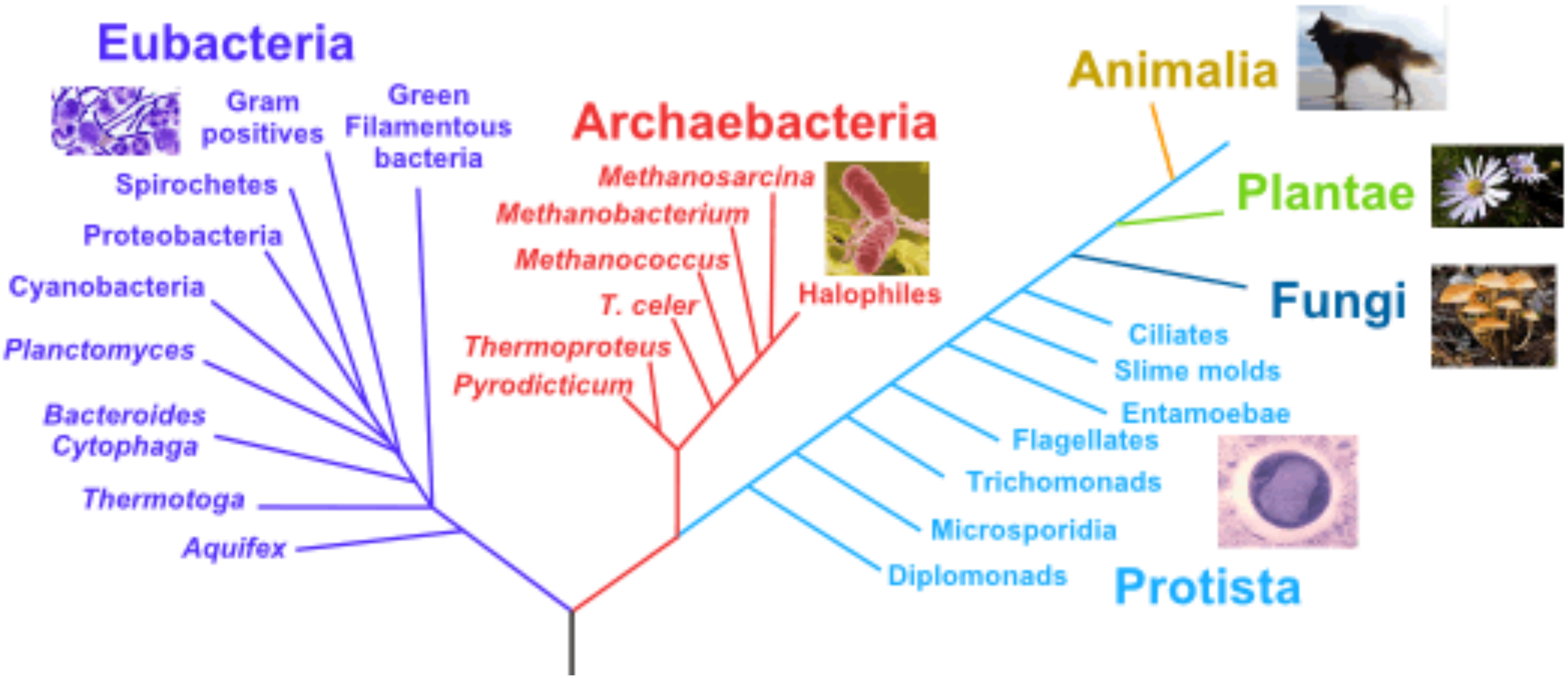
Categories and Concepts

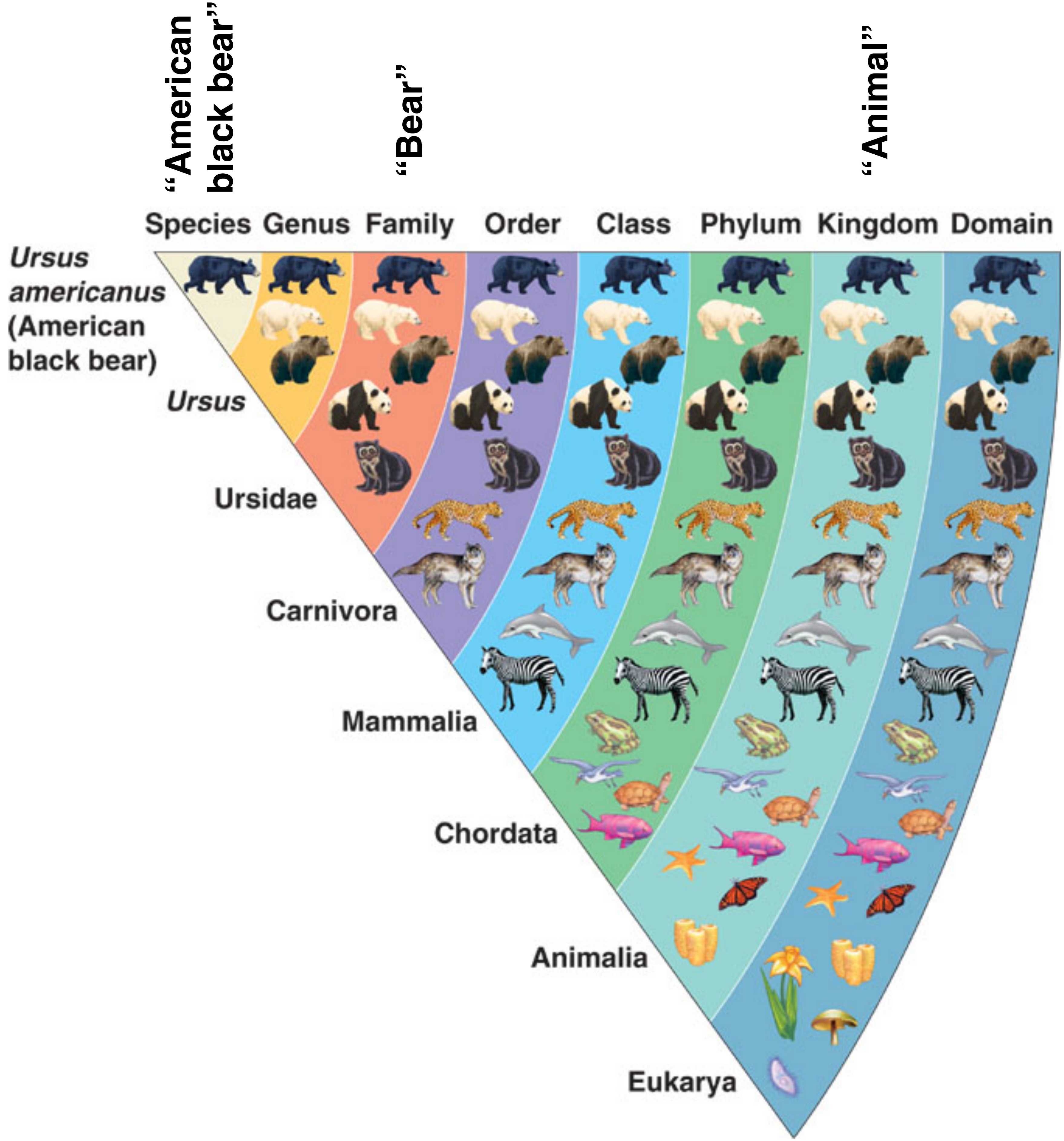
Taxonomic organization and the basic level

Brenden Lake

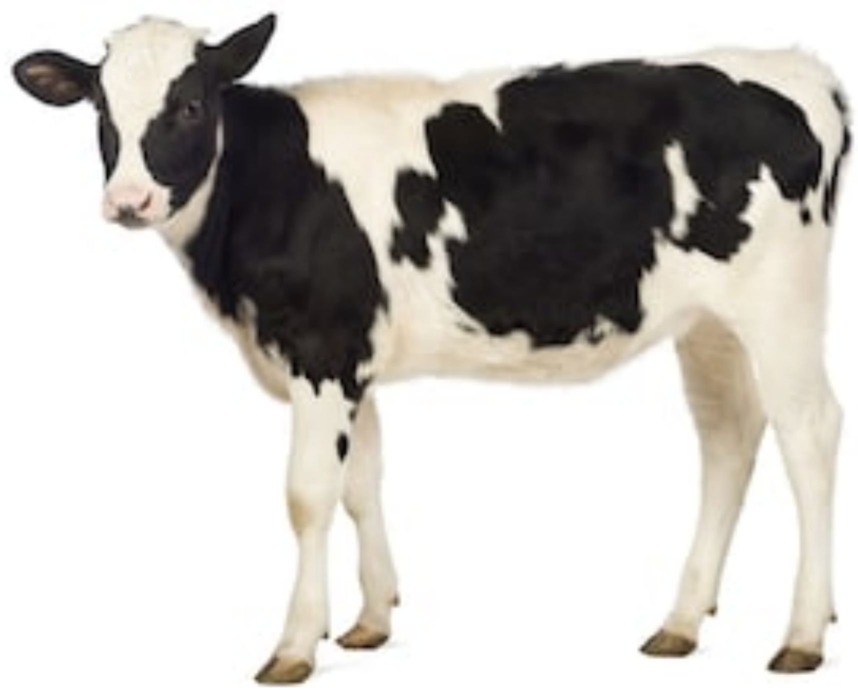
PSYCH-GA 2207

Taxonomic kingdoms of life





“American black bear”
“Bear”
“Animal”
Species
Genus
Family
Order
Class
Phylum
Kingdom
Domain
Ursus americanus (American black bear)
Ursus
Ursidae
Carnivora
Mammalia
Chordata
Animalia
Eukarya



Object?

