

Learning Linguistics

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Most Common Words

- ❖ Lemma: base form of a word
- ❖ Climb: climbs, climbing, climbed

Vocabulary size (no. lemmas)	% of content in OEC	Example lemmas
10	25%	the, of, and, to, that, have
100	50%	from, because, go, me, our, well, way
1000	75%	girl, win, decide, huge, difficult, series
7000	90%	tackle, peak, crude, purely, dude, modest
50,000	95%	saboteur, autocracy, calyx, conformist
>1,000,000	99%	laggardly, endobenthic, pomological

First Words

- ❖ Purely Statistical: the, be, to, of, and, a, in, that, have, I
- ❖ Experimental: mommy, hi, dog, woofwoof, baby, ouch, banana
- ❖ Society: vocabulary adapted before grammar

First Word Combinations

ANDREW'S WORD COMBINATIONS

more car ^a	no bed	other bib	boot off	see baby
more cereal	no down ^c	other bread	light off	see pretty
more cookie	no fix	other milk	pants off	see train
more fish	no home	other pants	shirt off	
more high ^b	no mama ^d	other part	shoe off	hi Calico
more hot	no more	other piece	water off	hi mama
more juice	no pee	other pocket	off bib	hi papa
more read	no plug	other shirt		
more sing	no water	other shoe	airplane all gone	airplane by ^h
more toast	no wet ^e	other side	Calico all gone ^f	siren by
more walk			Calico all done ^f	mail come
outside more	down there		all done milk	mama come
	clock on there		all done now	what's that
all broke	up on there		all gone juice	what's this
all buttoned	hot in there		all gone outside ^g	mail man
all clean	milk in there		all gone pacifier	mail car
all done	light up there		salt all shut	our car
all dressed	fall down there			our door
all dry	kitty down there		byebye back	papa away
all fix	more down there		byebye Calico	look at this
all gone	sit down there		byebye car	pants change
all messy	cover down there		byebye papa	dry pants
all shut	other cover down there		Calico byebye	
all through	up on there some more		papa byebye	
all wet				

^a "Drive around some more."

^b "There's more up there."

^c "Don't put me down."

^d "I don't want to go to mama."

^e "I'm not wet!"

^f Said after the death of Calico the cat.

^g Said when the door is shut: "The outside is all gone."

^h "A plane is flying past."

- ❖ Braine, Martin D. S. Children's First Word Combinations. Chicago: Published by the U of Chicago for the Society for Research in Child Development, 1976. Print.

Word Combination

* Braine, Martin D. S. Children's First Word Combinations. Chicago: Published by the U of Chicago for the Society for Research in Child Development, 1976. Print.

KENDALL I: WORD COMBINATIONS

Actor/Action Pattern			
Kendall sit	Mommy read	Daddy sit	Kimmy read
Kendall read	Mommy tie it	Daddy hide	Kimmy bite
Kendall walk	Mommy spider ^e	Daddy write	Kimmy BM ^a
Kendall bounce	Mommy oops ^f	Daddy walk	Bill talk
Kendall BM ^a	Melissa walk	Daddy teeth ^j	spider move
Kendall leave ^b	Melissa eye ^g	Daddy sock ^k	horse walk
Kendall foot ^c	Melissa away ^h	doggy . . sleepy ^l	horse run
Kendall Mommy ^d walk	Melissa car ⁱ	doggy bye ^m	ant away ⁿ
Possession			
Kendall chair	Mommy . . hand	Kimmy house	lady hat
Kendall house ^a	Mommy curly ^e	Melissa house	my penny
Bill house	Daddy book	doggy . . house	our car ⁿ
Bill book		animal house ^p	
Location			
Daddy here	pig water ^q	in Daddy ^r	back doggy ^t
Bill here	doggy slipper ^r	Mommy in ^s	tummy off ^u
penny innere	slipper doggy ^r	Mommy bathroom ^q	
Other Combinations			
more walk	Kimmy girl ^v	tie it	hand clean ^y
more lights	animal dog ^w	carry it	go home
no more	that book	horse . . see it ^x	sit lap
Kimmy Pam ^d	Kendall hurt	find Mommy	purse away
lady man ^d	refrigerator on	close . . door	walk self ^z
open close ^d	slipper on	close . . bathroom	tie it self ^z
		taste cereal	

SOURCE.—Bowerman 1973a, appendix B.

^a "made bowel movement."

^b Response to "Can you grab some leaves?"

^c She wants to take her shoe off.

^d "_____ and _____."

^e "Mommy is to watch the spider."

^f "Mommy said oops."

^g "Melissa is drawing an eye."

^h "went away."

ⁱ "Melissa is getting into [Kendall's family's] car."

^j "brushing teeth."

^k Daddy left to find socks.

^l Pretending to be a dog sleeping.

^m "Doggy went away."

ⁿ A routine.

^o Follows, after delay, "Mommy has curly hair."

^p Refers to a barn.

^q "_____ in the _____."

^r After talk about putting the slipper on the dog.

^s As she shuts a parent in a room.

^t As she puts a toy dog in back of her.

^u "off tummy."

^v "Kimmy is a girl."

^w "A dog is an animal" (?).

^x "See the horse."

^y "Wash my hands."

^z "by myself."

KENDALL II: WORD COMBINATIONS

Actor/Action			
Kimmy spit	Kendall bite	Kendall Kristin ^f sit	Melissa bounce
Kimmy come	Kendall break	Daddy pick up	Melissa read
Kimmy swim	Kendall turn	Daddy break it	Phil running
Kimmy blow	Kendall fix it	Mommy bounce	Pam running
Kimmy bite	Kendall hath ^g	Mommy sleep	Scott scream
Kimmy running	Kendall shower	Mommy read	cow moo
Kimmy eat	Kendall book ^h	Mommy break it	doggy bark
Kimmy ride bike	Kendall spider ^e	Mommy . . sew doggy	doggy woof ^h
Kimmy eat hand	Kendall turn page	Mommy pick up . . Kendall	
Kendall bark	see Kendall ^d	Mommy fix it . . ear	
Kendall swim	Mommy hit Kendall ^g	hug Mommy ^g	
Possessives			
Kendall rocking-chair	Kendall presents	Kimmy bike	pig tail
Kendall turn	Kendall dinner	Kimmy pail	cow tail
Kendall birthday	Kendall doggy	Kimmy doggy	daddy tail . . nope
	Papa door	doggy hole	
Locatives			
there cow	sit there	towel bed	lotion tummy
here mess	Kimmy change here ⁱ	play bed	ear outside
here moonbook	Kimmy kick there ^j	Kendall pool	Kendall down
mess here	Kendall innere	sit pool	where doggy go?
pillow here	Kendall innere bed	Kendall water	where pillow go?
	Kendall bed	water Ben ^k	
Actor-Action-Locative			
Ben swim pool	Kristin sit chair	Kendall play bed	Kendall crying there
Identification or Class Membership			
that Kimmy	that Kimmy ball	Mommy lady	Kendall monkey
that Scott	that . . candy	Daddy Shawn ^l	Kimmy monkey
that lady	that Daddy's	Kurt boy	Scott monkey too
that hole	that blow	hair wet	
Other Combinations			
more lotion	picture Kendall ^m	pillow fell	open . . lotion
Kimmy Phil ^l	Kendall picture ⁿ	thread break	Kimmy kick ^o
poor doggy	picture water	break Fur-book	Kendall pick up ^o
blue Mommy	shoe off	read . . book	look Kendall
big bed	fell off	writing book	doggy look it ^o
dear . . horsie	hat on	leave it heel	Kimmy look at Kimmy ^r
red Kendall	lotion away	bite finger	see running
		doggy sew ⁿ	

SOURCE.—Bowerman 1973a, appendix C.

