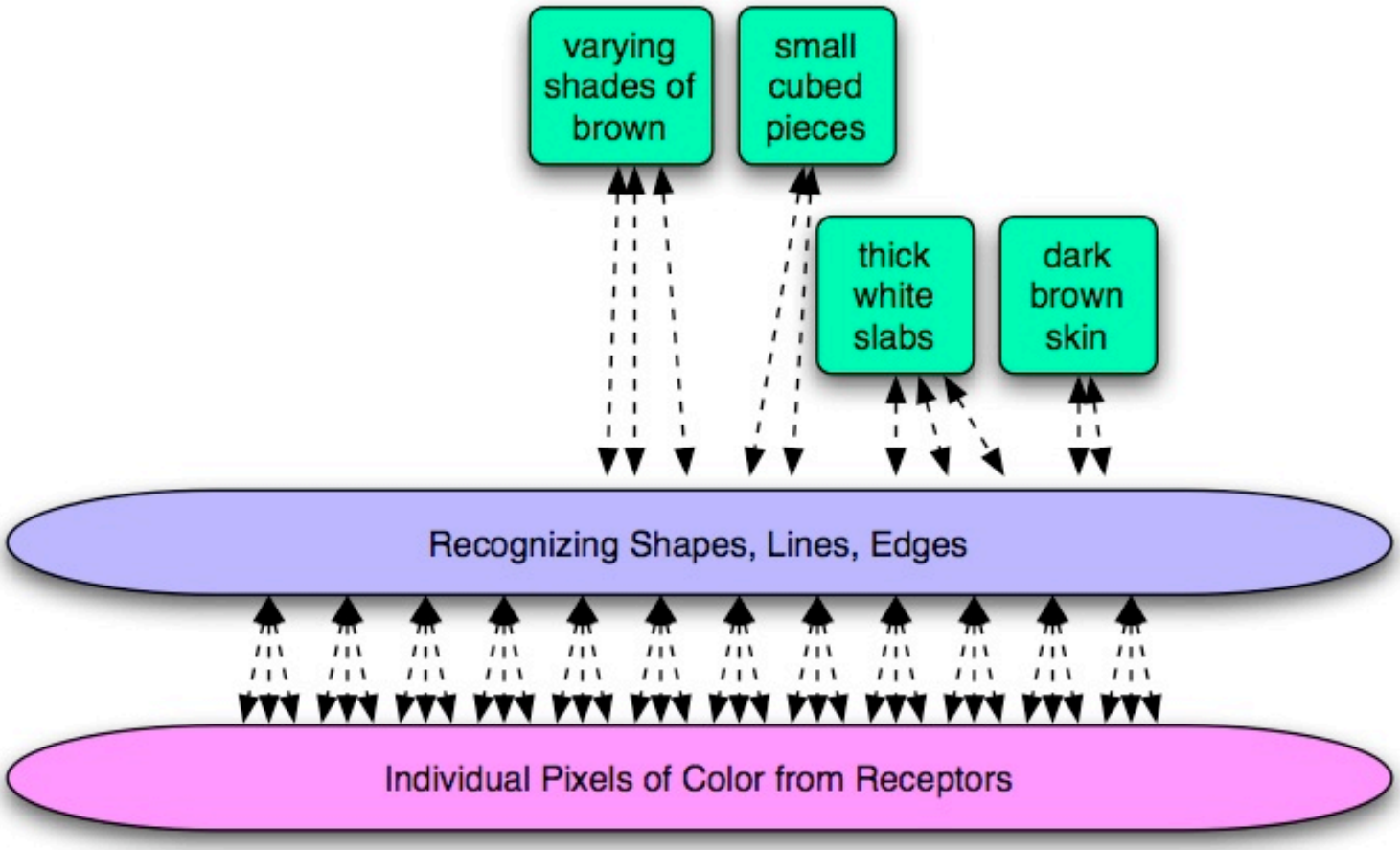
- Hawkins's point of interest in the brain
  - "Where the magic happens"
- Hierarchically-arranged in regions
- Communication up the hierarchy
  - Regions classify patterns of their inputs
  - Regions output a 'named' pattern up the hierarchy
- Communication down the hierarchy
  - A high-level region has made a prediction
  - Alerts lower-level regions what to expect

Examples Would Be Nice

First, a basic picture recognition…


Individual Pixels of Color from Receptors


Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


varying shades of brown
small cubed pieces
thick white slabs
dark brown skin
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors

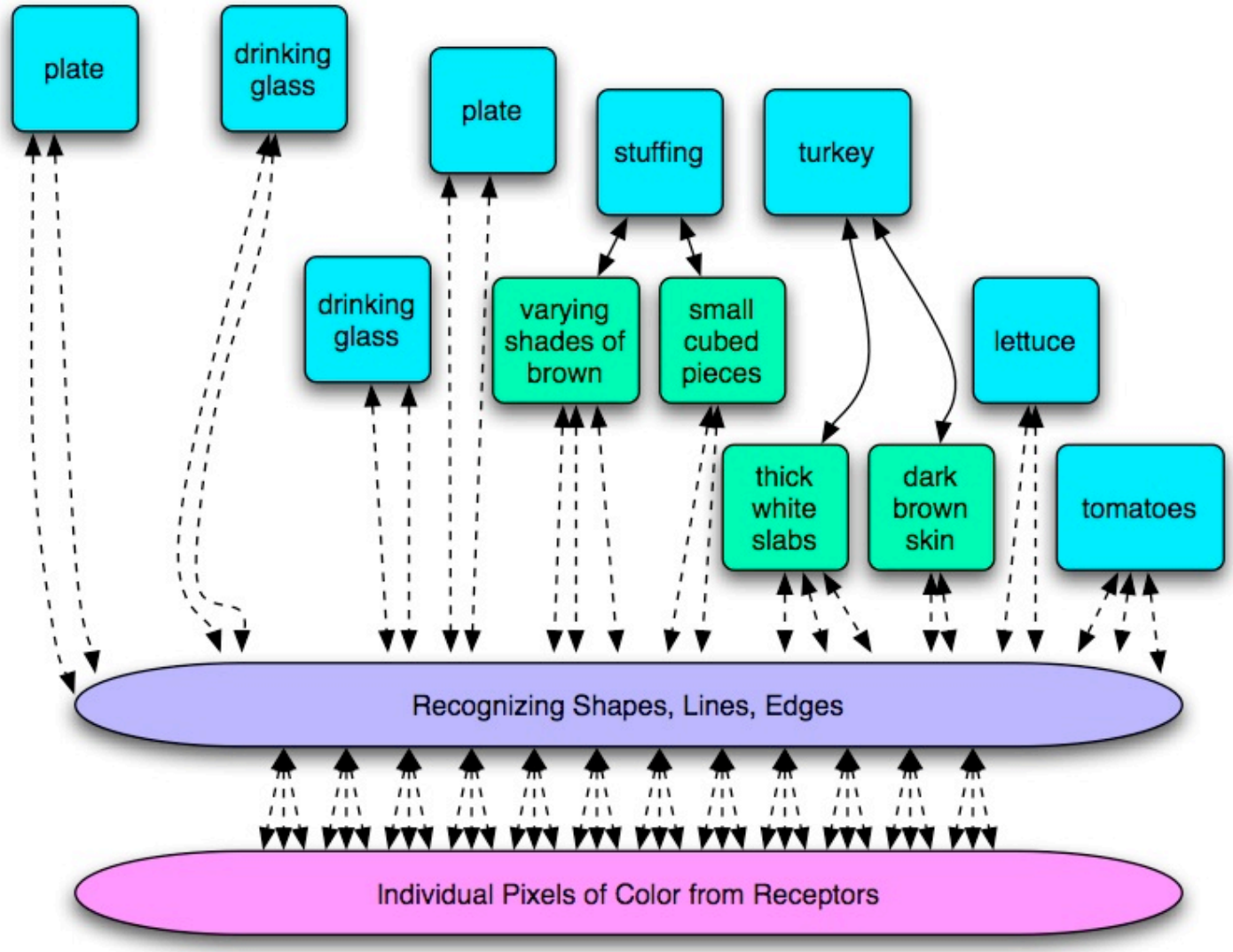


plate
drinking glass
plate
stuffing
turkey
drinking glass
varying shades of brown
small cubed pieces
lettuce
thick white slabs
dark brown skin
tomatoes
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors

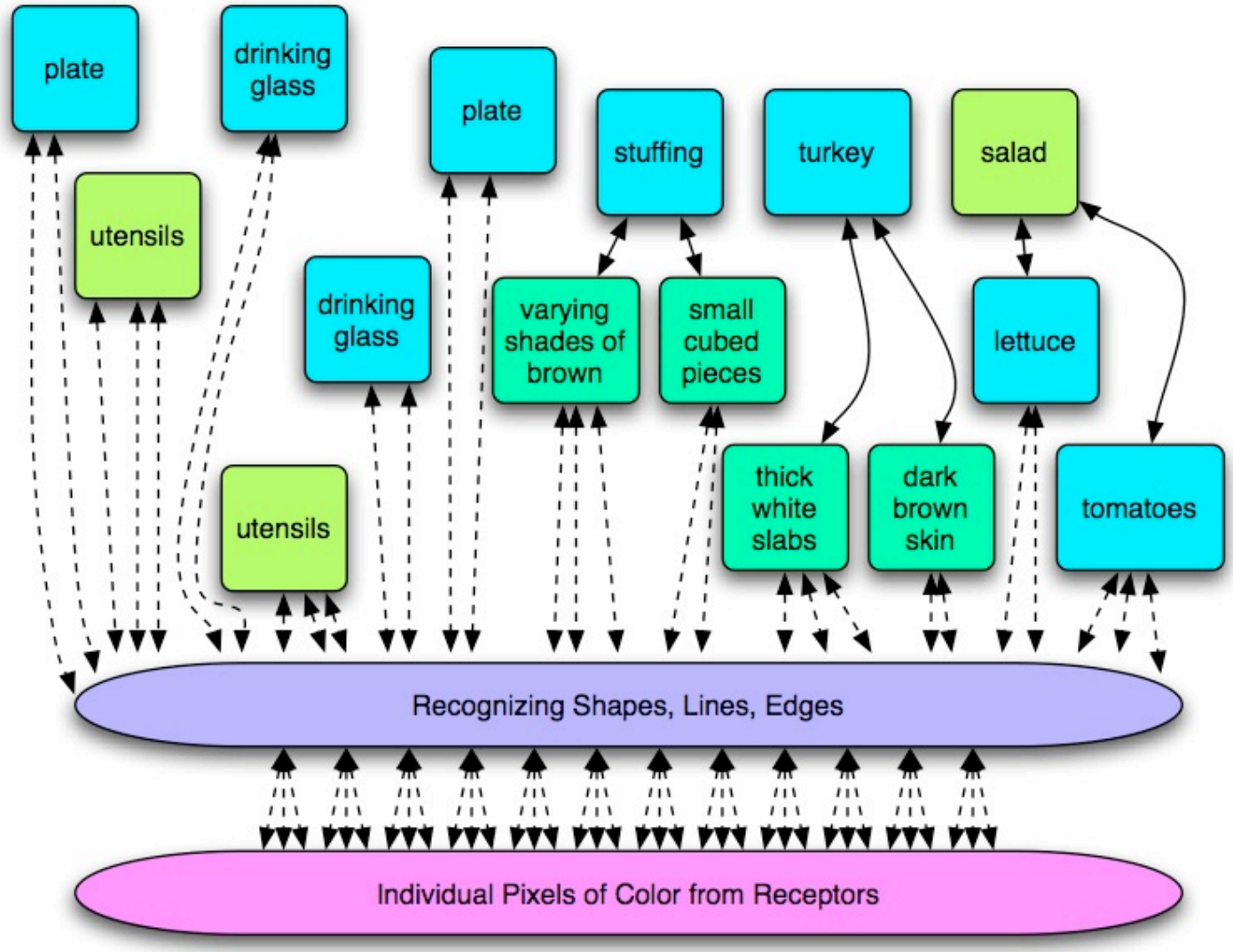
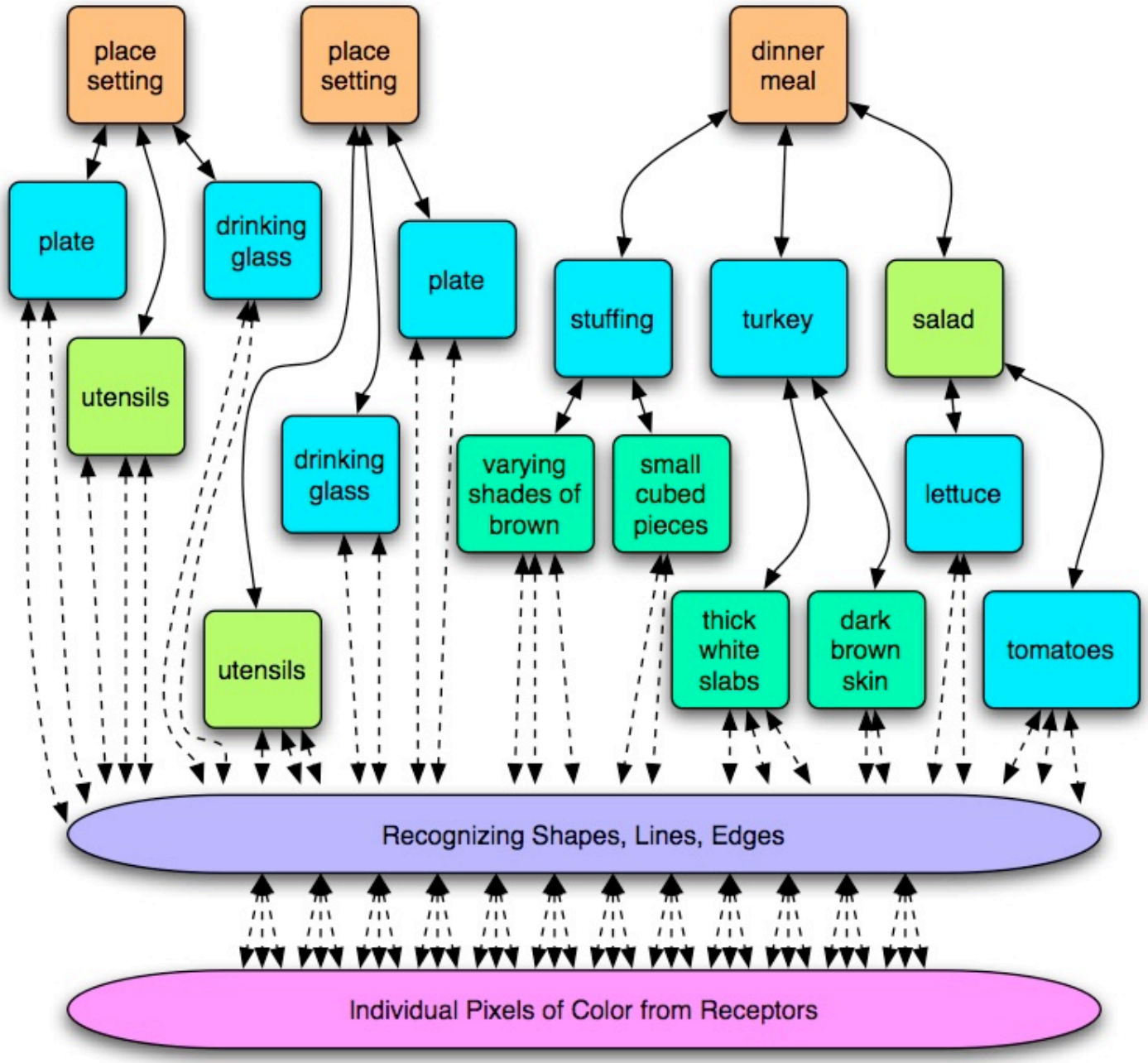
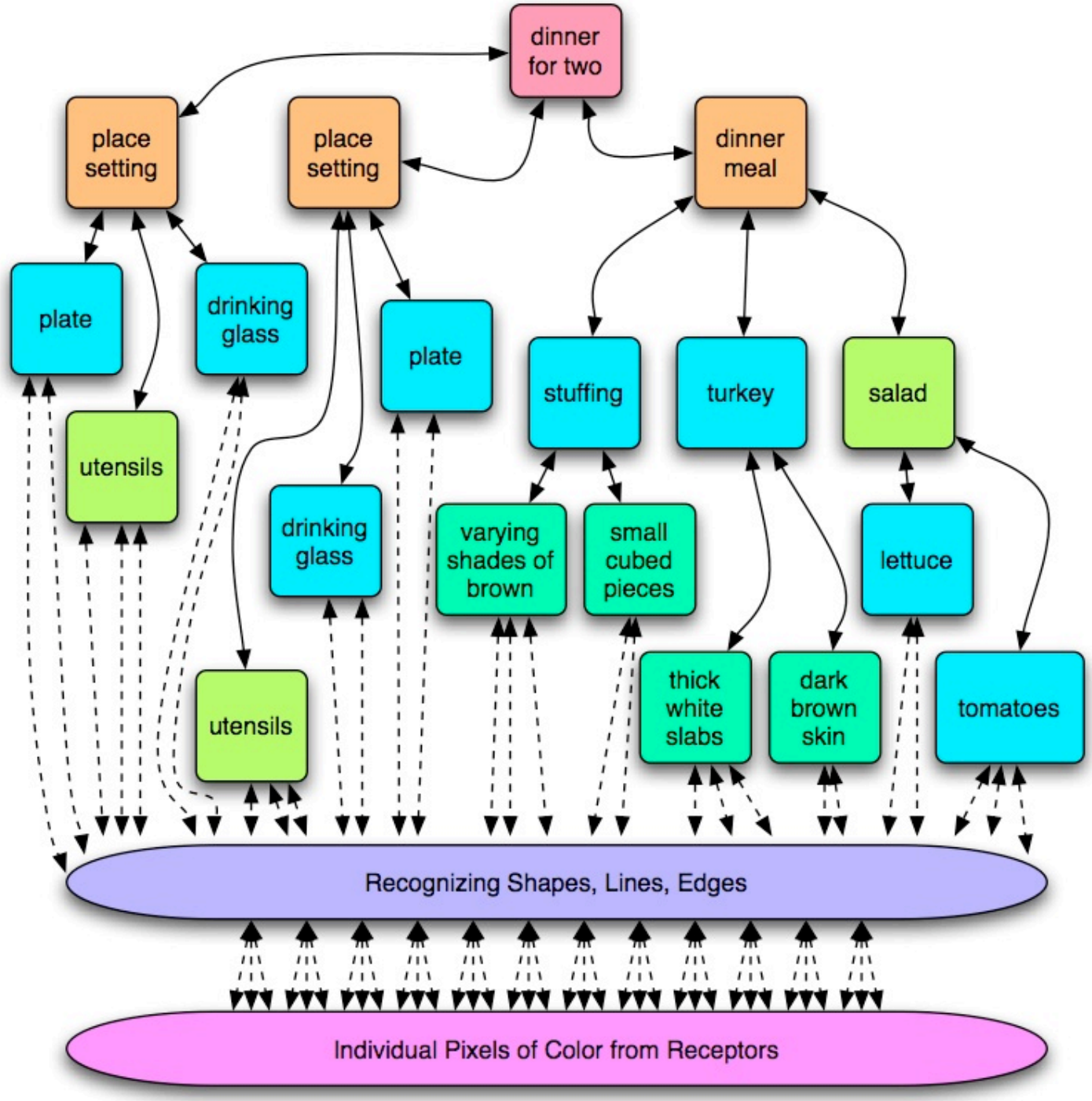


plate
drinking glass
plate
stuffing
turkey
salad
utensils
drinking glass
varying shades of brown
small cubed pieces
lettuce
utensils
thick white slabs
dark brown skin
tomatoes
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


place setting
place setting
dinner meal
plate
drinking glass
plate
stuffing
turkey
salad
utensils
drinking glass
varying shades of brown
small cubed pieces
lettuce
utensils
thick white slabs
dark brown skin
tomatoes
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


dinner for two
place setting
place setting
dinner meal
plate
drinking glass
plate
stuffing
turkey
salad
utensils
drinking glass
varying shades of brown
small cubed pieces
lettuce
utensils
thick white slabs
dark brown skin
tomatoes
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Wait A Minute

- Don’t the higher levels have much, much, much more data to interpret?
  - Not really
  - Maybe even less
- But isn’t it harder to recognize ‘dinner’ than it is to recognize ‘fork’?
  - Surprisingly, no