Living thing?

Animal?

Mammal?

Ungulate?

Bovine?

Cow?

Holstein Friesian cow?

My cow, “Betsy"?

First explorations

Roger Brown (1958, *Psych Review*)
“How Shall a Thing be Called?”

- It shall be called by the name that is functionally most important.

Animal?… Dog?… Sheepdog?... Fido?

But what makes a name useful, especially if there is no obvious use at the moment?

- e.g., I’m not herding “sheep” right now.

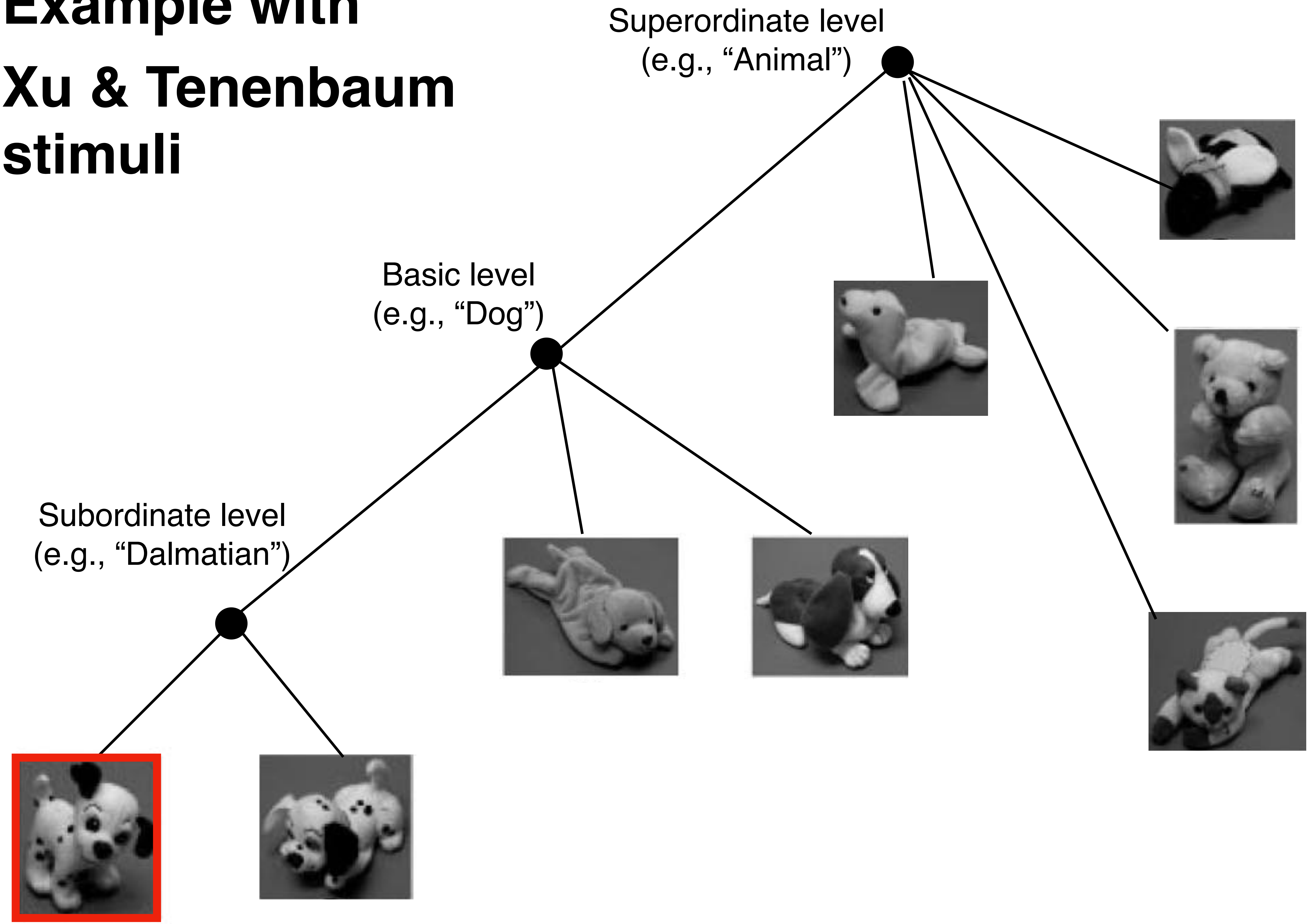
approximately 3 levels of categorization

- Basic Level: the neutral, “preferred” level
- Subordinate level: more specific, detailed
- Superordinate level: more general, abstract

- But there are often many levels reaching above and below the basic level.

- All the more specific ones are “subordinates”, and all the more general ones are “superordinates.”

Example with Xu & Tenenbaum stimuli



COGNITIVE PSYCHOLOGY 8, 382–439 (1976)

Basic Objects in Natural Categories

ELEANOR ROSCH, CAROLYN B. MERVIS, WAYNE D. GRAY, DAVID M. JOHNSON, AND PENNY BOYES-BRAEM

University of California, Berkeley

Categorizations which humans make of the concrete world are not arbitrary but highly determined. In taxonomies of concrete objects, there is one level of abstraction at which the most basic category cuts are made. Basic categories are those which carry the most information, possess the highest category cue validity, and are, thus, the most differentiated from one another. The four experiments of Part I define basic objects by demonstrating that in taxonomies of common concrete nouns in English based on class inclusion, basic objects are the most inclusive categories whose members: (a) possess significant numbers of attributes in common, (b) have motor programs which are similar to one another, (c) have similar shapes, and (d) can be identified from averaged shapes of members of the class. The eight experiments of Part II explore implications of the structure of categories. Basic objects are shown to be the most inclusive categories for which a concrete image of the category as a whole can be formed, to be the first categorizations made during perception of the environment, to be the earliest categories sorted and earliest named by children, and to be the categories most codable, most coded, and most necessary in language.

The world consists of a virtually infinite number of discriminably different stimuli. One of the most basic functions of all organisms is the cutting up of the environment into classifications by which nonidentical stimuli can be treated as equivalent. Yet there has been little explicit attempt to determine the principles by which humans divide up the world in

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Carolyn Mervis is now at the University of Illinois. She was a National Science Foundation predoctoral fellow during performance of the research.

Requests for reprints should be sent to Eleanor Rosch, Department of Psychology, University of California at Berkeley, Berkeley, CA 94720.

Rosch et al. (1976), Part I:

Converging definitions for identifying the basic level

1. Feature listings. Look for “elbow” in curve.
2. List movements associated with objects. Ditto.
3. Shape commonality to identify average shapes.

Note that these operations generally separate the basic level from the superordinate, but not the basic from subordinate.