^a "Kendall takes a bath."

^b "Kendall is reading a book."

^c "Kendall looked at a spider."

^d "Kendall sees."

^e "Kendall hit Mommy."

^f "_____ and _____."

^g "Mommy bugs."

^h "Doggy says 'woof.'"

ⁱ "Change Kimmy here."

^j "Kick Kimmy there."

^k "Ben is in the water" or "In the water with Ben."

^l "Daddy is named Shawn."

^m "Picture of Kendall."

ⁿ "Sew doggy."

^o "Kick Kimmy."

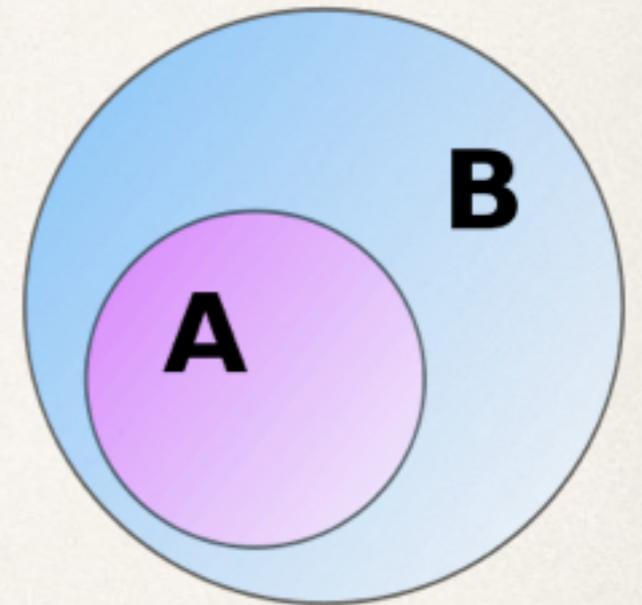
^p "Pick up Kendall."

^q "Look at the doggy."

^r "Look at Kimmy."

Definitions

- ❖ Set - a collection of well defined and distinct objects
- ❖ Subset - set A is a subset of a set B
- ❖ Superset - set B is a superset of a set A
- ❖ Isomorphism - map that preserves sets and relations among elements



Category Theory

- ❖ algebraic structure - a set with one or more finitary operations defined on it
- ❖ category - an algebraic structure that comprises "objects" that are linked by "arrows"
 - ❖ A category has two basic properties:
 - ❖ the ability to compose the arrows associatively
 - ❖ the existence of an identity arrow for each object.

Operad Theory

* arXiv:math/0305049

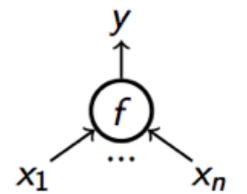
* <http://nilesjohnson.net/homotopy-special-session/Marcy.Robertson.pdf>