Back to the Hierarchy

- Lowest visual level inputs pixels
- Second level recognizes edges, lines, etc from known patterns of pixels
- Third level recognizes shapes from known patterns of edges, lines, etc
- Fourth level recognizes objects from known patterns of shapes

One Step at a Time

- The jump between levels is one ‘unit of abstraction’ in a sense
- Patterns of level 16 output are classified and outputted by level 17 as input to 18
- Level X inputs level X-1 data and outputs a classification to level X+1
- Patterns of patterns of patterns of…

Naming is Powerful

- Some region of level 48 inputs ‘fork’, ‘knife’, ‘plate’, ‘glass’, ‘meat’, ‘potatoes’
- That region outputs ‘dinner’
- Not too hard for a brain

Without Names, All is Lost

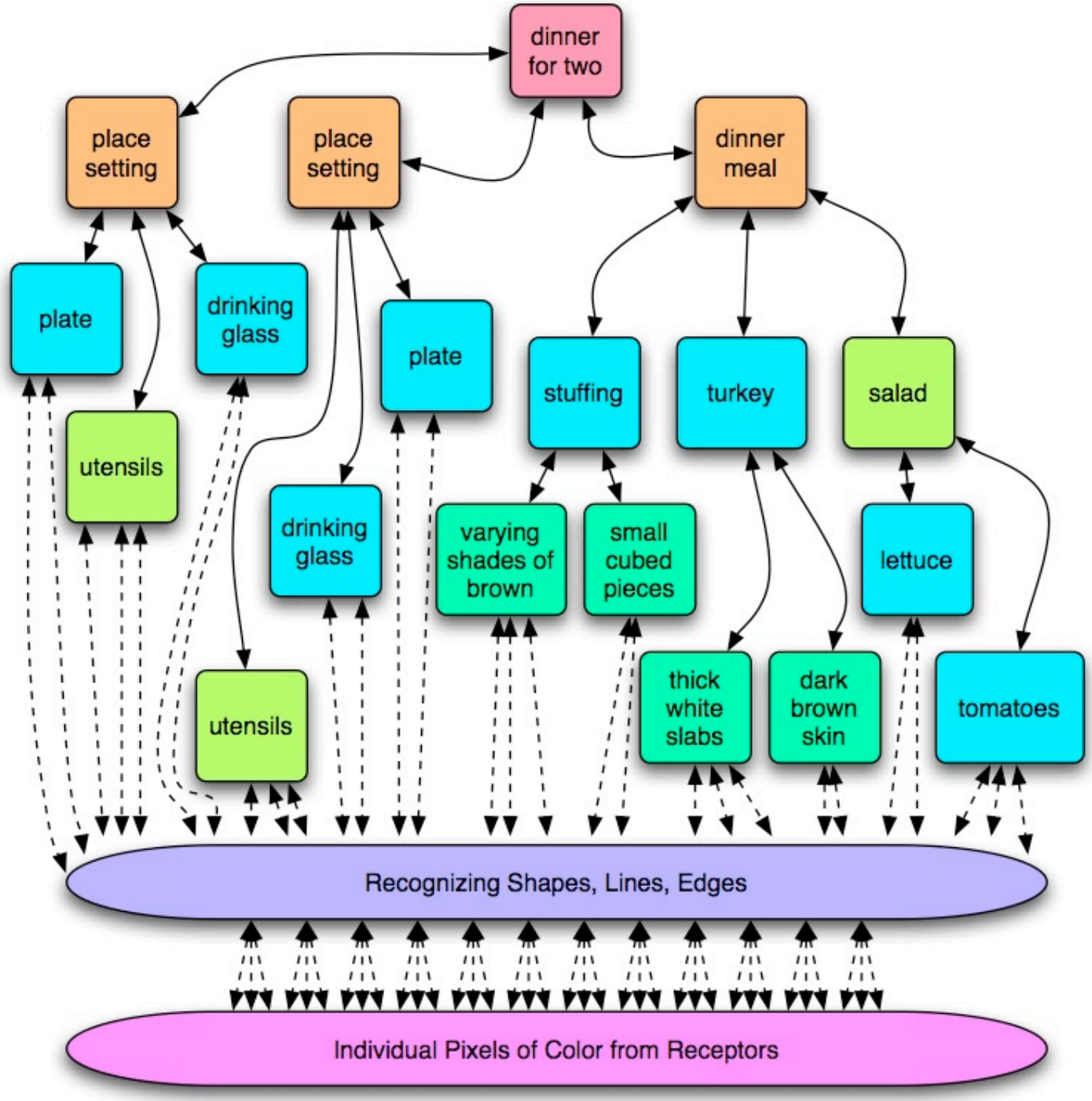
- The raw data for ‘fork’ was:
  - ‘1001101011101110001010110 11…’
  - Could be a million bits of data
- Without names, level 48 is a mess
  - ‘dinner’ = ‘[fork=100…101], [knife=111…110], [plate=001…100], …’
- Before, we had 6 names
- Now, we have to decipher millions of bits

Names as Invariants

- If we look at a table from a 45 degree angle, we see ‘dinner’
- If we look from a 60 degree angle, we still see ‘dinner’
- BUT: all the raw visual data is different
- Still see ‘knife’, ‘fork’, etc so we still output ‘dinner’, but only due to naming
- Lower levels handle the small changes
- The bigger picture doesn’t change

A Further Example

The cortex allows for extension of ideas


dinner for two
place setting
place setting
dinner meal
plate
drinking glass
plate
stuffing
turkey
salad
utensils
drinking glass
varying shades of brown
small cubed pieces
lettuce
utensils
thick white slabs
dark brown skin
tomatoes
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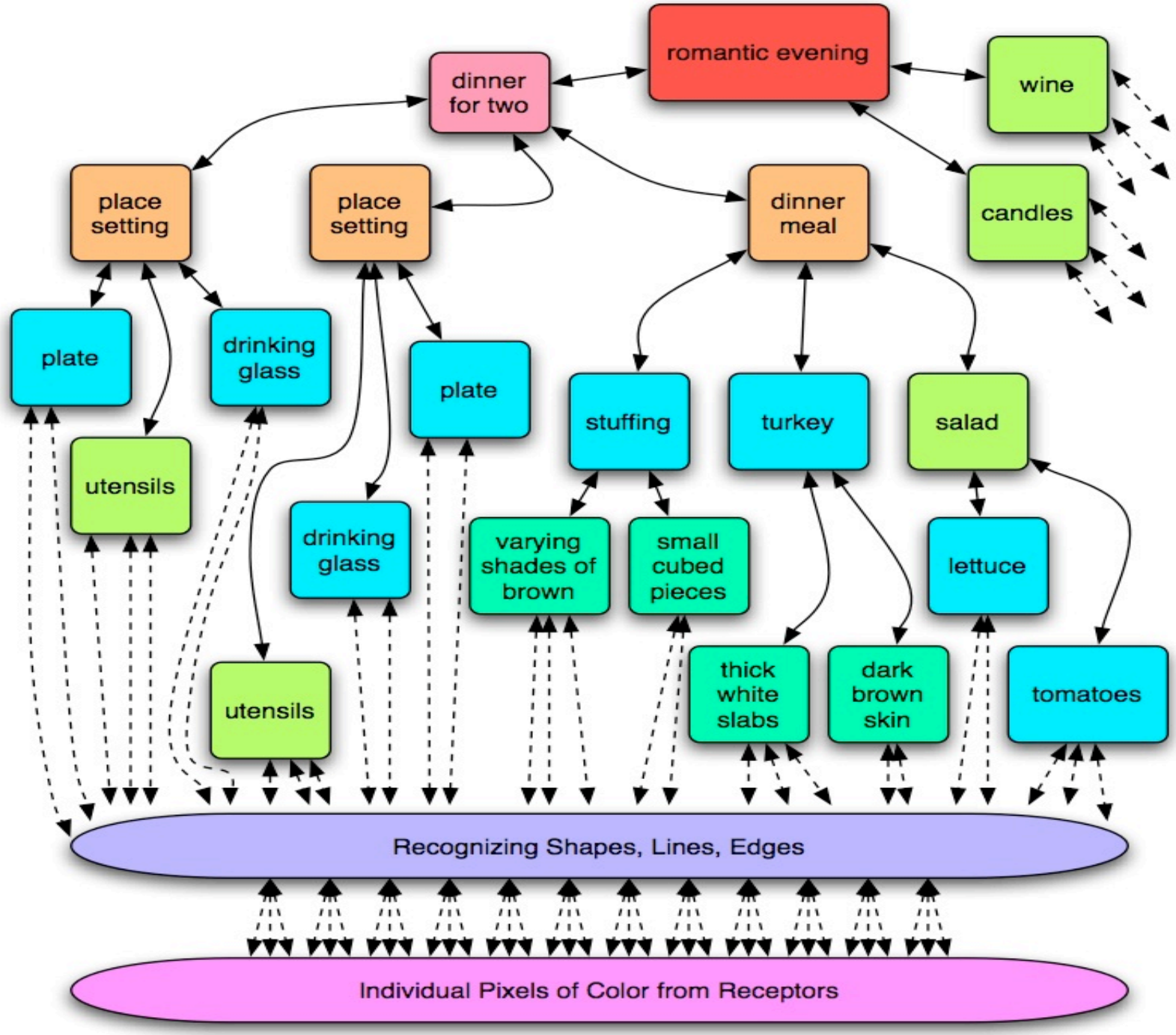
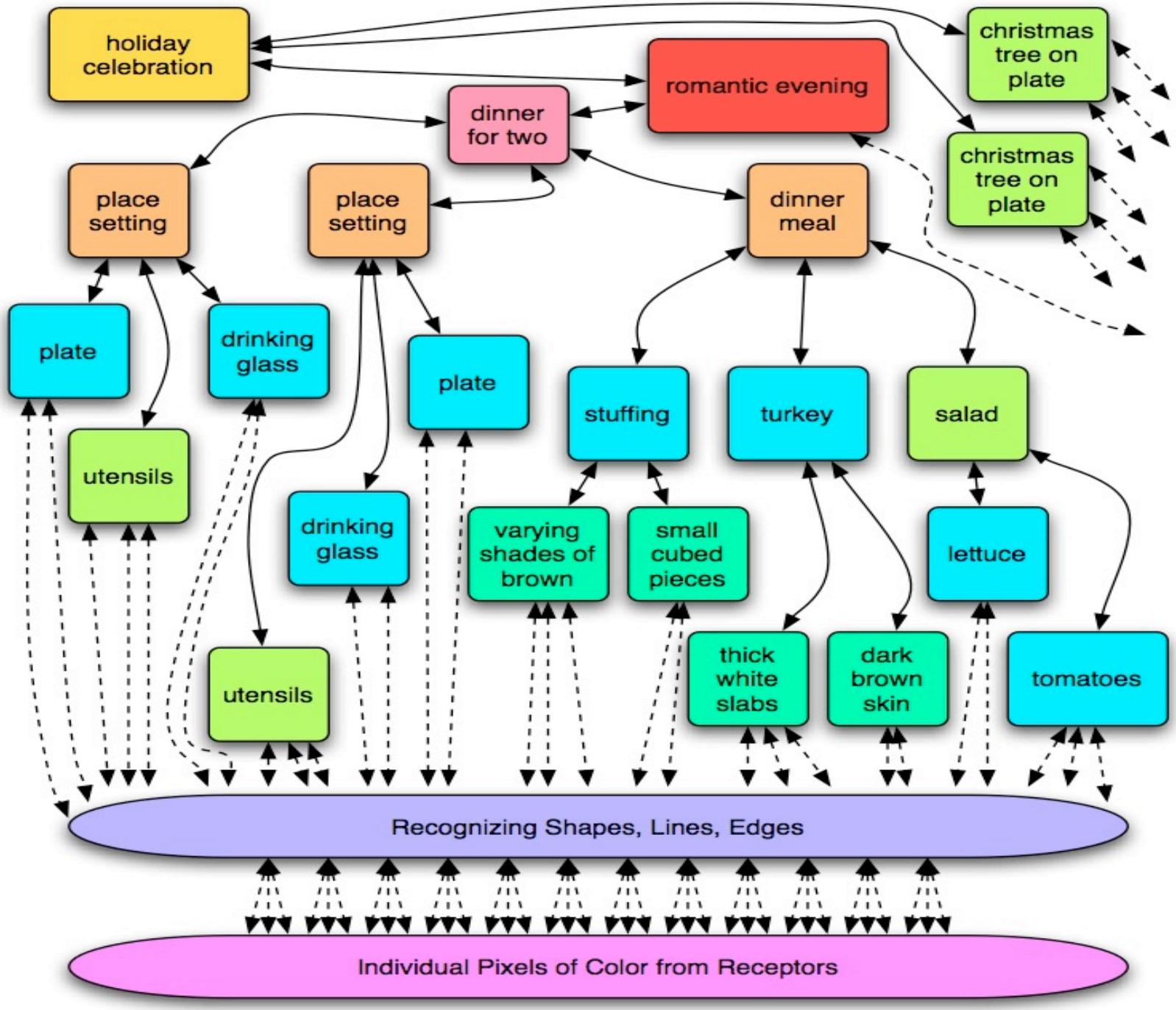