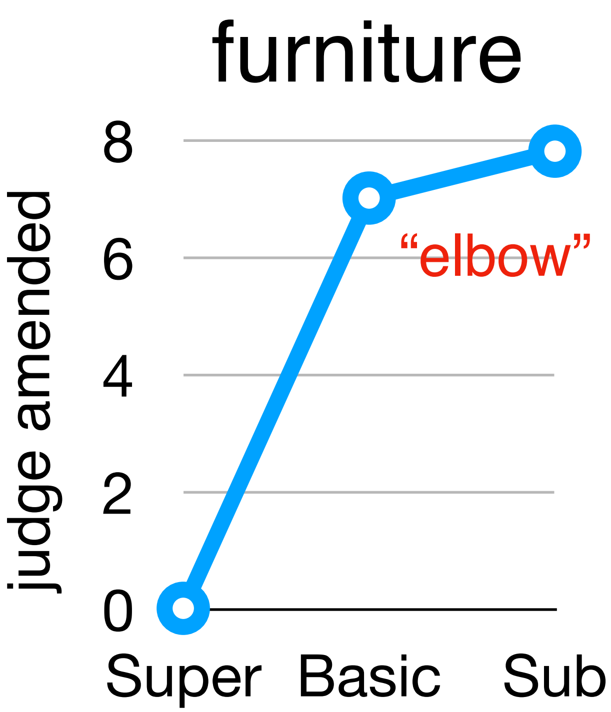
Feature listings

THE NINE TAXONOMIES USED AS STIMULI

Superordinate	Basic level	Subordinates	
		Nonbiological taxonomies	
Musical instrument	Guitar	Folk guitar	Classical guitar
	Piano	Grand piano	Upright piano
	Drum	Kettle drum	Base drum
Fruit[a]	Apple	Delicious apple	Mackintosh apple
	Peach	Freestone peach	Cling peach
	Grapes	Concord grapes	Green seedless grapes
Tool	Hammer	Ball-peen hammer	Claw hammer
	Saw	Hack hand saw	Cross-cutting hand saw
	Screwdriver	Phillips screwdriver	Regular screwdriver
Clothing	Pants	Levis	Double knit pants
	Socks	Knee socks	Ankle socks
	Shirt	Dress shirt	Knit shirt
Furniture	Table	Kitchen table	Dining room table
	Lamp	Floor lamp	Desk lamp
	Chair	Kitchen chair	Living room chair
Vehicle	Car	Sports car	Four door sedan car
	Bus	City bus	Cross country bus
	Truck	Pick up truck	Tractor-trailer truck
		Biological taxonomies	
Tree	Maple	Silver maple	Sugar maple
	Birch	River birch	White birch
	Oak	White oak	Red oak
Fish	Bass	Sea bass	Striped bass
	Trout	Rainbow trout	Steelhead trout
	Salmon	Blueback salmon	Chinook salmon
Bird	Cardinal	Easter cardinal	Grey tailed cardinal
	Eagle	Bald eagle	Golden eagle
	Sparrow	Song sparrow	Field sparrow

[a] Fruit is not considered a biological taxonomy by the criteria in Berlin (1972).

Feature listings

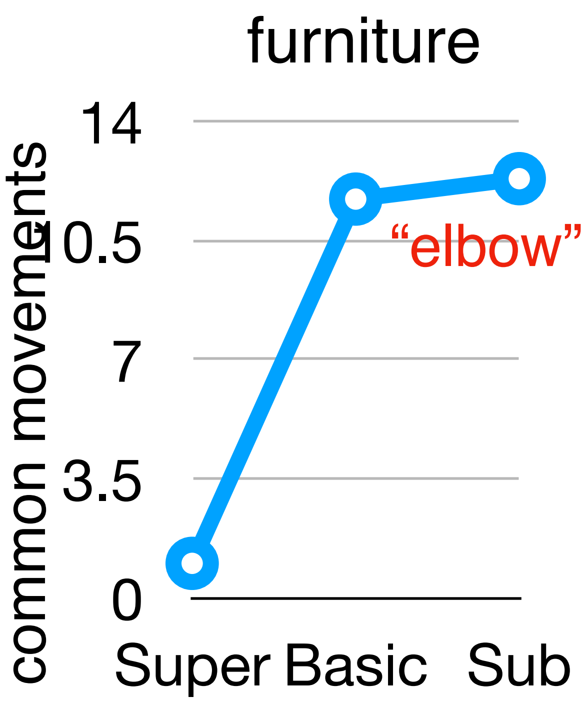


definition: "basic level" is the most inclusive level at which categories have many features in common

NUMBER OF ATTRIBUTES IN COMMON AT EACH LEVEL OF ABSTRACTION

Category	Number of attributes in common					
	Raw tallies			Judge-amended tallies		
	Super-ordinate	Basic level	Sub-ordinate	Super-ordinate	Basic level	Sub-ordinate
Nonbiological taxonomies						
Musical instrument	1	6.0	8.5	1	8.3	8.7
Fruit	7	12.3	14.7	3	8.3	9.5
Tool	3	8.3	9.7	3	8.7	9.2
Clothing	3	10.0	12.0	2	8.3	9.7
Furniture	3	9.0	10.3	0	7.0	7.8
Vehicle	4	8.7	11.2	1	11.7	16.8
Biological taxonomies						
Tree	9	10.3	11.2	10	11.0	11.5
Fish	6	8.7	9.3	8	9.7	10.0
Bird	11	14.7	15.3	14	16.0	16.5

Movements associated with objects



definition:"basic level" is the most inclusive level at which categories have many movements in common, when you use or interact with that object

example

Tool
Hand: grasp
Fingers: grasp
Hammer
Arm: extend
Hand: big grasj position
Fingers: position
Other hand: position
Body: bend
Neck: bend

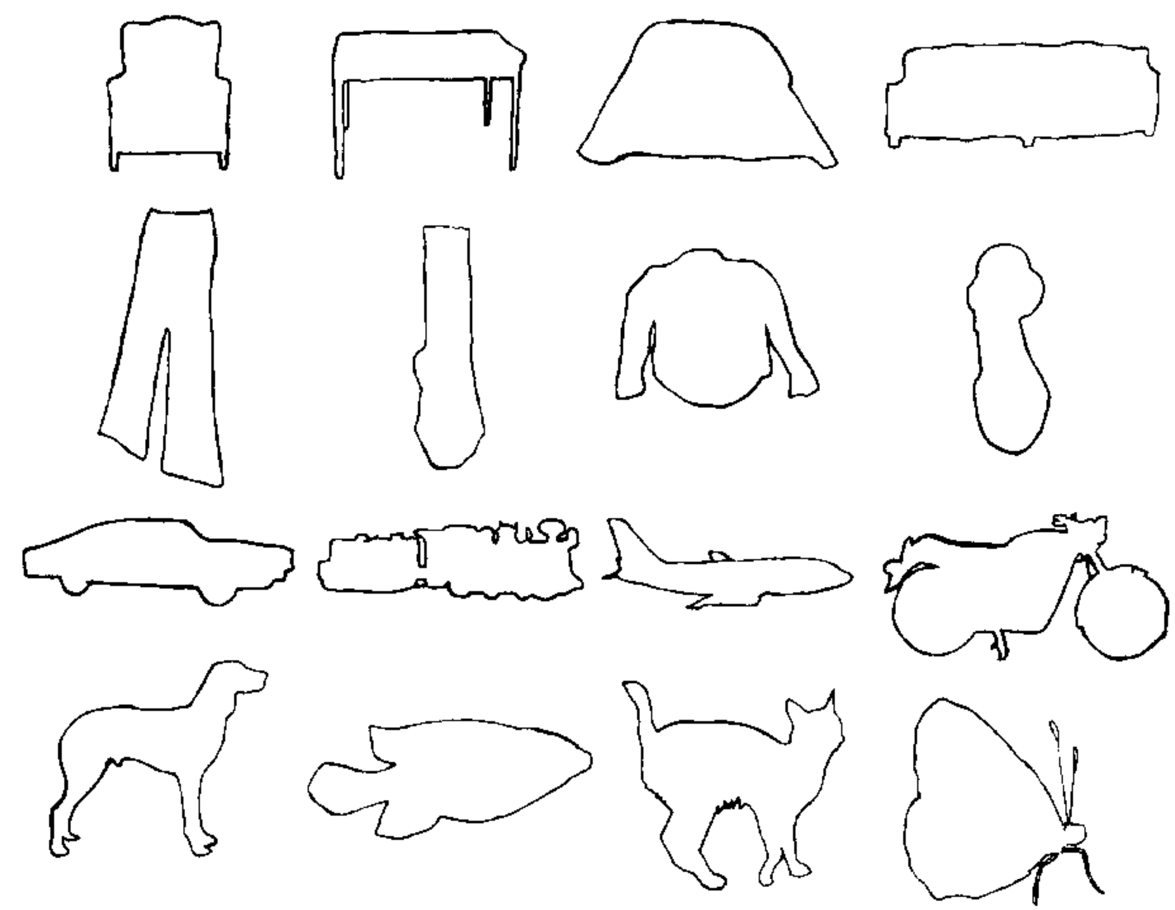
NUMBER OF MOTOR MOVEMENTS IN COMMON AT EACH LEVEL OF ABSTRACTION

Category	Number of motor movements in common				
	Super-ordinate	Basic level	Subordinate mean	Subordinate number added	Subordinate number subtracted
Nonbiological taxonomies					
Musical instrument	0	16.7	16.2	2.2	2.6
Fruit	4	21.3	20.5	2.5	3.3
Tool	2	19.2	18.0	1.2	2.7
Clothing	2	19.0	19.2	1.5	1.5
Furniture	1	11.7	12.3	1.3	.7
Vehicle	1	18.0	18.2	2.8	2.5
Biological taxonomies					
Tree	8	6.0	6.8	.7	.8
Fish	17	14.0	17.0	1.2	1.7
Bird	7	7.3	7.2	.3	.5