* Category

$$x \xrightarrow{f} y$$

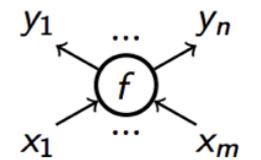
* Operad

$$(x_1, \dots, x_n) \xrightarrow{f} y$$

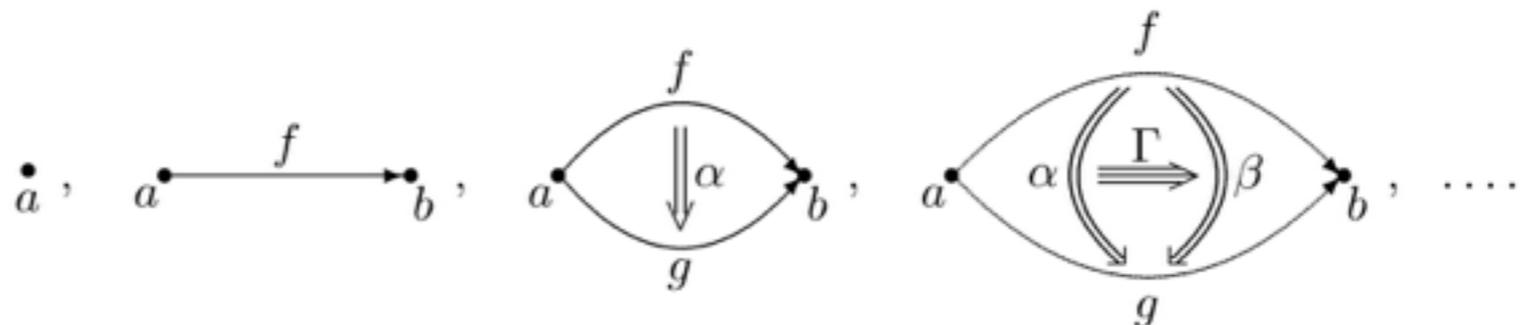


* Properad

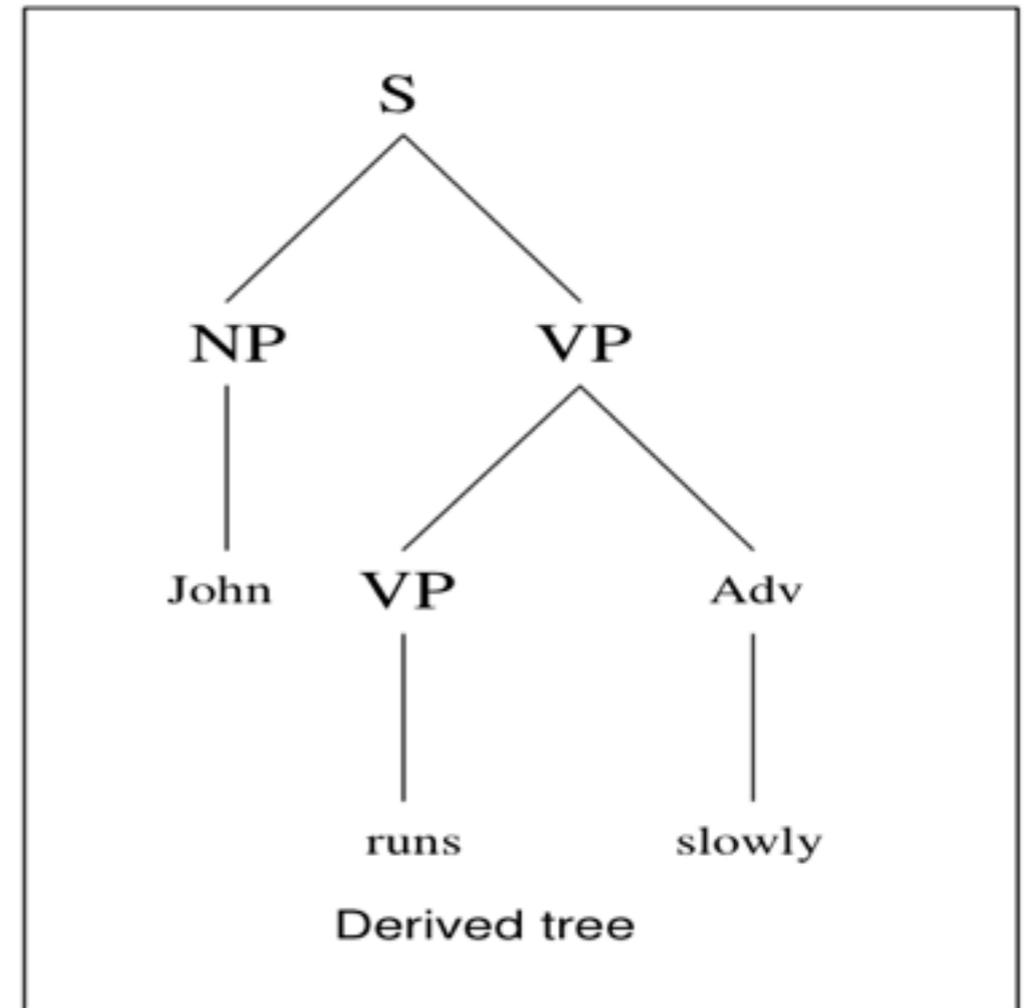
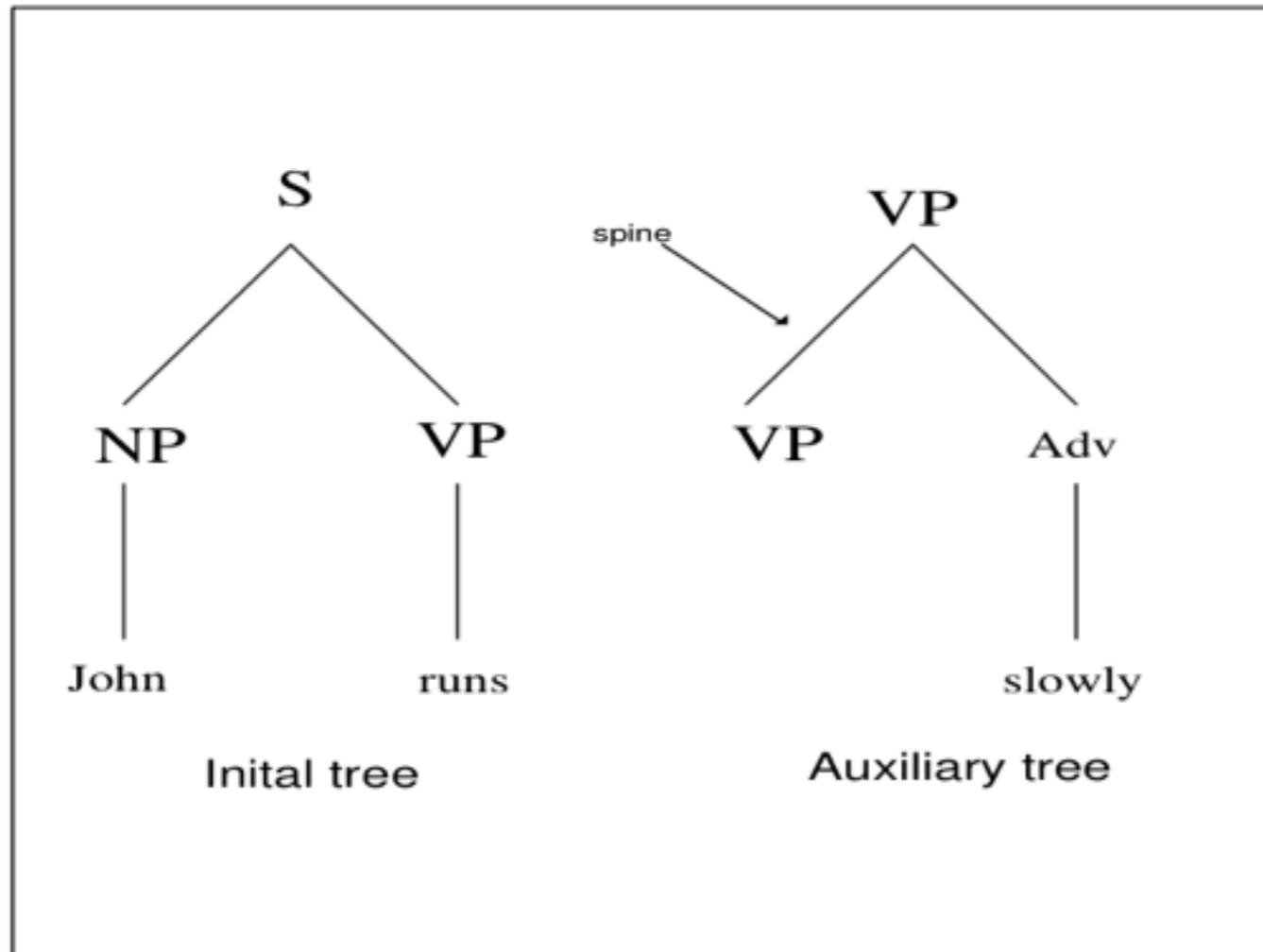
$$(x_1, \dots, x_m) \xrightarrow{f} (y_1, \dots, y_n)$$