romantic evening
dinner for two
wine
place setting
place setting
dinner meal
candles
plate
drinking glass
plate
stuffing
turkey
salad
utensils
drinking glass
varying shades of brown
small cubed pieces
lettuce
utensils
thick white slabs
dark brown skin
tomatoes
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


holiday celebration
romantic evening
christmas tree on plate
dinner for two
christmas tree on plate
place setting
place setting
dinner meal
plate
drinking glass
plate
stuffing
turkey
salad
utensils
drinking glass
varying shades of brown
small cubed pieces
lettuce
utensils
thick white slabs
dark brown skin
tomatoes
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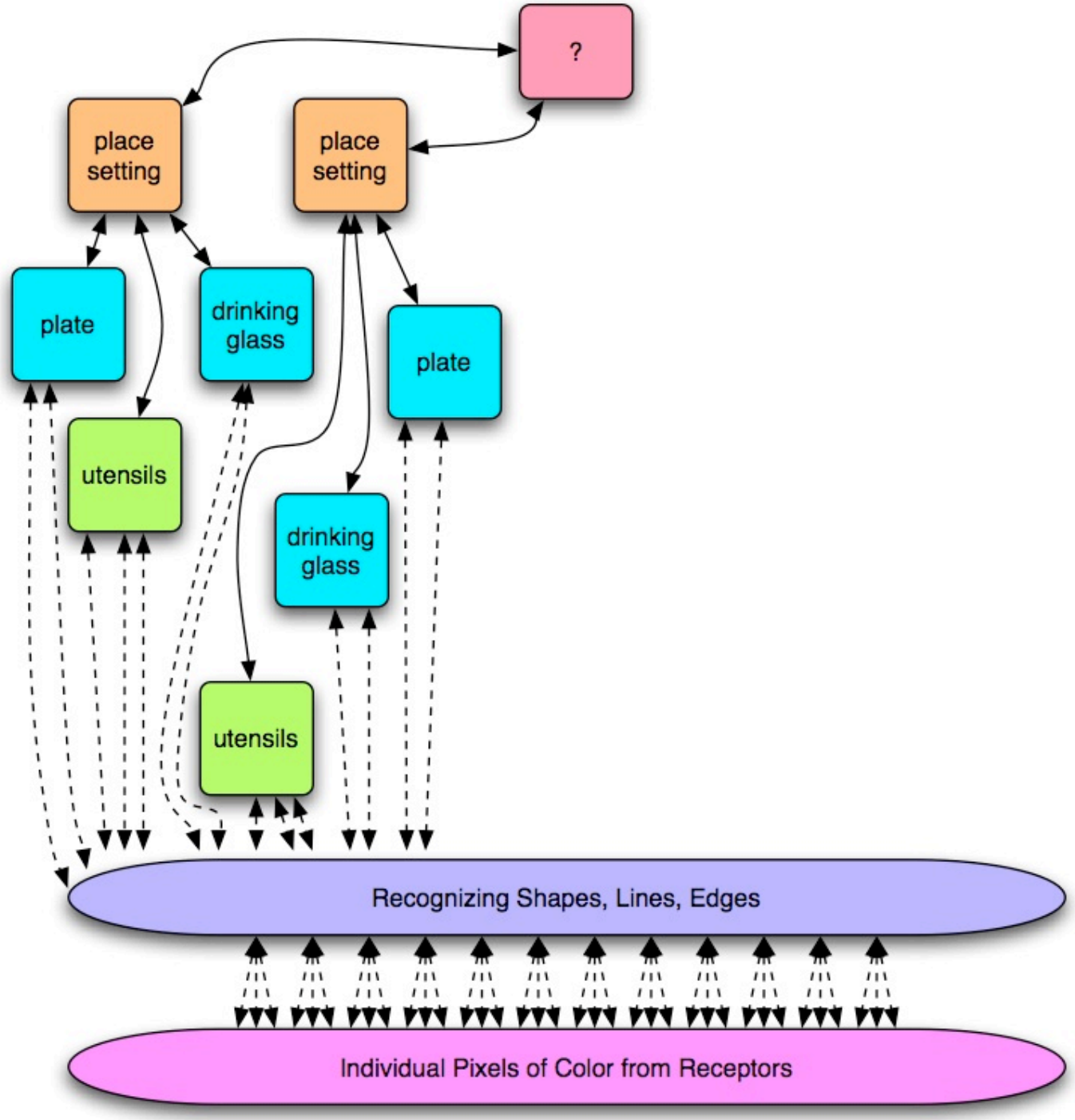
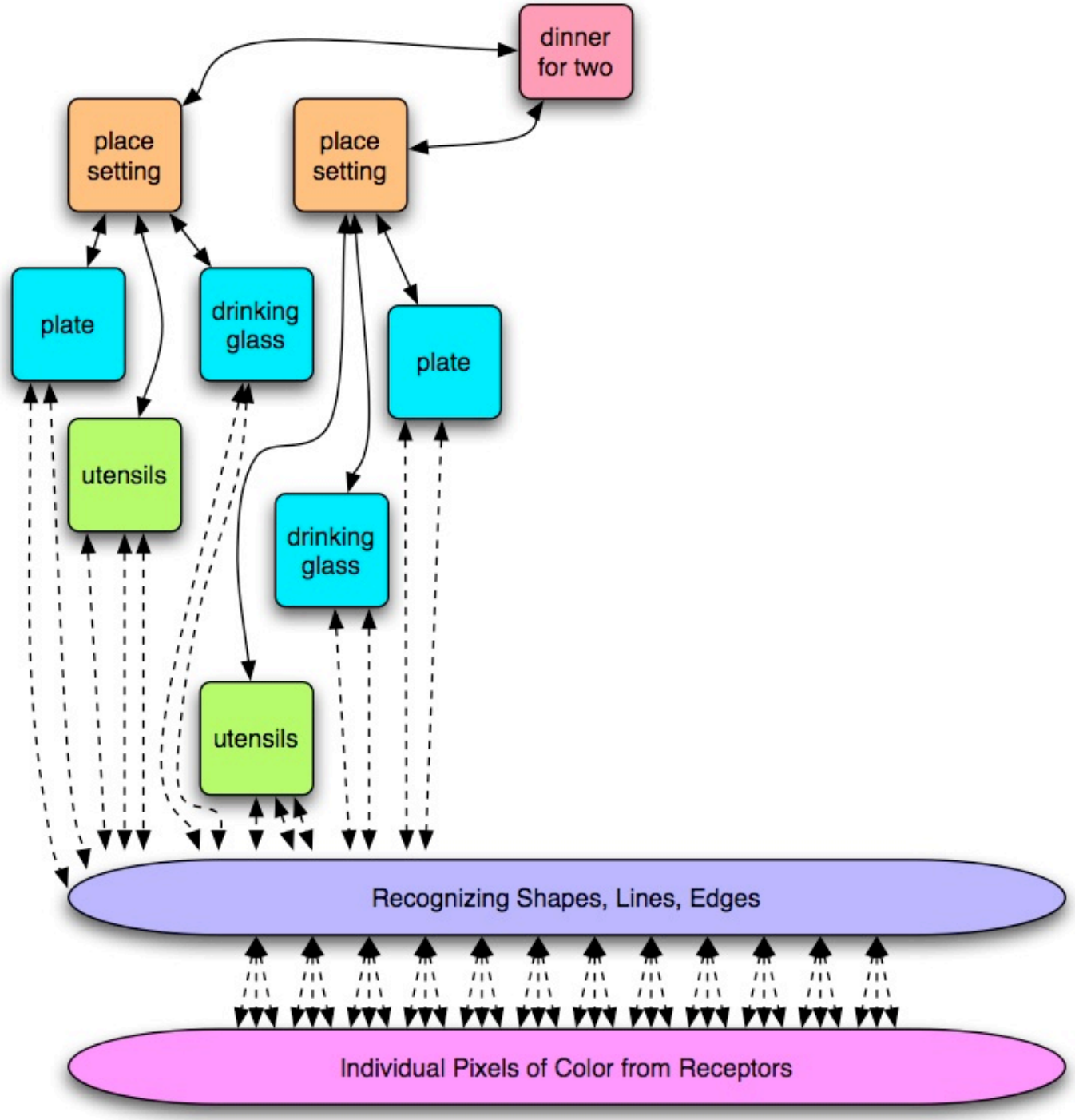
Memory-Prediction Model