Shape overlap

definition: “basic level” is the most inclusive level at which categories have a common shape

example object outlines



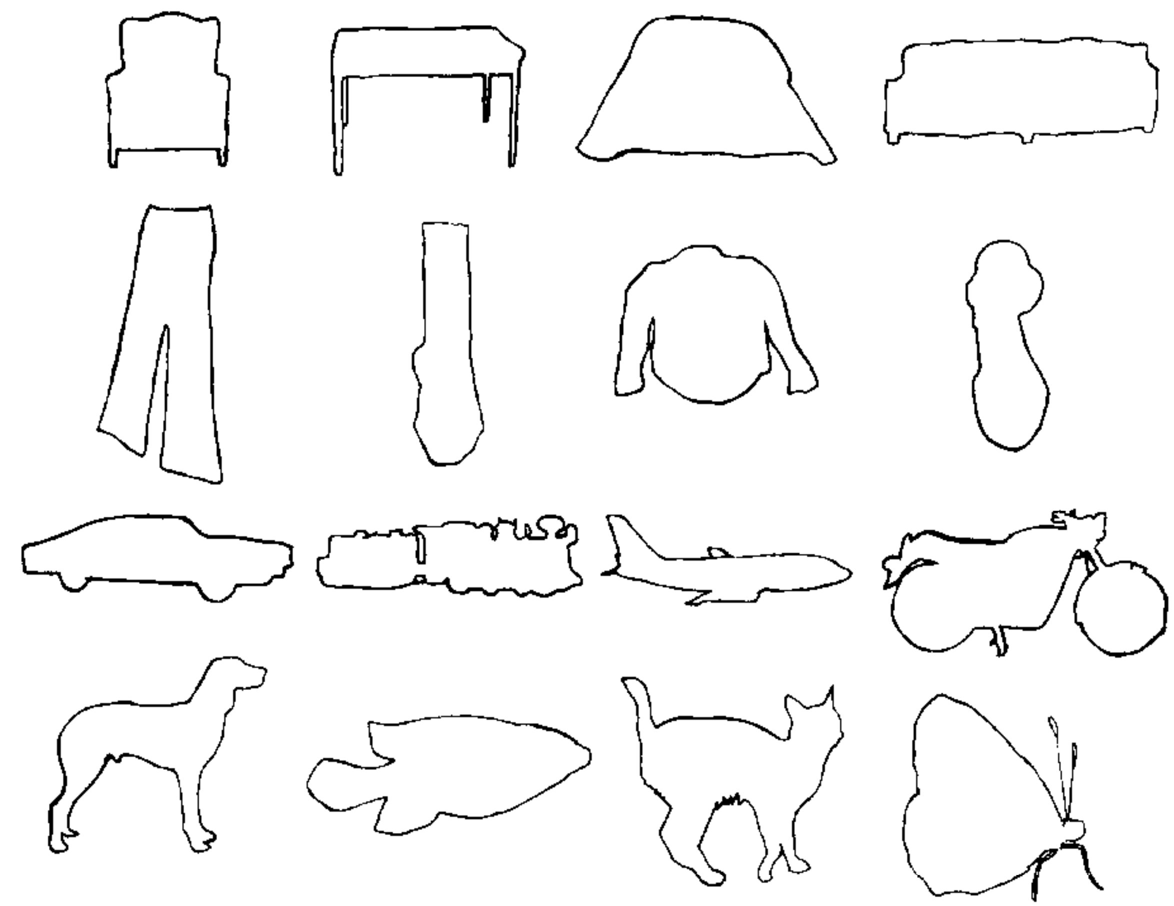
Two silhouettes were compared for overlap, when drawn from the same subordinate, basic, or super category

There is a similar “elbow” in the overlap measure, where silhouettes from different super categories don’t overlap much

Shape identification

"basic level" is the most inclusive level at which categories have an identifiable shape

example object outlines



The average of two object shapes identified correctly at this level, when the objects were from the same:

- super. category: 33% accuracy
- basic level category: 78%
- sub. level category: 84%

Identifying the basic level from raw images

(Yu, Maxfield, & Zelinsky, 2016)

- Based on tightly cropped web images of vehicles, furniture, clothing, desserts

- Features extract using (outdated) computer vision algorithm (SIFT features)
- **Informativeness:** The number of features in common amongst all the exemplars of a category (to some criterion)
- **Distinctiveness:** distance in feature space to contrasting (sibling) categories

Identifying the basic level from raw images

(Yu, Maxfield, & Zelinsky, 2016)

Basic-level has balance of informativeness and distinctiveness

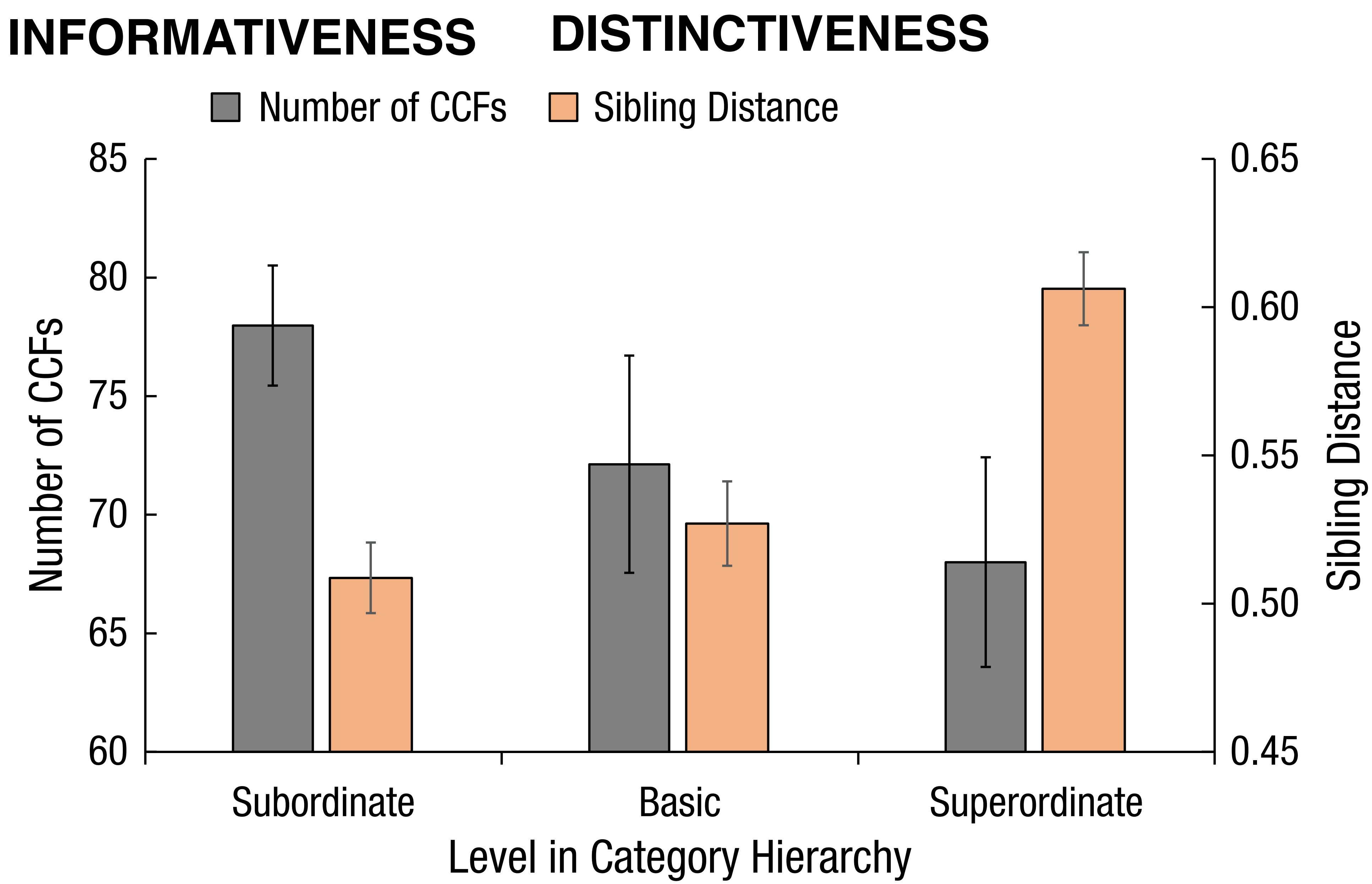
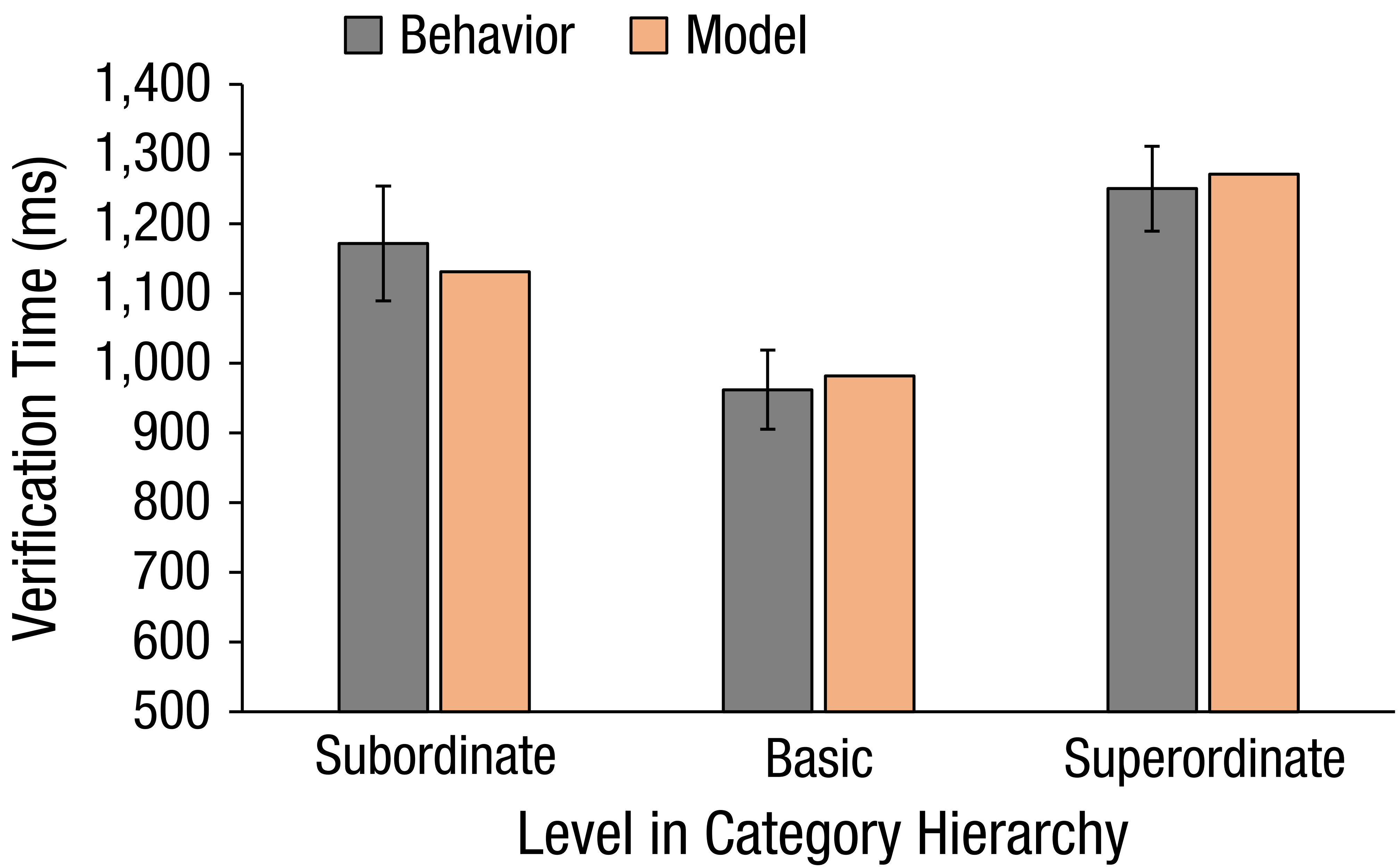