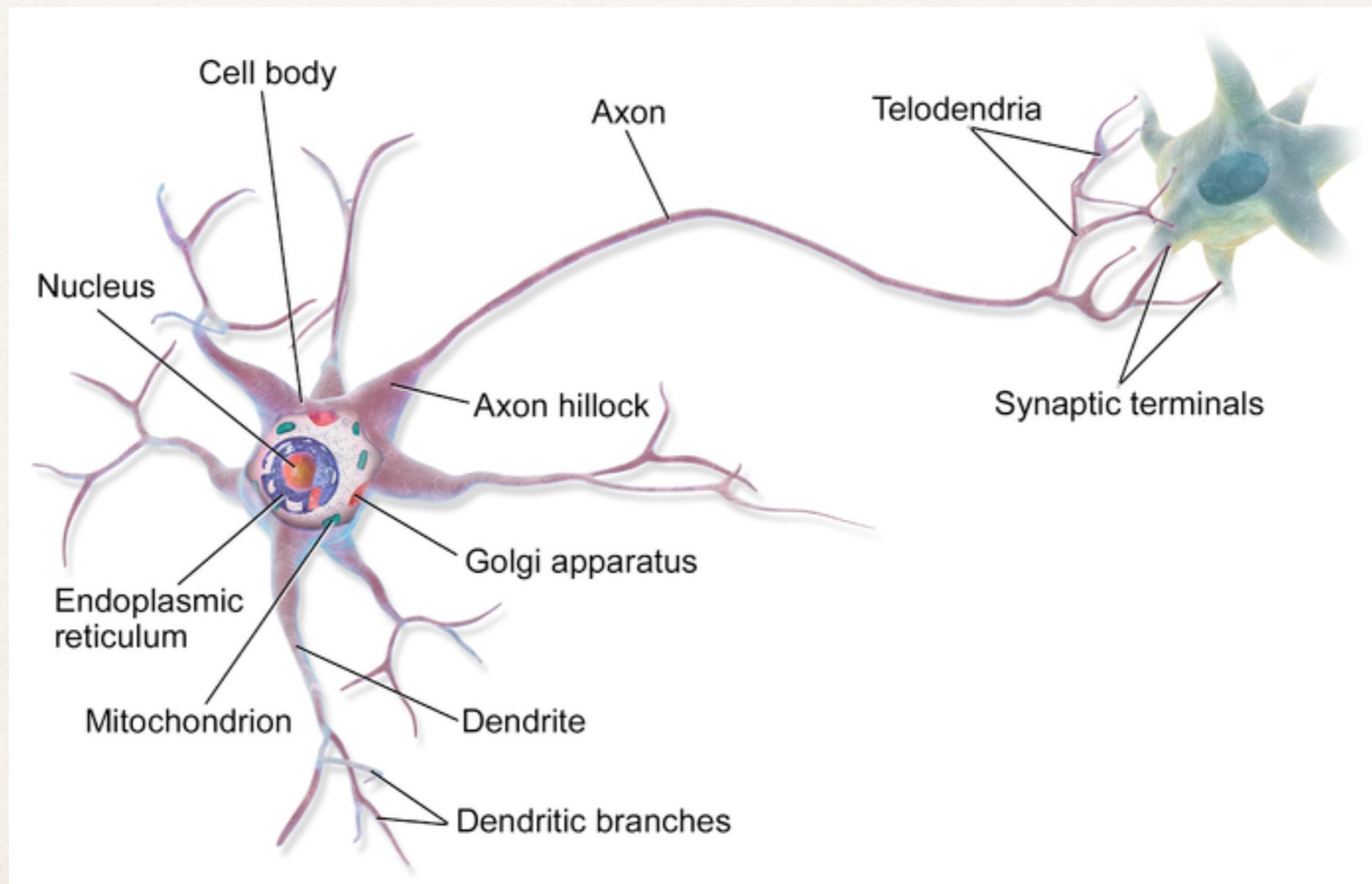
* Higher Category



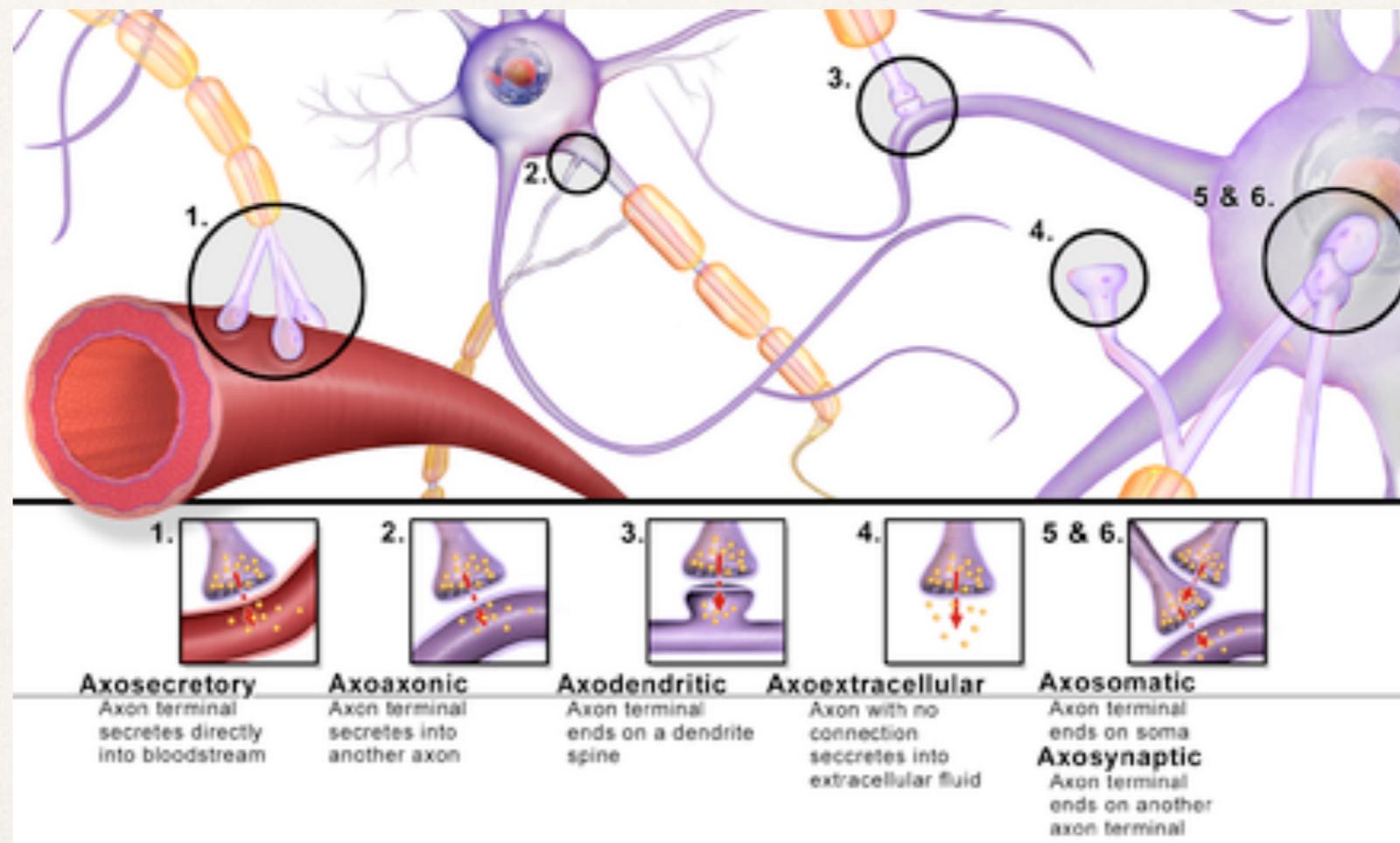
Learning Parse Tree Components



Neurons and Synapses



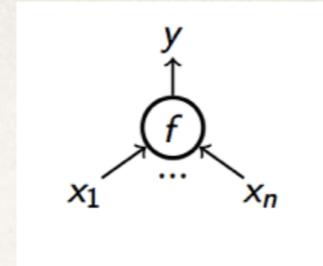