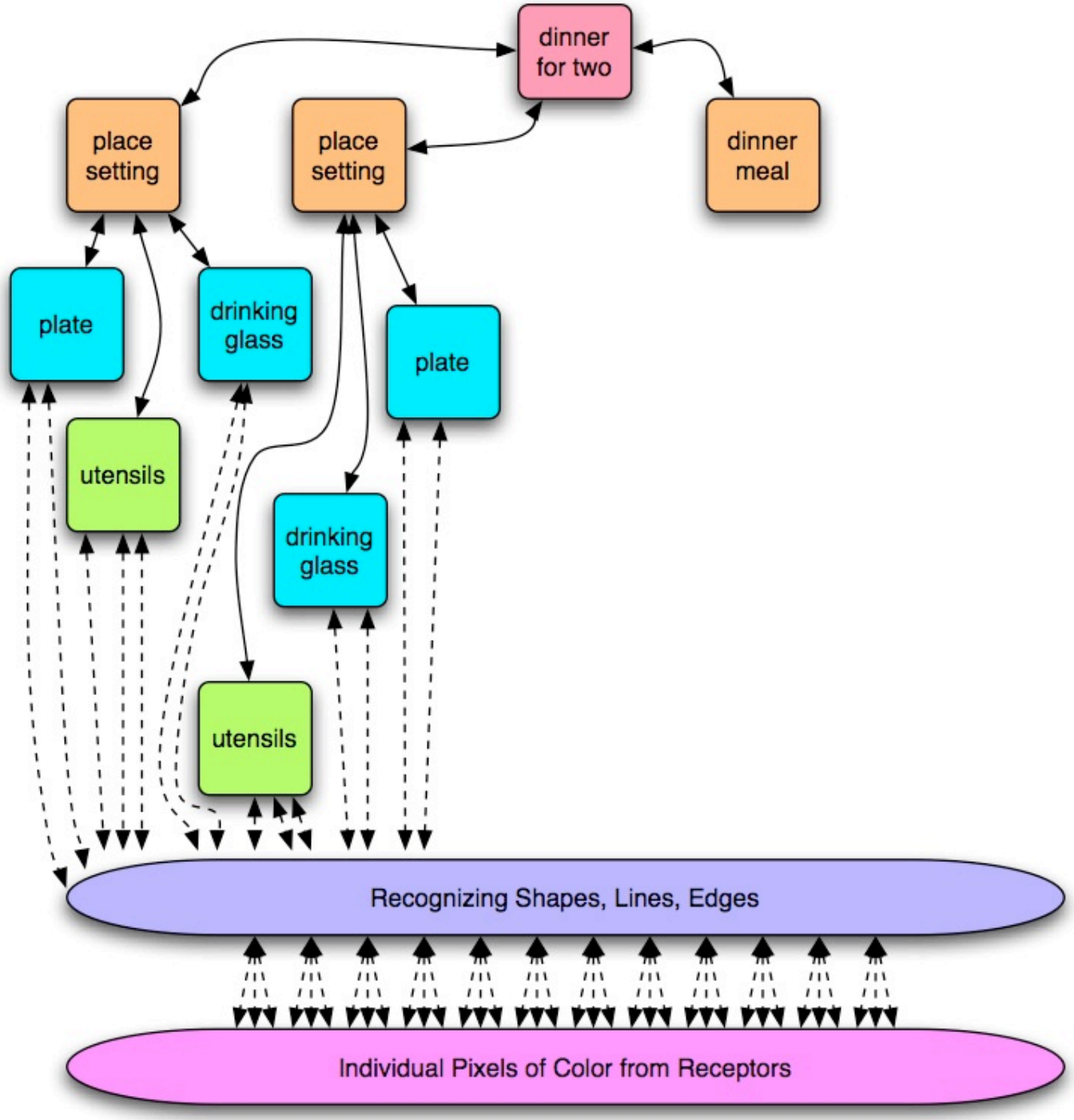
- Term Hawkins gives to describe the workings of the cortex
- Memory refers mostly to classification as we go up the hierarchy
- Prediction allows us to make decisions in the world
- Prediction is related to the ‘down’

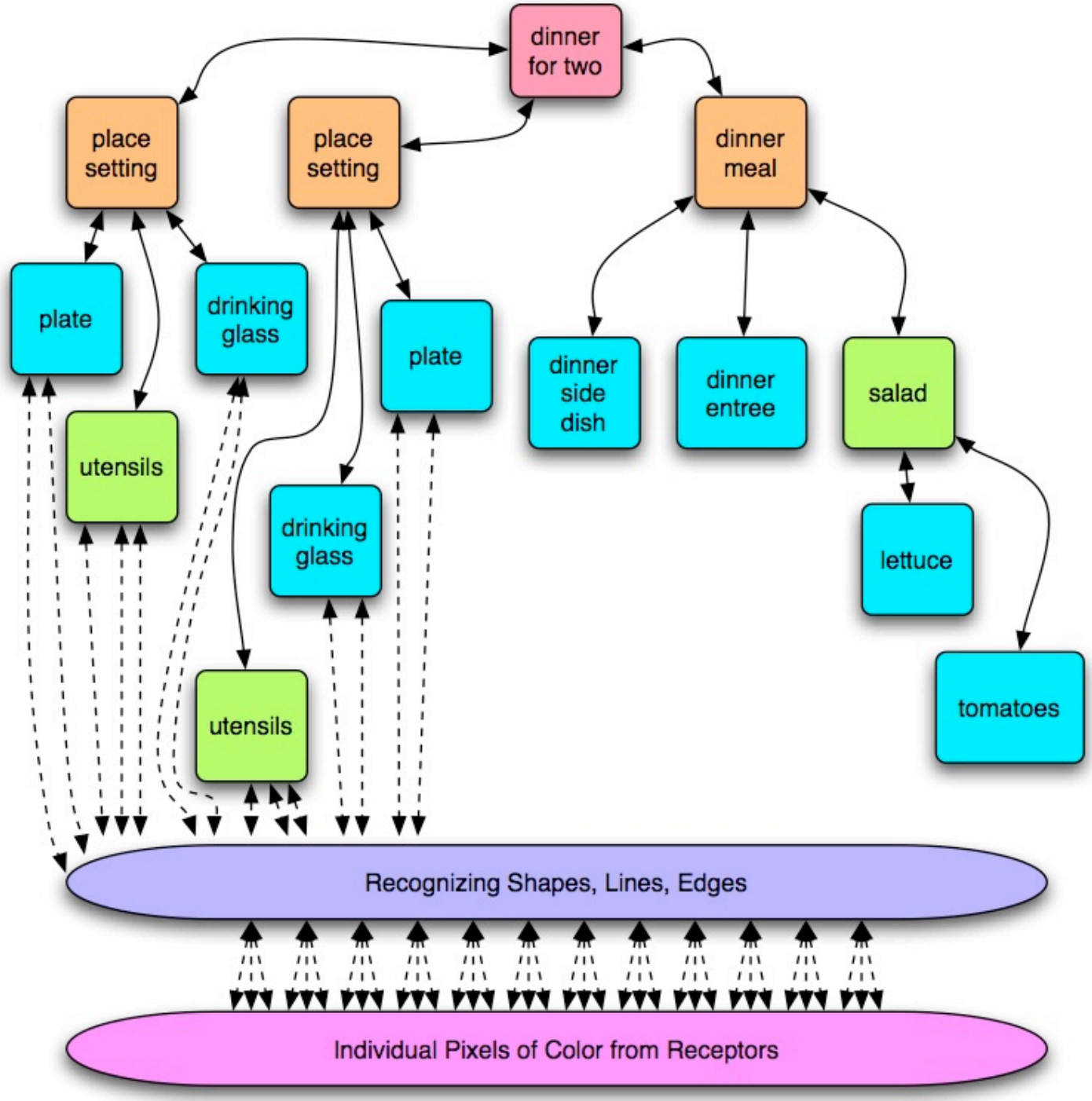
The Last Example (I promise)