Fig. 6. Mean number of category-consistent features (CCFs) and mean sibling distance from the CCF model by hierarchical level. Error bars indicate ±1 *SEM*, computed by treating the number of categories at each level as the number of sample observations (n).

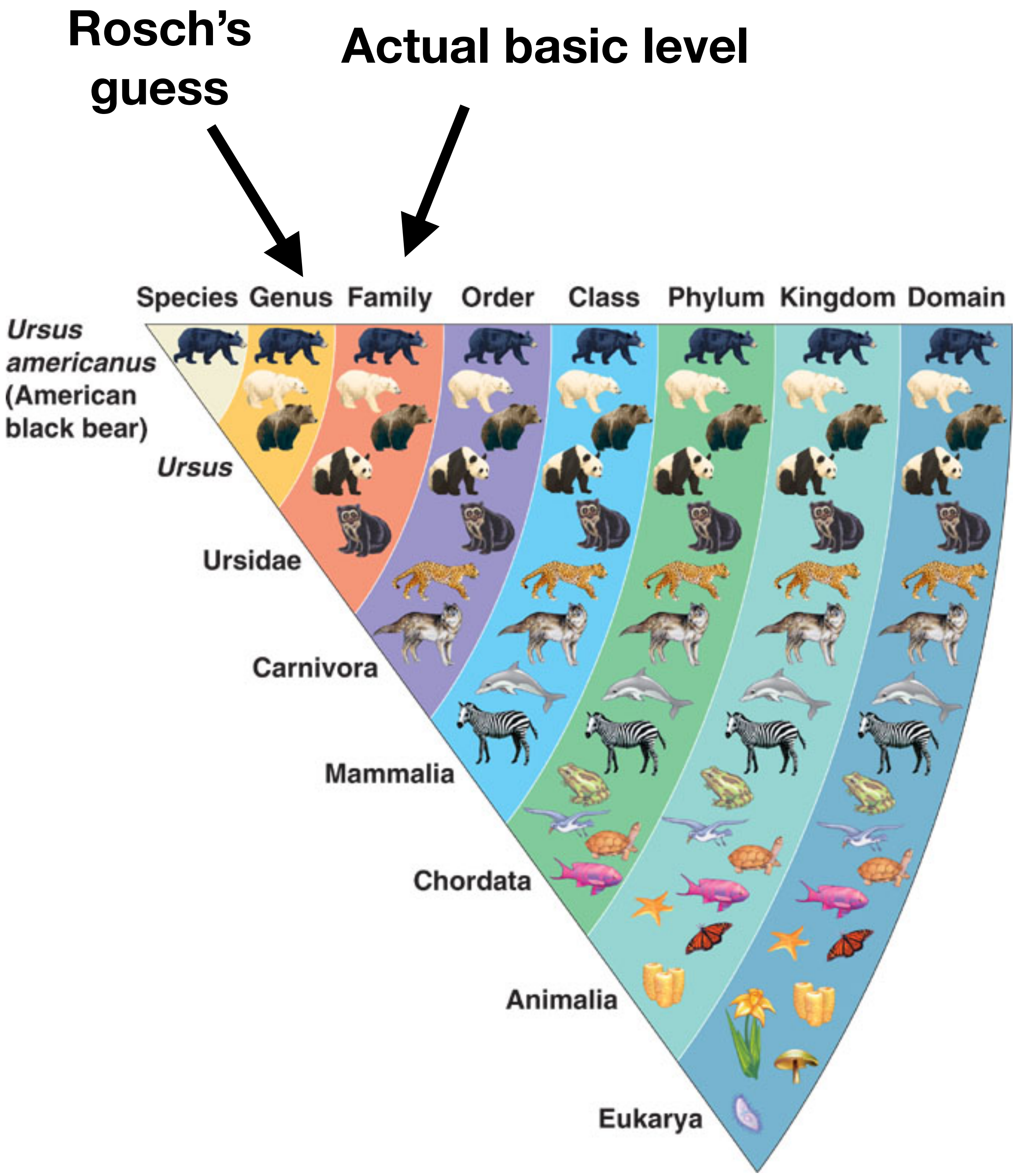
Identifying the basic level from raw images

(Yu, Maxfield, & Zelinsky, 2016)

Basic-level advantage in category verification can be modeled as product of informativeness x distinctiveness measure



Biological categories



- Rosch et al. guessed that the *genus level* would be basic
  - oak, maple, trout, salmon, sparrow, parrot
- The *family* level turned out to be the basic level
  - tree, fish, bird, etc.

Rosch et al. (1976), Part II:

Testing performance on the different levels

- Exp. 5: Use of category names to prime detection under noise
- Exp. 6: Use of category names to prime same-different picture judgments
- Exp. 7: Picture categorization
- Expt. 8 & 9: Categorization in triads or large sets by children

Rosch et al. (1976), Part III:

Linguistic measures of performance

- Exp. 10: Free naming of pictures
- Exp. 11: Acquisition of concrete nouns at the three levels
- Exp 12: Existence of conventional signs in ASL

Exp 5 and 6: Priming influenced by level of name

Conclusion: There is a basic-level advantage for priming.