Types of Synapse Interfaces



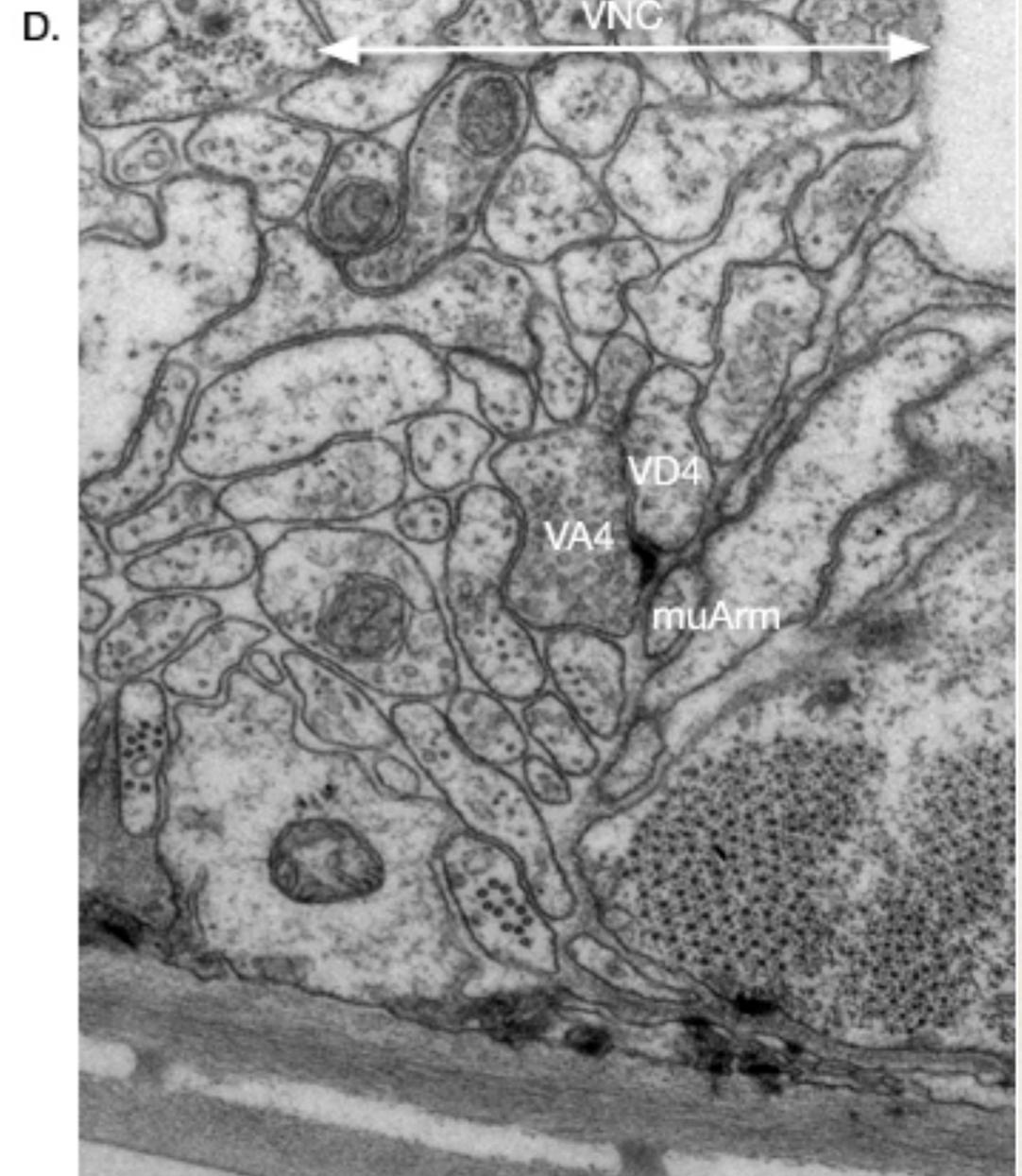
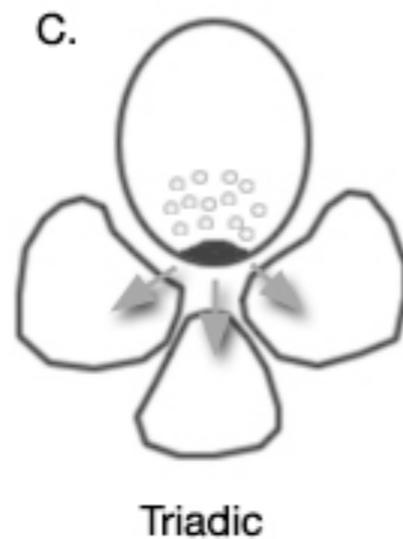
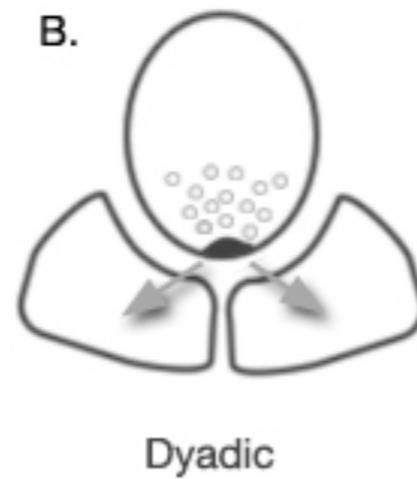
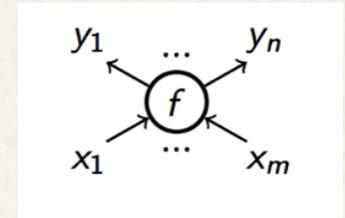
❖ Doesn't have to be axodendritic!