The cortex can predict and revise


?
place setting
place setting
plate
drinking glass
plate
utensils
drinking glass
utensils
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


dinner for two
place setting
place setting
plate
drinking glass
plate
utensils
drinking glass
utensils
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


dinner for two
place setting
place setting
dinner meal
plate
drinking glass
plate
utensils
drinking glass
utensils
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


dinner for two
place setting
place setting
dinner meal
plate
drinking glass
plate
dinner side dish
dinner entree
salad
utensils
drinking glass
lettuce
utensils
tomatoes
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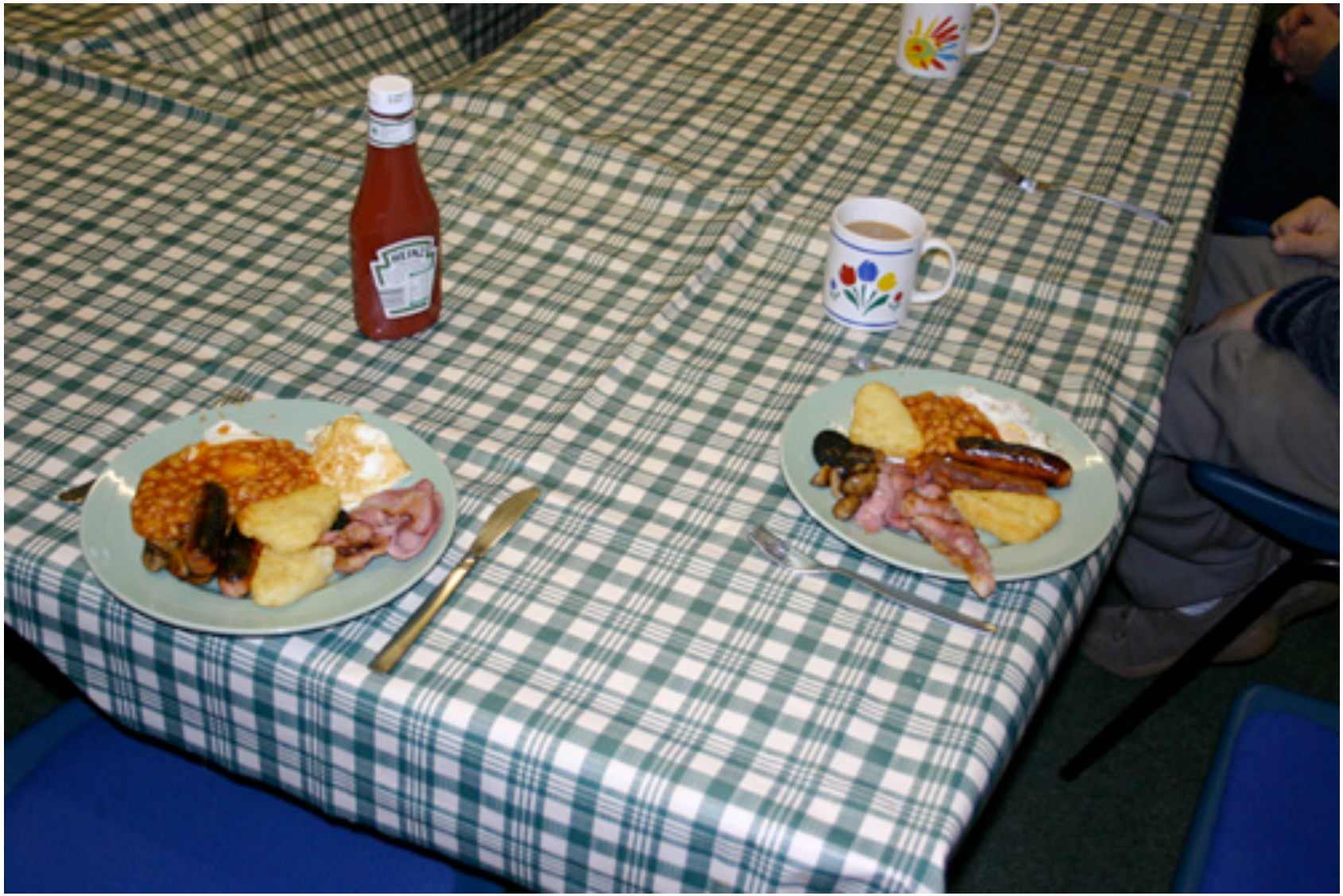
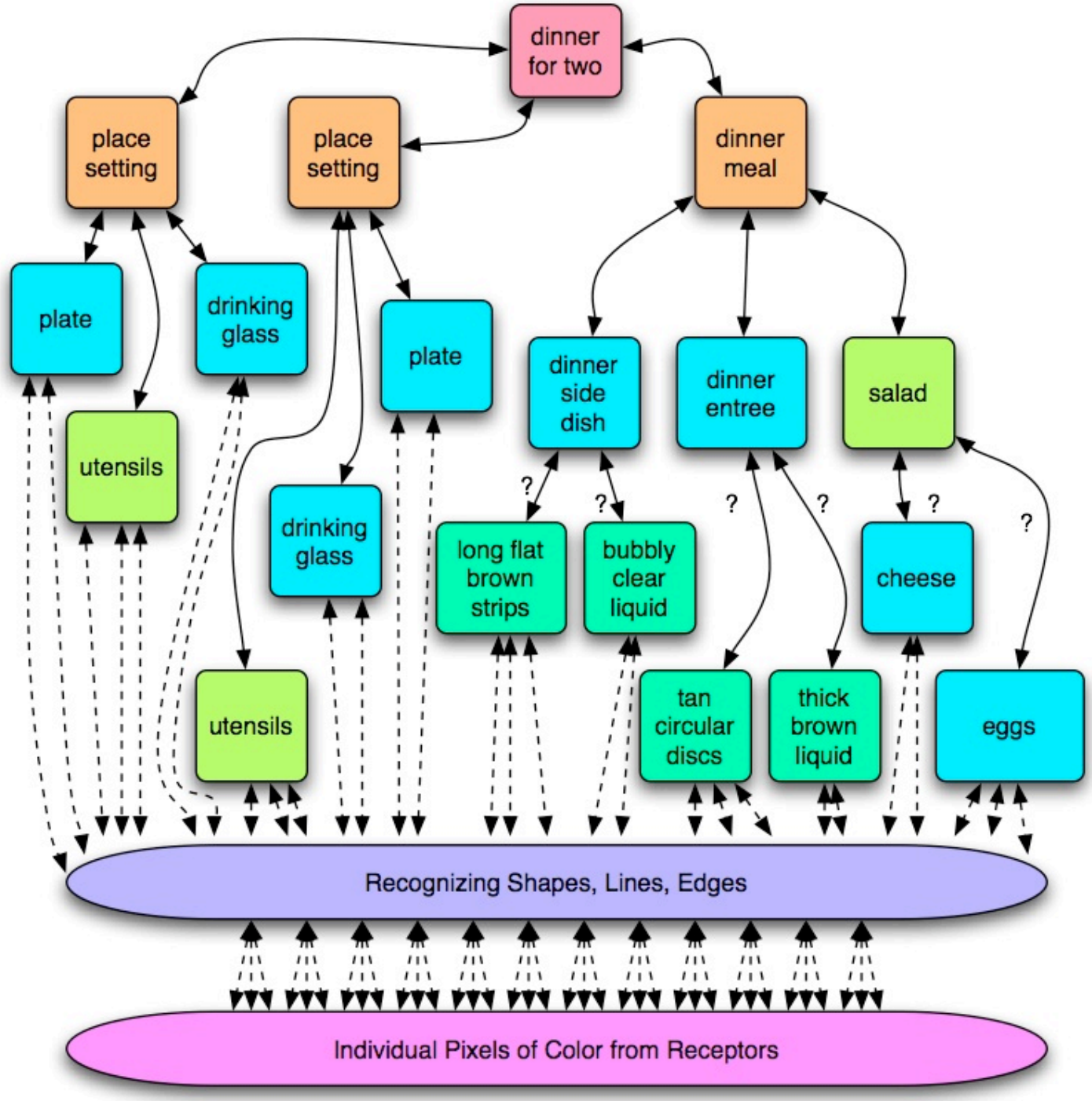
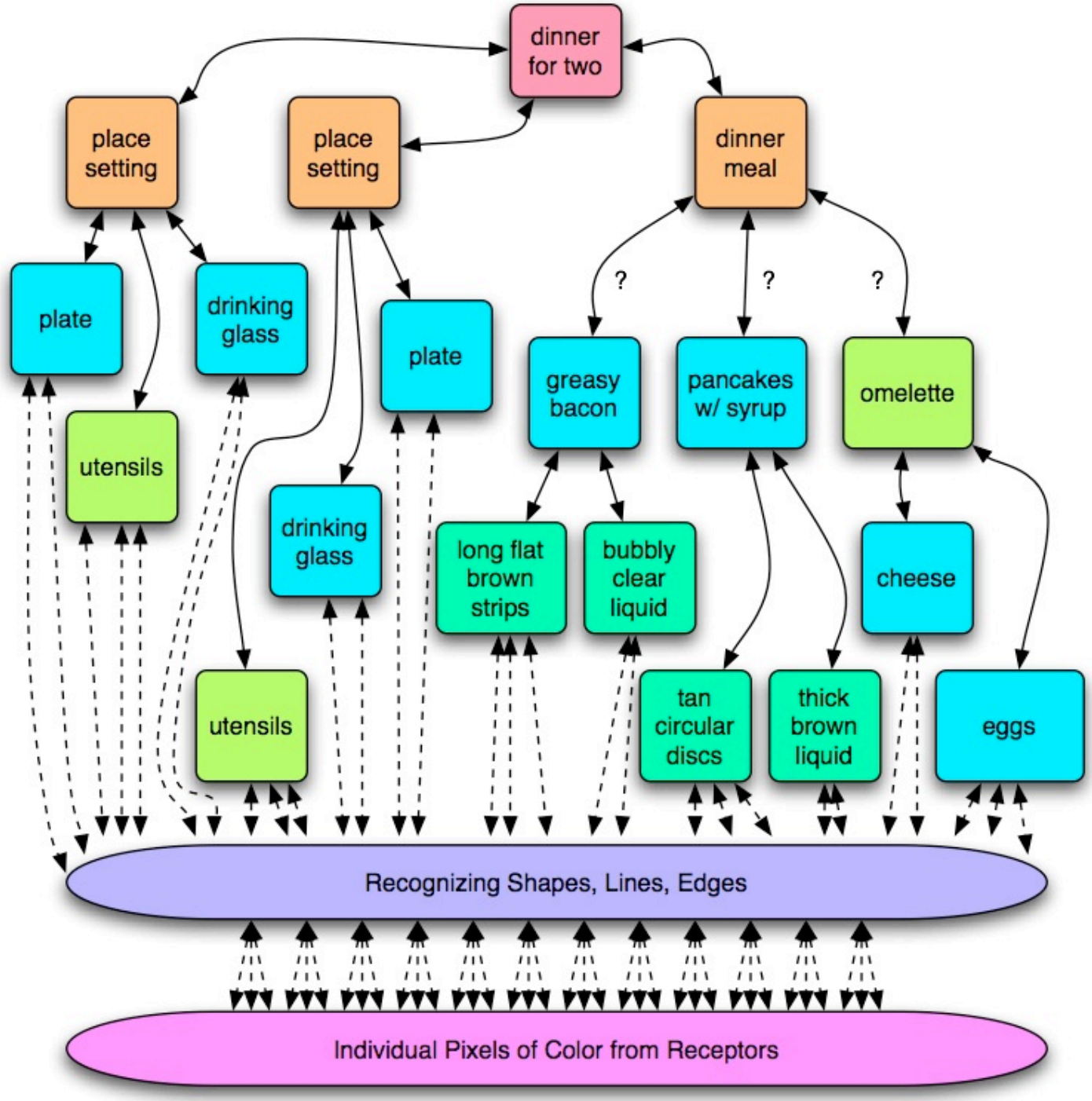
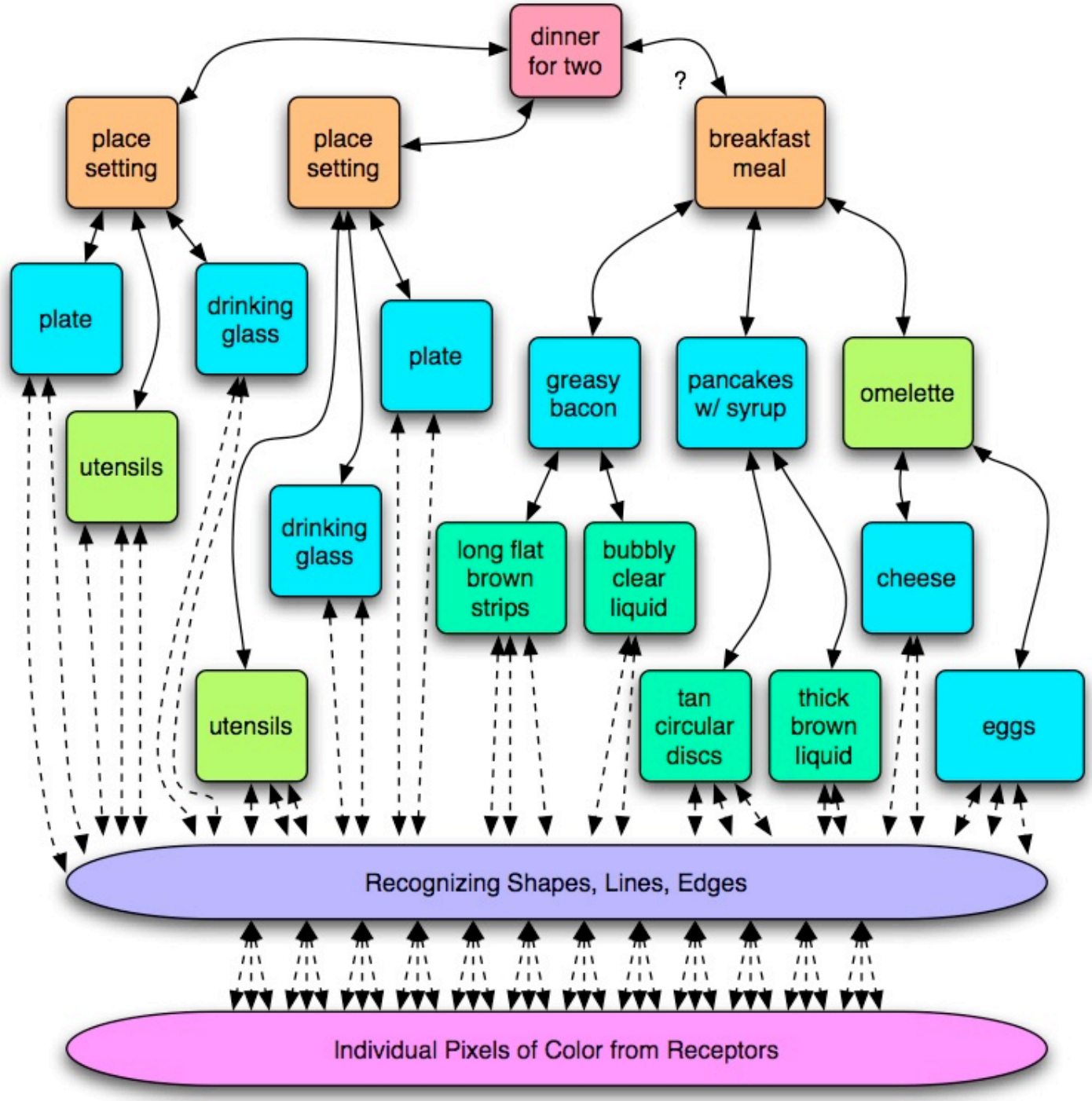
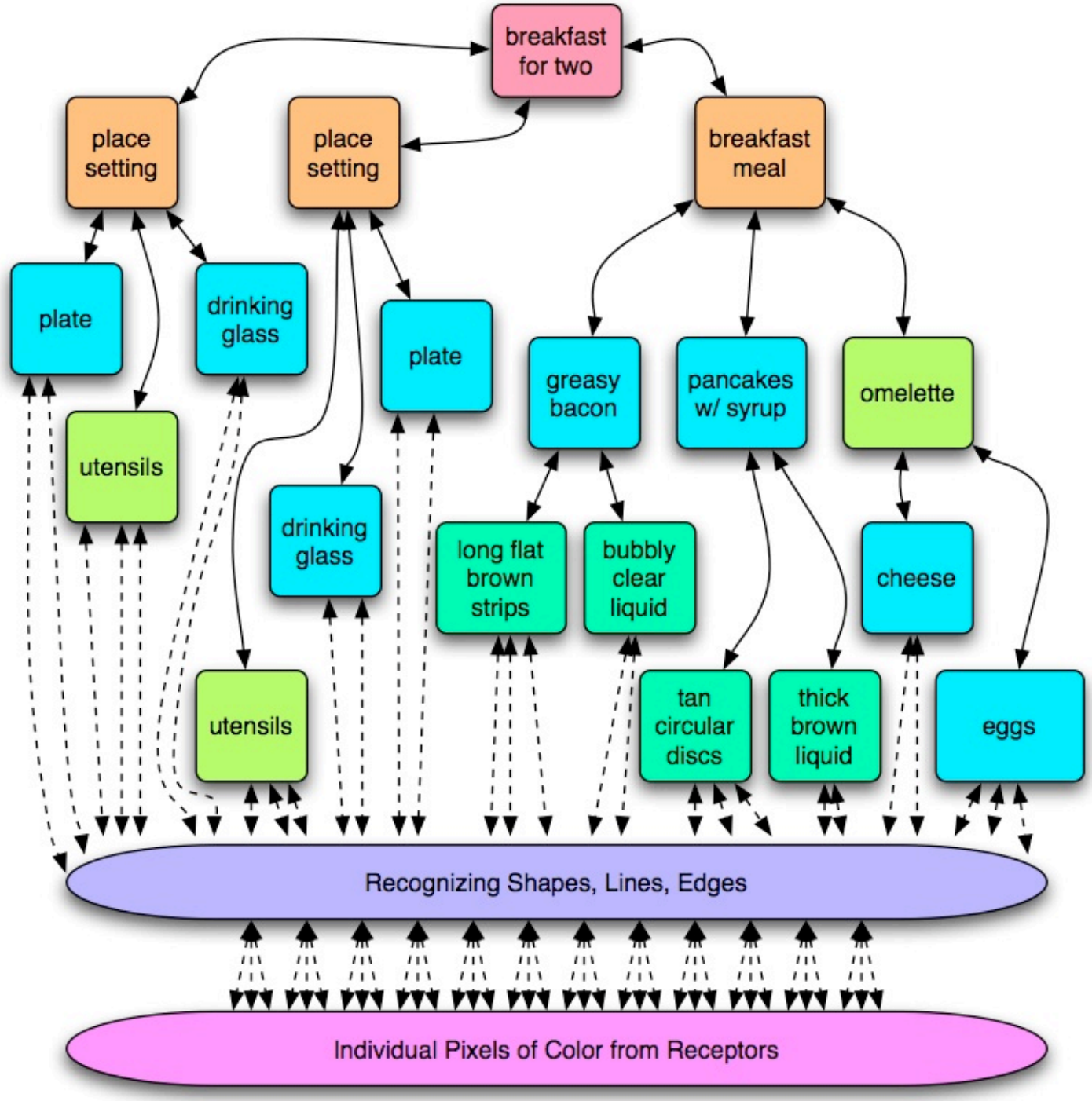
Individual Pixels of Color from Receptors