Experiment 5

- Object name was presented at sub, basic, or super level
- **Task:** Given two images, detect whether line drawing of object is on left or right of screen, under speed/noise (200 ms)
- **Results:** Accuracy is highest for basic-level prime (90%), compared to no prime (81%), super prime (69%), and sub prime (88%)

Experiment 6

- Again, object name was presented at sub, basic, or super level
- **Task:** Detect whether two images are physically identical or different (color photos, line drawings, etc.)
- **Results:** Response time is fastest for basic-level prime (average of 554 ms), compared to sub (620 ms) and super (568 ms), for color photos in this case

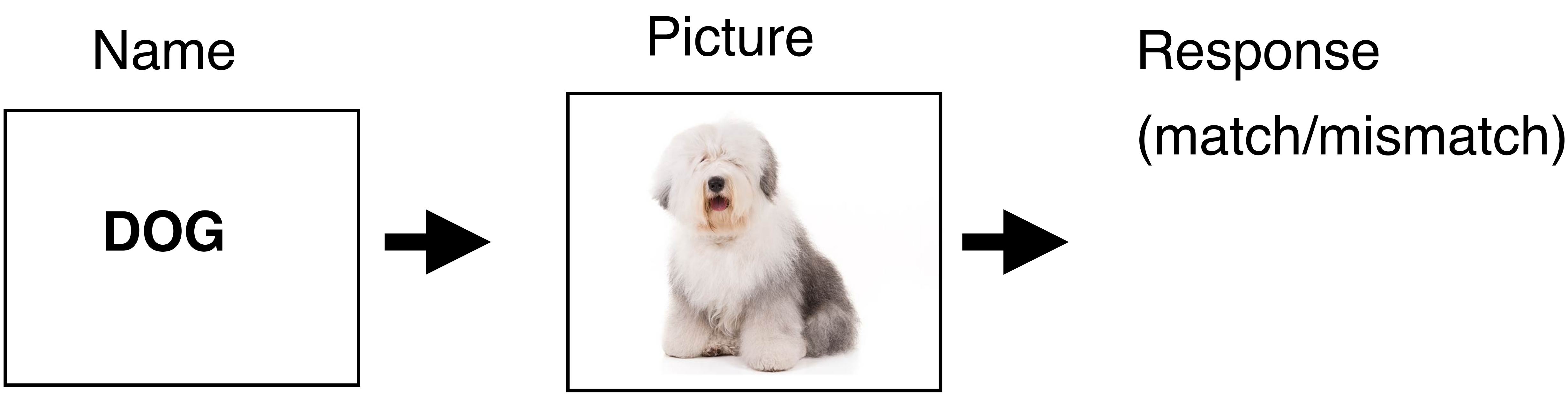
Exp 7: Category verification

There is a basic-level advantage for category verification.

Task: shown word (“dog”), then show color photo, participants press “match” or “mismatch”

Results

- Response time on match responses is fastest for basic-level prime (average of 535 ms), compared to sub (659 ms) and super (591 ms)



Exp 10: Free naming

There is a basic-level advantage for free naming — i.e., the default name of an object used by a speaker

Task: shown a color photo ("dog") and wrote name underneath

Results

- Naming overwhelming favors basic level

Written prompt:

"What is this called?"

TYPE OF NAME GIVEN IN FREE NAMING OF PICTURES

	Type of name given			
Contrast set	Superordinate	Basic level	Subordinate	Other
Superordinate	0	532	5	2
Basic level	0	533	4	2
Subordinate	1	530	5	4

Exp 11: Language development

Children learn basic level words first.

Case study: Sally used primarily only basic-level words for objects, in large corpus of recorded speech.

CONCRETE NOUNS USED IN STAGE I OF LANGUAGE ACQUISITION

	Taxonomic level of word used					
	Superordinate		Basic level		Subordinate	
Category	Tokens[a]	Types[a]	Tokens	Types	Tokens	Types
			Nonbiological			
Musical instrument	0	0	13	6	0	0
Fruit	0	0	7	3	0	0
Tool	0	0	37	13	0	0
Clothing	2	1	91	18	4	1
Furniture	0	0	75	16	1	1
Vehicle	0	0	50	11	3	2
			Biological[b]			

Summary of the basic level

- Paraphrasing Rosch et al.: For concrete objects, the basic level is generally the most useful for categorization.
- The basic level is the most inclusive level of classification where
  - attributes are predictable
  - objects in a class can be used the same way
  - objects in a class have a canonical shape
  - objects are imageable

- If you want to know the basic level, give someone a photo of an object and ask them to name it! [works say ~90% of the time; but not always for atypical items like “penguin” (Murphy and Brownell)]

COGNITIVE PSYCHOLOGY 23, 457–482 (1991)

Object Categories and Expertise: Is the Basic Level in the Eye of the Beholder?

JAMES W. TANAKA AND MARJORIE TAYLOR

University of Oregon

Classic research on conceptual hierarchies has shown that the interaction between the human perceiver and objects in the environment specifies one level of abstraction for categorizing objects, called the basic level, which plays a primary role in cognition. The question of whether the special psychological status of the basic level can be modified by experience was addressed in three experiments comparing the performance of subjects in expert and novice domains. The main findings were that in the domain of expertise (a) subordinate-level categories were as differentiated as the basic-level categories, (b) subordinate-level names were used as frequently as basic-level names for identifying objects, and (c) subordinate-level categorizations were as fast as basic-level categorizations. Taken together, these results demonstrate that individual differences in domain-specific knowledge affect the extent that the basic level is central to categorization.

In a series of important experiments, Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976) established that a basic level of abstraction has special significance in human categorization (also see Brown, 1958). The basic level was shown to be the most inclusive level at which a generalized shape of category exemplars is identifiable and imaginable. In addition, basic categories elicit similar motor programs and basic-level category labels are the first names learned by children. Based on their analysis of structure at the basic level, Rosch et al. (1976) predicted that basic-level categories would be the classifications made when objects are first perceived.

Rosch et al. (1976) demonstrated the special status of basic-level cate-

Tanaka and Taylor’s study of expertise and the basic level

What is the psychological status of the basic level: can it be modified by experience?

Structure of the world vs. structure of the mind?

Participants were “dog experts” or “bird experts”:

- “members of local dog or birdwatching clubs”

Studied effect of expertise on

1. Feature listings
2. Free naming
3. Category verification

Exp 1: Expertise influences feature listing

Task: List as many attributes of each category as you can (2 mins)

Results

- Novice domain: participants list more new features for basic level, compared to previous level
- Expert domain: almost as many new features at subordinate level as basic levels