Polyadic Synapse

Operad



Properad



Neural Cell Types

❖ Spatial Information Processing

❖ Place Cells

❖ Grid Cells

❖ Head Direction Cells

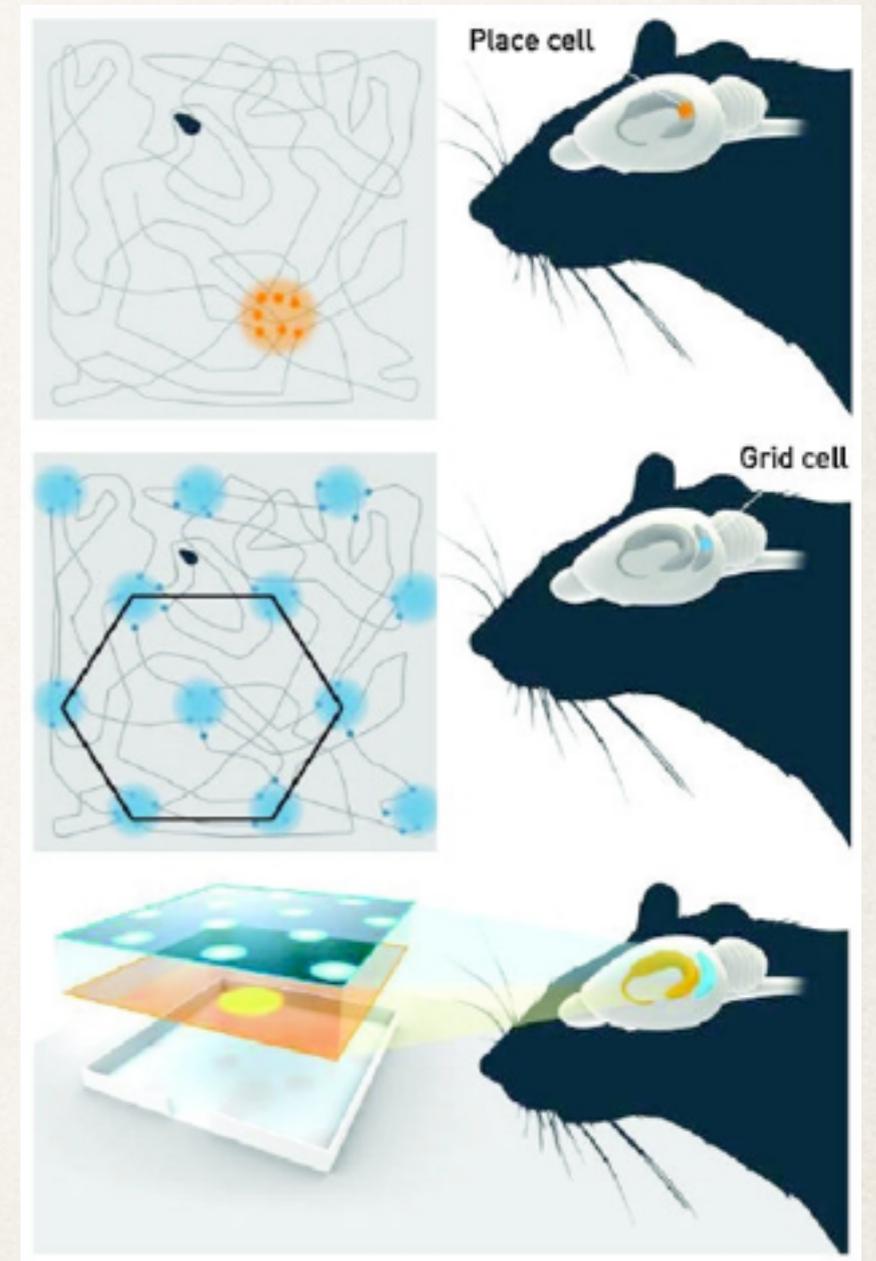
- ❖ Brandon, M. P., Koenig, J. and Leutgeb, S. (2014), Parallel and convergent processing in grid cell, head-direction cell, boundary cell, and place cell networks. *WIREs Cogn Sci*, 5: 207–219. doi: 10.1002/wcs.1272

❖ Temporal Information Processing

❖ Time Cells

- ❖ Jin DZ, Fujii N, Graybiel AM. 2009. Neural representation of time in cortico-basal ganglia circuits. *Proc. Natl. Acad. Sci. USA* 106:19156–61