dinner for two
place setting
place setting
dinner meal
plate
drinking glass
plate
dinner side dish
dinner entree
salad
utensils
drinking glass
long flat brown strips
bubbly clear liquid
cheese
utensils
tan circular discs
thick brown liquid
eggs
?
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


dinner for two
place setting
place setting
dinner meal
plate
drinking glass
plate
?
?
?
greasy bacon
pancakes w/ syrup
omelette
utensils
drinking glass
long flat brown strips
bubbly clear liquid
cheese
utensils
tan circular discs
thick brown liquid
eggs
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


dinner for two
?
place setting
place setting
breakfast meal
plate
drinking glass
plate
greasy bacon
pancakes w/ syrup
omelette
utensils
drinking glass
long flat brown strips
bubbly clear liquid
cheese
utensils
tan circular discs
thick brown liquid
eggs
Recognizing Shapes, Lines, Edges
Individual Pixels of Color from Receptors


breakfast for two
place setting
place setting
breakfast meal
plate
drinking glass
plate
greasy bacon
pancakes w/ syrup
omelette
utensils
drinking glass
long flat brown strips
bubbly clear liquid
cheese
utensils
tan circular discs
thick brown liquid
eggs
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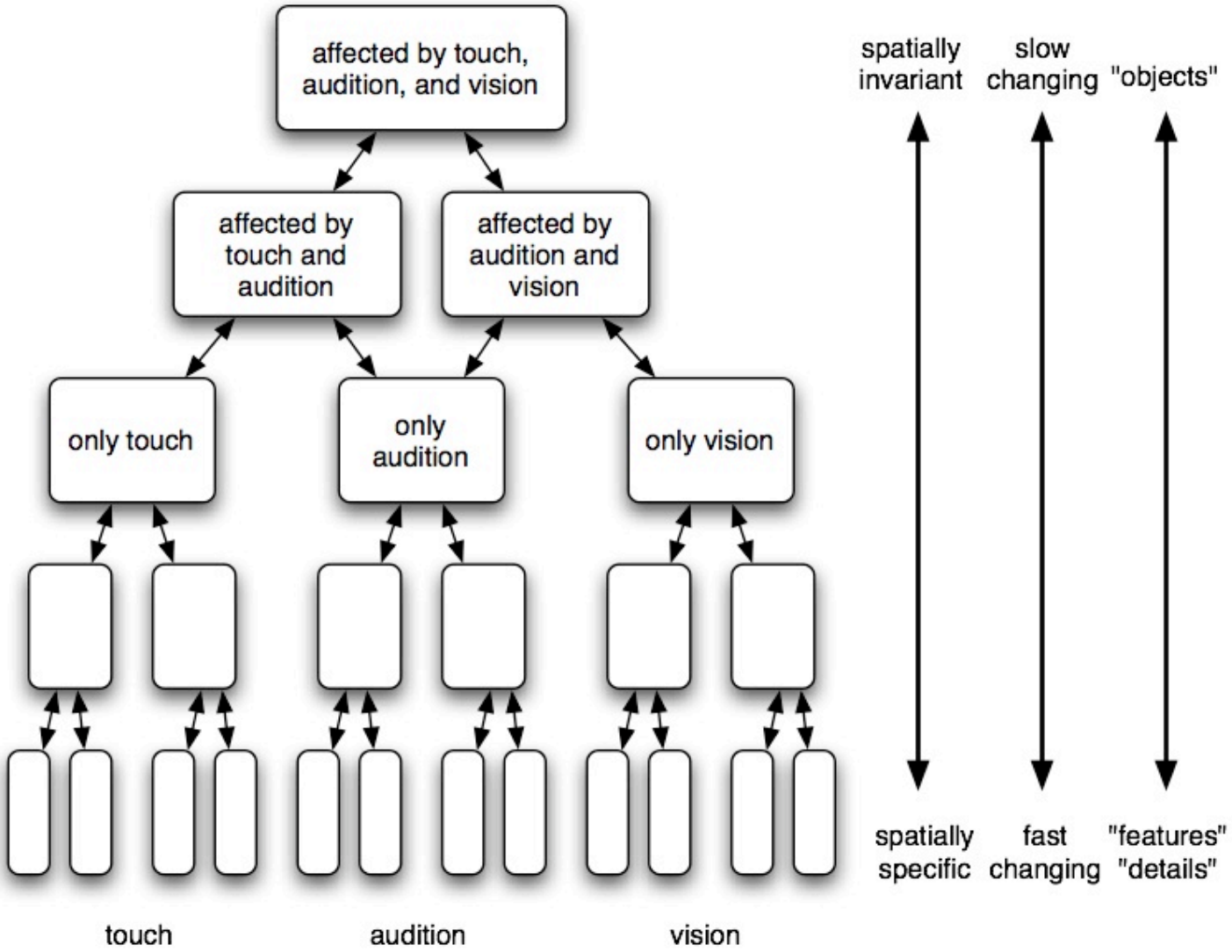
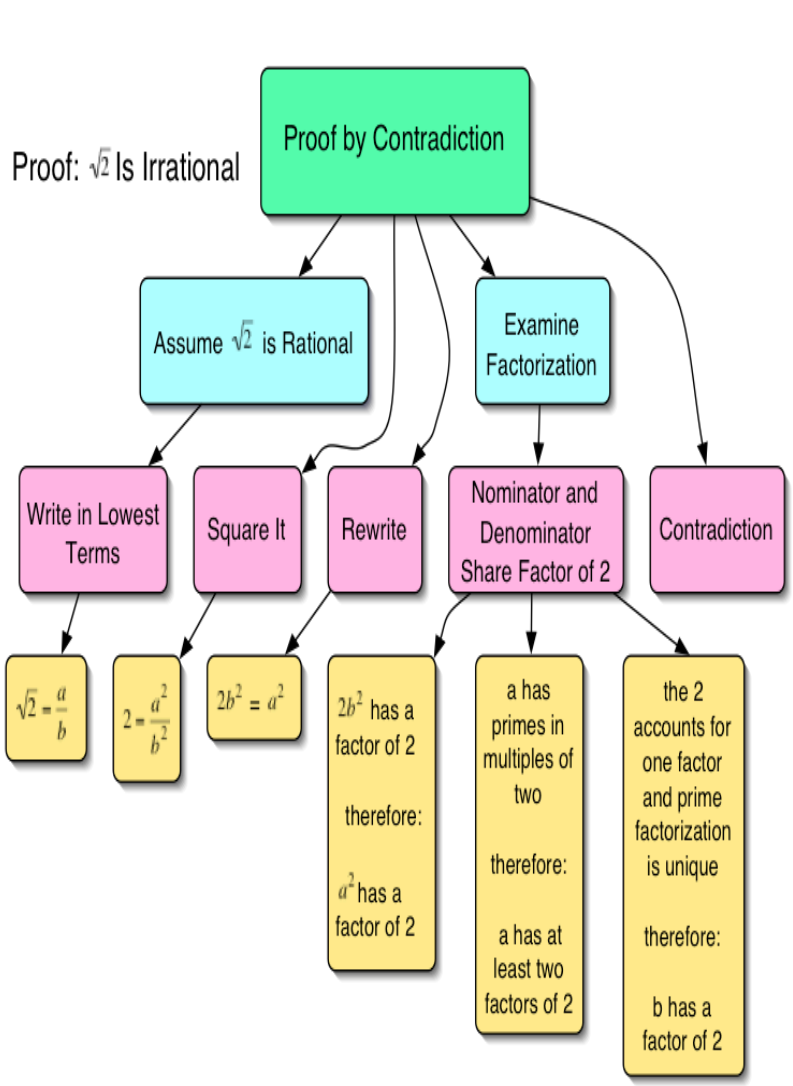
Bringing It All Together

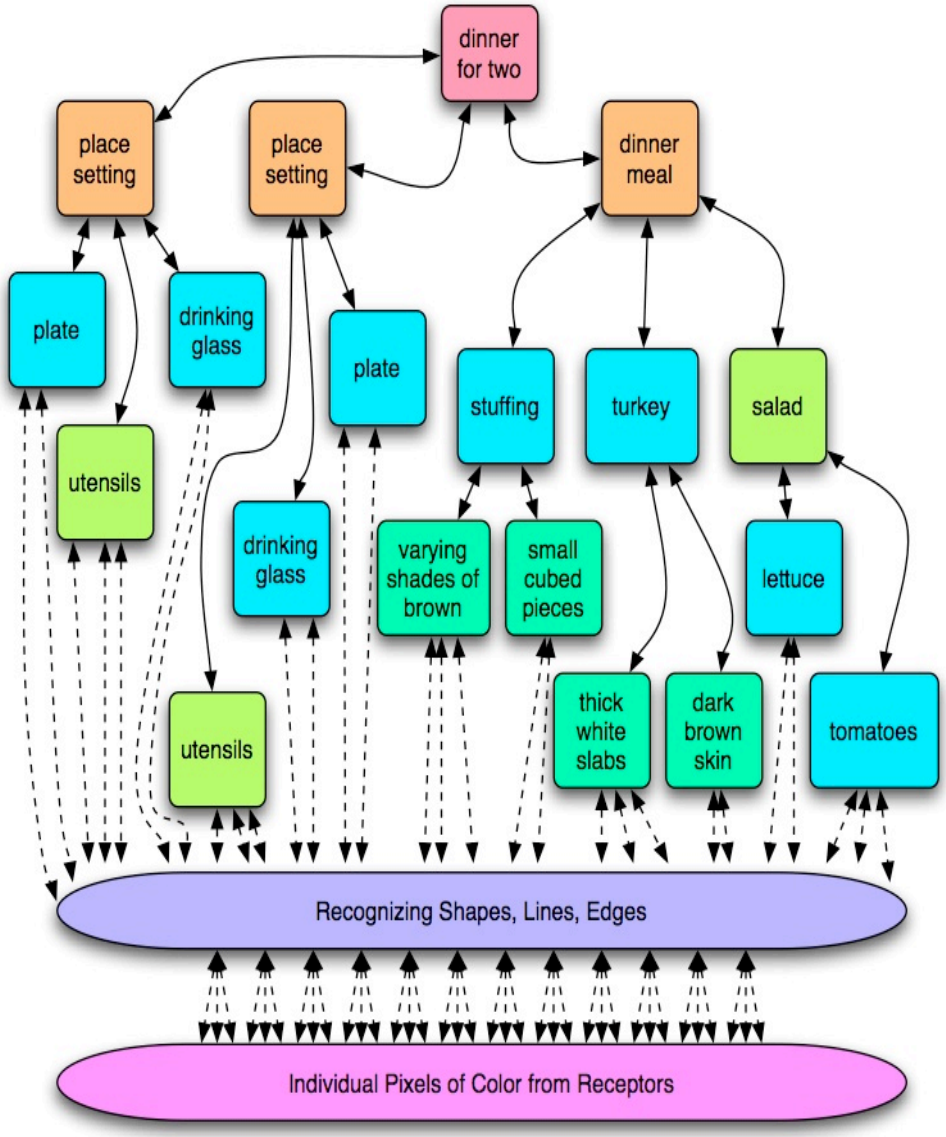
- All sensory data is essentially the same
- The brain handles generic patterns
- Common Cortical Algorithm
  - Vision handled same as touch, taste, etc
  - Uniformity of the cortex
- Patterns of different sensory perceptions combine for modeling


affected by touch, audition, and vision
affected by touch and audition
affected by audition and vision
only touch
only audition
only vision
touch
audition
vision
spatially invariant
slow changing
"objects"
spatially specific
fast changing
"features" "details"

Most importantly, though,…

…notice and remember the similarity between the proof plan and the cortical hierarchy


Proof: $\sqrt{2}$ Is Irrational
Proof by Contradiction
Assume $\sqrt{2}$ is Rational
Examine Factorization
Write in Lowest Terms
Square It
Rewrite
Nominator and Denominator Share Factor of 2
Contradiction
$\sqrt{2} = \frac{a}{b}$
$2 = \frac{a^2}{b^2}$
$2b^2 = a^2$
$2b^2$ has a factor of 2
therefore:
a^2 has a factor of 2
a has primes in multiples of two
therefore:
a has at least two factors of 2
the 2 accounts for one factor and prime factorization is unique
therefore:
b has a factor of 2


dinner for two
place setting
place setting
dinner meal
plate
drinking glass
plate
stuffing
turkey
salad
utensils
drinking glass
varying shades of brown
small cubed pieces
lettuce
utensils
thick white slabs
dark brown skin
tomatoes
Recognizing Shapes, Lines, Edges
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That’s it…

…and now for Brendan…unless you have any questions before we continue.