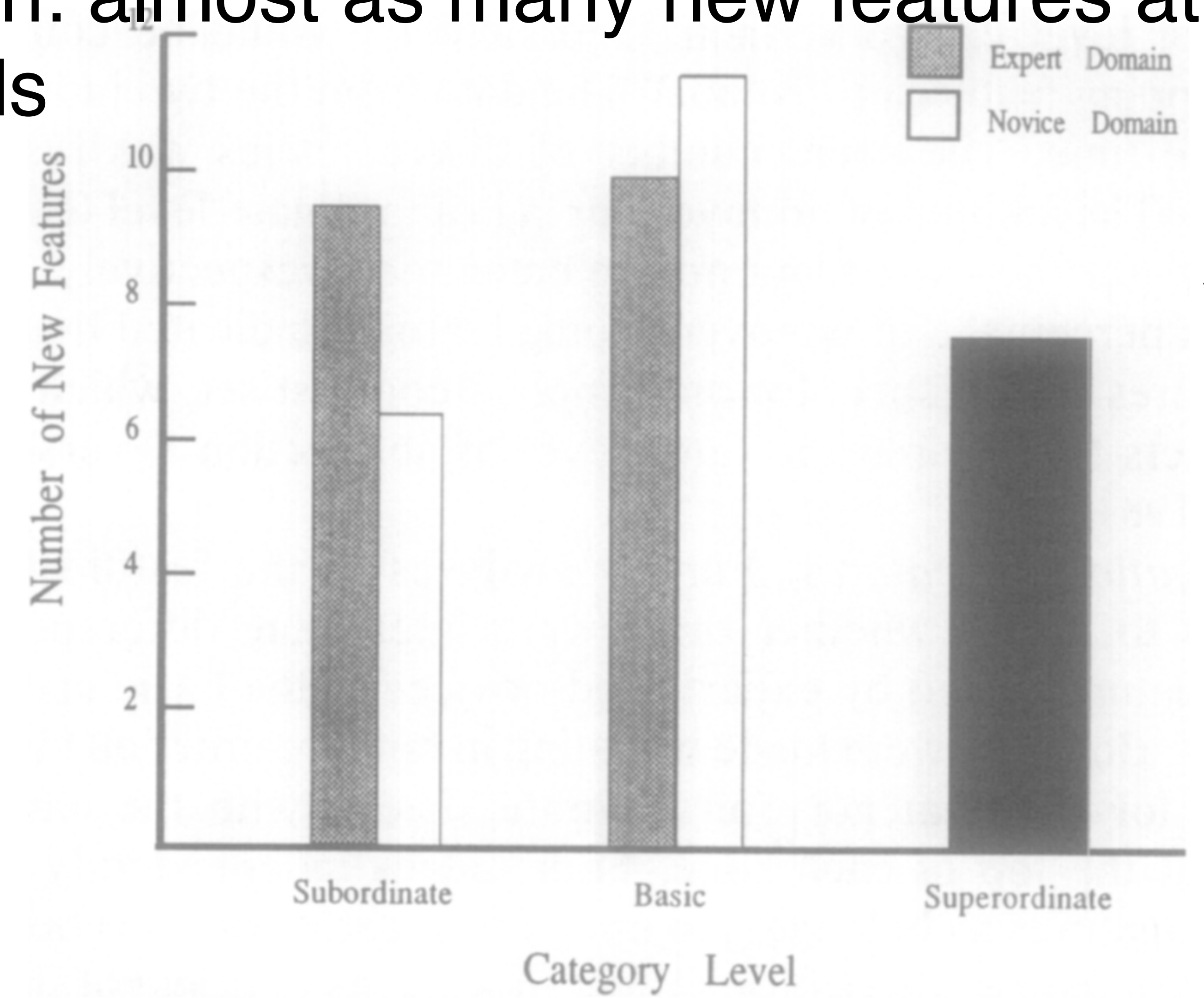


FIG. 1. Mean number of new features listed by subjects as a function of knowledge domain (expert and novice) and category level (subordinate, basic, and superordinate). Note that the basic-level categories "bird" and "dog" share the same superordinate category "animal."

Exp 1: Expertise influences feature listing

Task: List as many attributes of each category as you can (2 mins)

The type of features produce can vary as a function of domain and expertise:

- dog experts listed more *part features* than novices at subordinate level
- bird experts listed more *behavioral features* than novices at subordinate level
- both bird and dog experts listed more *dimensional features* than novices at subordinate level, related to size or color of the animals

Are you an expert?

Take the expertise test!**

Instructions: “Identify this object with the first name that comes to mind”

** modified from James Tanaka and Gary Cottrell

“Identify this object with the first name that comes to mind”

Ready…

“Identify this object with the first name that comes to mind”

“Car” - not an expert!

“2016 BMW M5” - expert!

“Identify this object with the first name that comes to mind”

Ready…

“Identify this object with the first name that comes to mind”

“Bird” or “Blue bird” - not an expert!

“Indigo bunting” - expert!

“Identify this object with the first name that comes to mind”

Ready…

"Identify this object with the first name that comes to mind"

"**Man**" - not an expert!

"**Donald Trump**" - expert!

Other names are possible!

Exp 2: Expertise influences free naming

Task: Given a picture, say the word that names the object as quickly as possible

Results

- bird experts tend to use subordinate-level name, while novices use basic-level
- dog experts use both subordinate and basic-level names, while novices use basic-level names

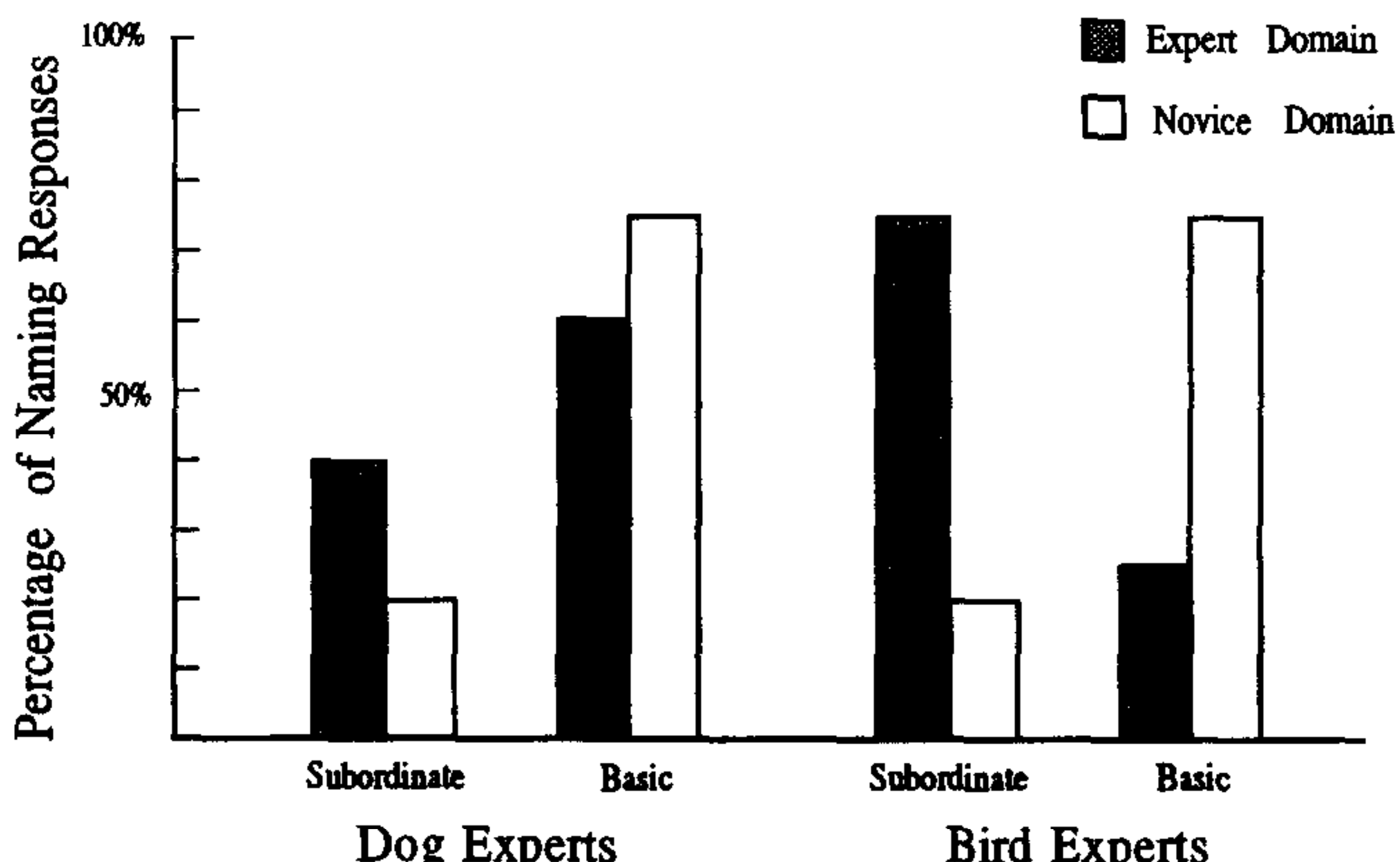
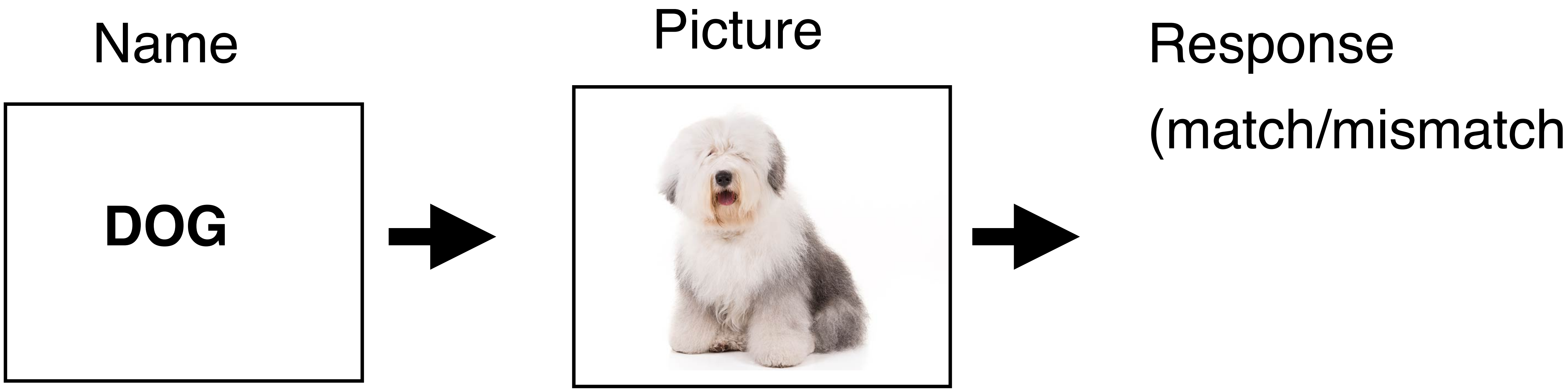


FIG. 2. Percentage of pictures identified with subordinate-level and basic-level names as a function of knowledge domain (expert and novice) and expert type (dog experts and bird experts).