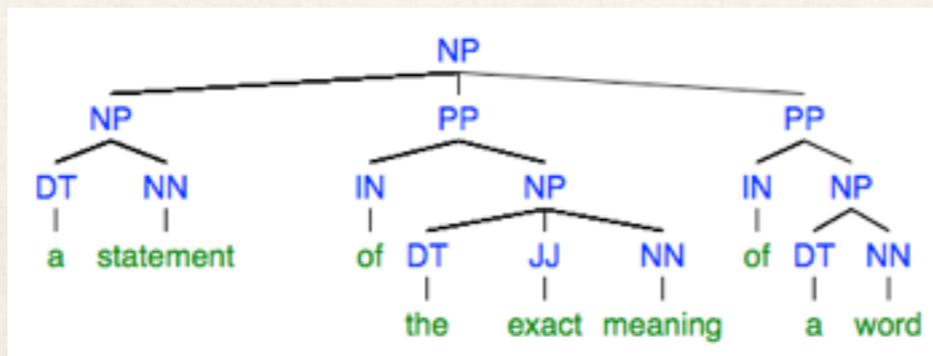
❖ Sensory Information Processing



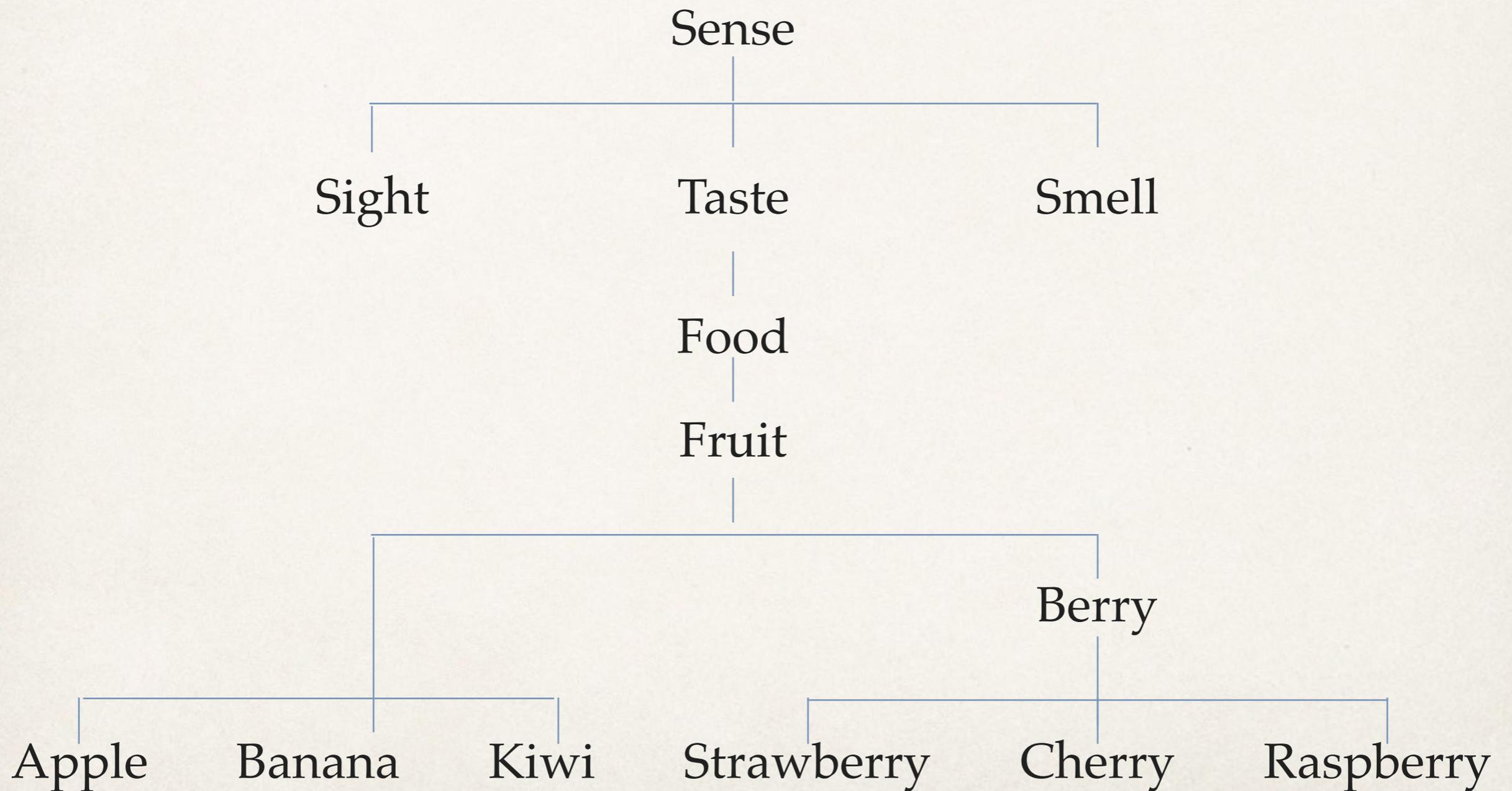
Grandmother Cell

- ❖ grandmother cell - neuron that represents a complex but specific concept or object
- ❖ lower dimensional grandmother cells are defined by sensory inputs
- ❖ higher dimensional grandmother cells are not defined by sensory inputs but rather other words

❖ definition -



Higher Dimensional Grandmother Cell



Superset Isomorphism: Learning from Input

❖ Input Learned Information

❖ $A+B \rightarrow \underline{AB}$

❖ $\text{Micro} + \text{Wave} \rightarrow \underline{\text{Microwave}}$

❖ $AB \rightarrow \underline{A} + \underline{B}$

❖ $\text{Microwave} \rightarrow \underline{\text{Micro}} + \underline{\text{Wave}}$

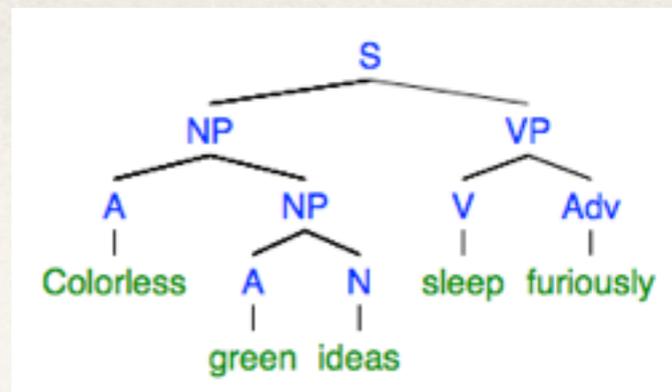
❖ $AB \rightarrow \underline{A} + \underline{B} + \underline{C} \rightarrow AC$

❖ $\text{Microwave} \rightarrow \underline{\text{Micro}} + \underline{\text{Wave}} + \underline{\text{Scope}} \rightarrow \text{Microscope}$

English Lemma

Rule	Input A	Input B	Isomorphic Superset	Variable Subset
Past Tense	learned	walked	(verb)ed	learn, walk
Gerund	running	walking	(verb)ing	run, walk
Article	the cat	a cat	(article) cat	the, a
Prefix	microwave	microscope	micro(noun)	wave, scope

English Grammar

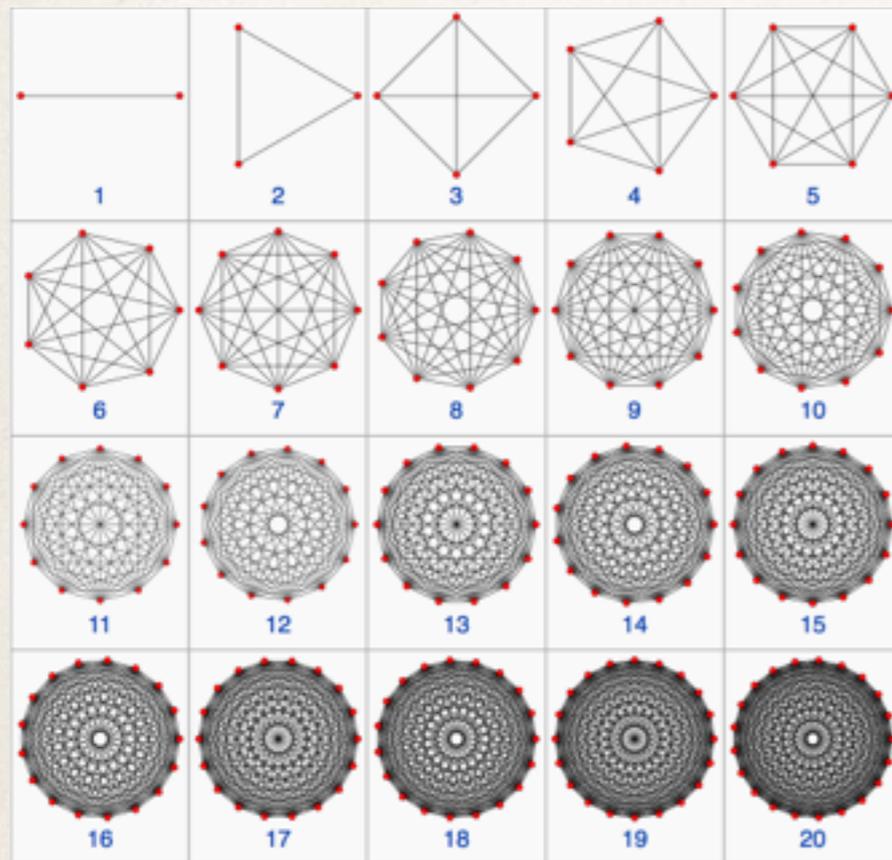


Rule	Input A	Input B	Isomorphic Superset	Variable Subset
Adj-N				green, blue
N-V-Adv				ideas, dogs
V-Adv				furiously, madly
N-V				sleep, dream

Opetope

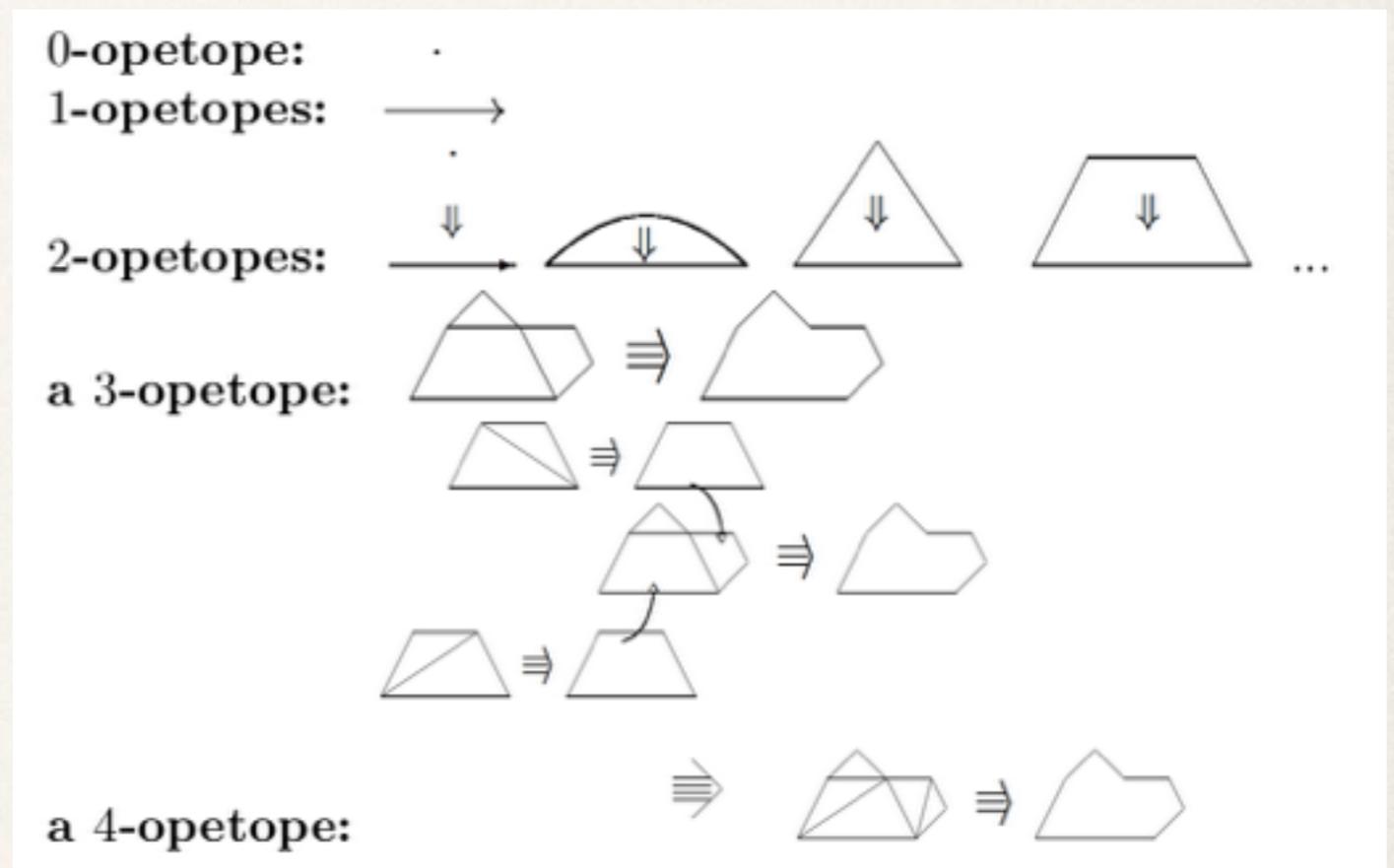
- ❖ weak - order is remembered
- ❖ strong - order doesn't matter
- ❖ simplex - generalization of the notion of a triangle or tetrahedron to arbitrary dimensions
 - ❖ 2-simplices can only take a pair of composable arrows as input
- ❖ opetope - underlying shapes of cells of weak n-categories
 - ❖ 2-opetopes can take any integer-length string of composable arrows as input
- ❖ pasting diagram $a_1 \xrightarrow{f_1} a_2 \xrightarrow{f_2} \dots \xrightarrow{f_n} a_{n+1} .$
 - ❖ Given an ordinary category C, a pasting diagram in C is a sequence of composable morphisms in C. Arrows are pasted together at their objects.

Higher Dimensional Opetopes



Higher Dimensional Simplex

<http://en.wikipedia.org/wiki/Simplex>



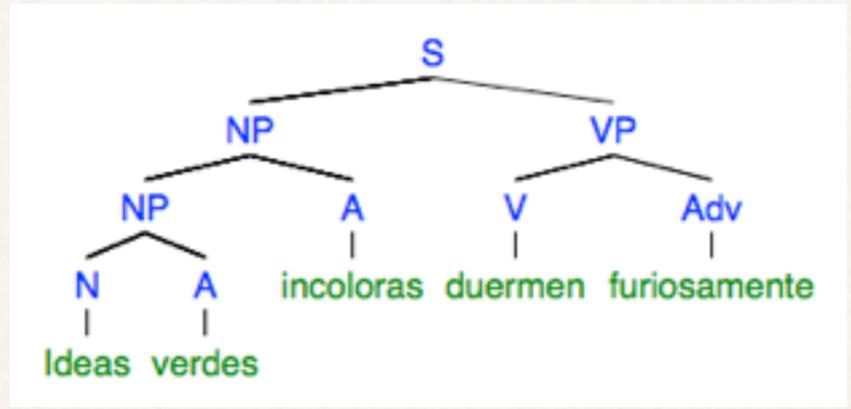
Higher Dimensional Opetope

http://math.uchicago.edu/~ctomesch/topic_proposal.pdf

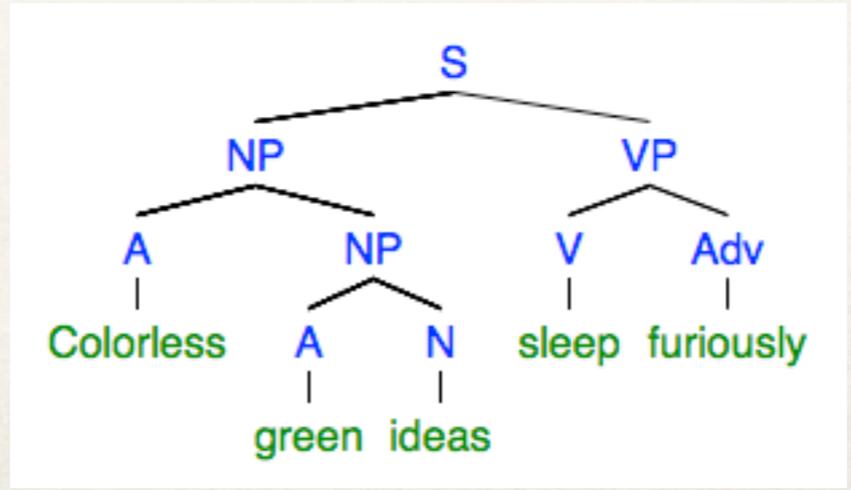
Opetopic Parse Trees

set of words {colorless, green, ideas, sleep, furiously}

N-A
A-N



English-Spanish Translation



concept of
colorless
green ideas
sleeping
furiously

End

❖ Future Work:

- ❖ Superset Isomorphism applied to meaning, not grammatical structure.
 - ❖ i.e. difference between:
 - ❖ Blue and green are my favorite colors. & My favorite colors are green and blue.
 - ❖ Cats chase dogs. & Dogs chase cats.

❖ References:

- ❖ Operads, quasiorders and regular languages (arXiv:1401.2010)
- ❖ Higher Operads, Higher Categories (arXiv:math/0305049)
- ❖ Higher dimensional categories: an illustrated guidebook (<http://cheng.staff.shef.ac.uk/guidebook/guidebook-new.pdf>)