Exp 3: Expertise influences category verification



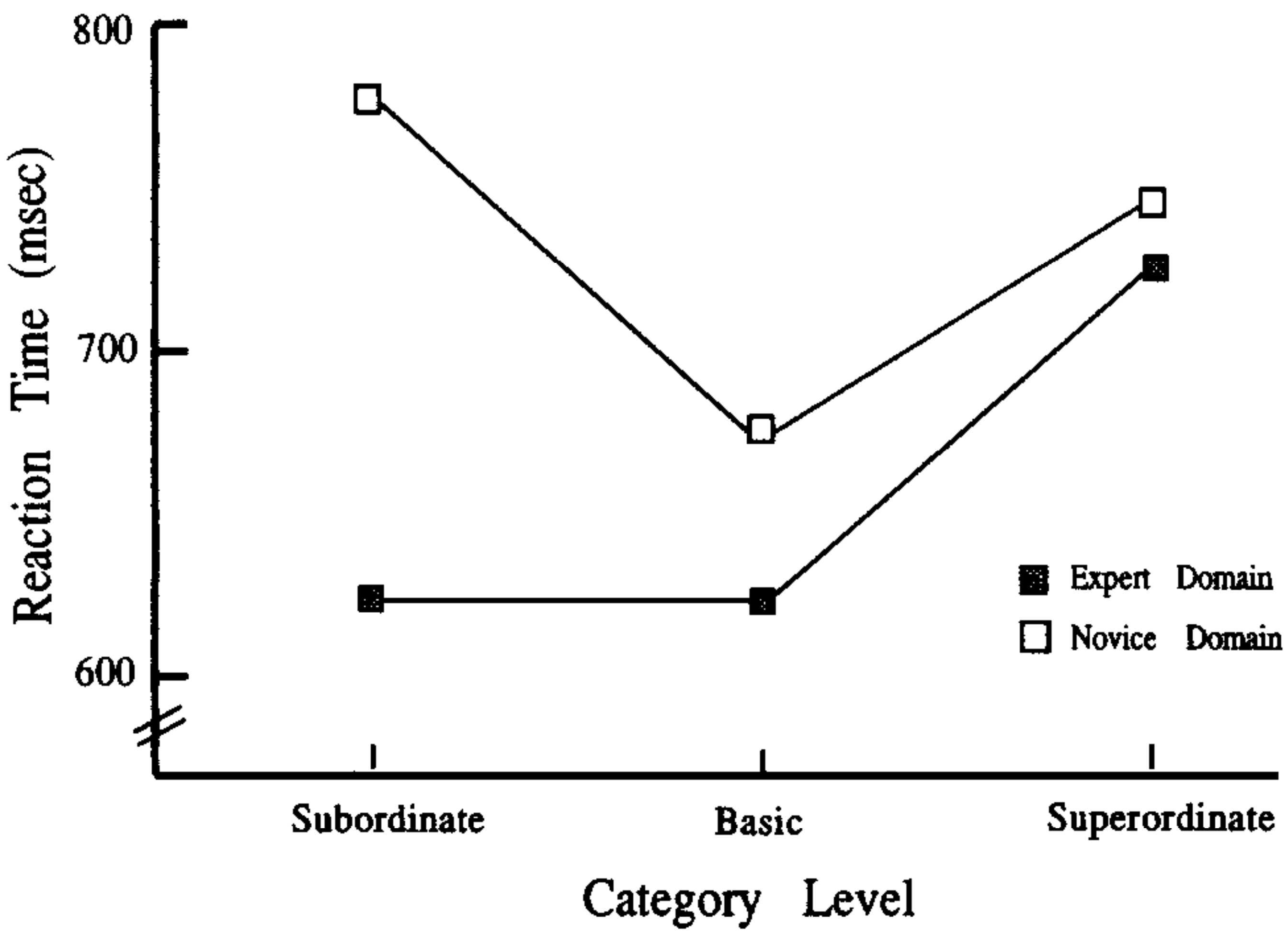


FIG. 3. Mean reaction times for TRUE responses as a function of knowledge domain (expert and novice) and category level (subordinate, basic, and superordinate).

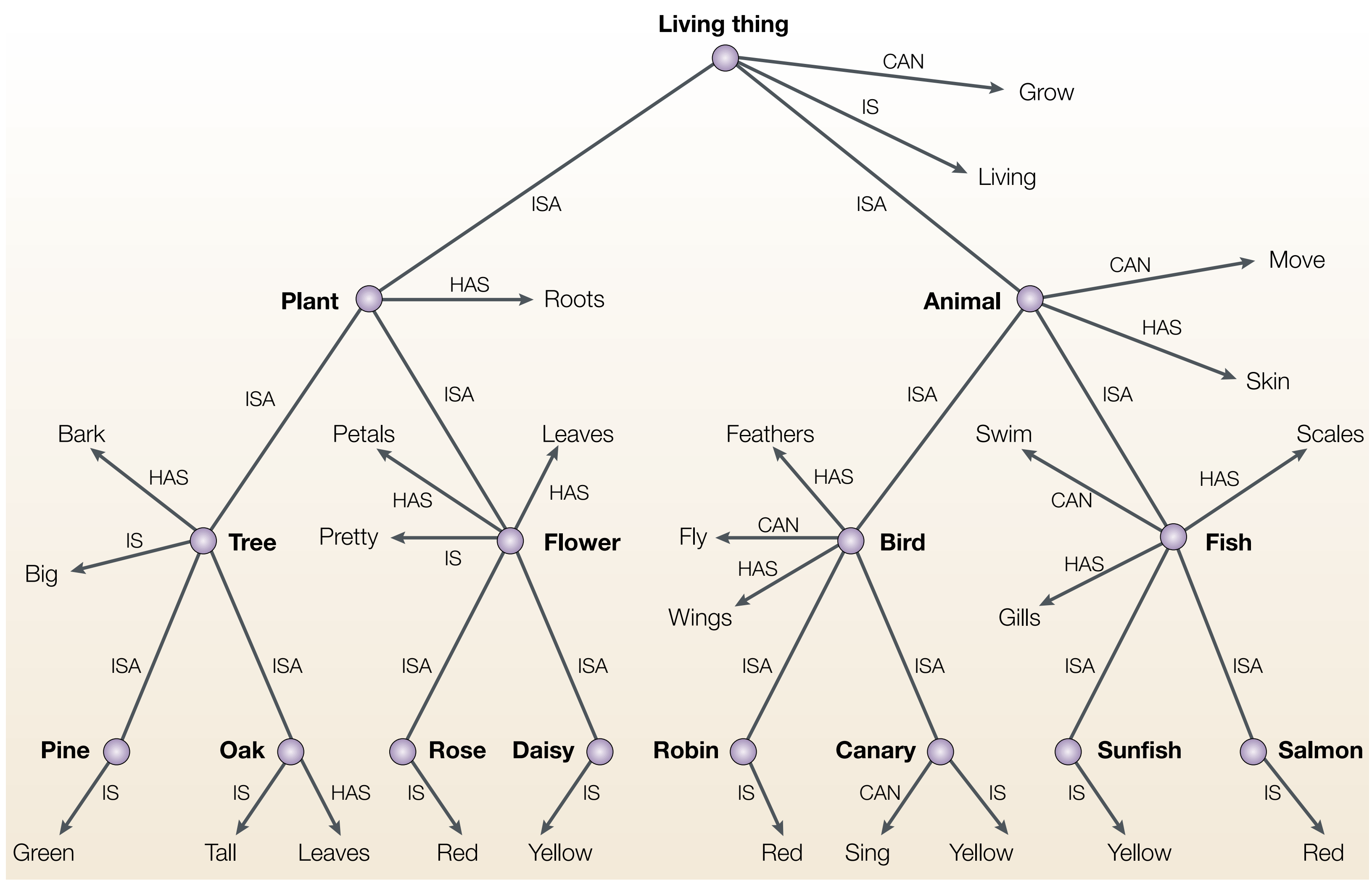
- Experts are fast for both subordinate and basic-level judgments
- Novices are fastest for basic-level judgments

Tanaka and Taylor implications for basic level

- Tanaka and Taylor suggest we shouldn't redefine the basic level for experts — the basic level is still the most inclusive category in which objects are identifiable
    - Basic level takes the “structure of the world” more than “structure of the mind”
- But experts have improved accessability to the sub-ordinate level

Collins and Quillian's hierarchical model of category representation

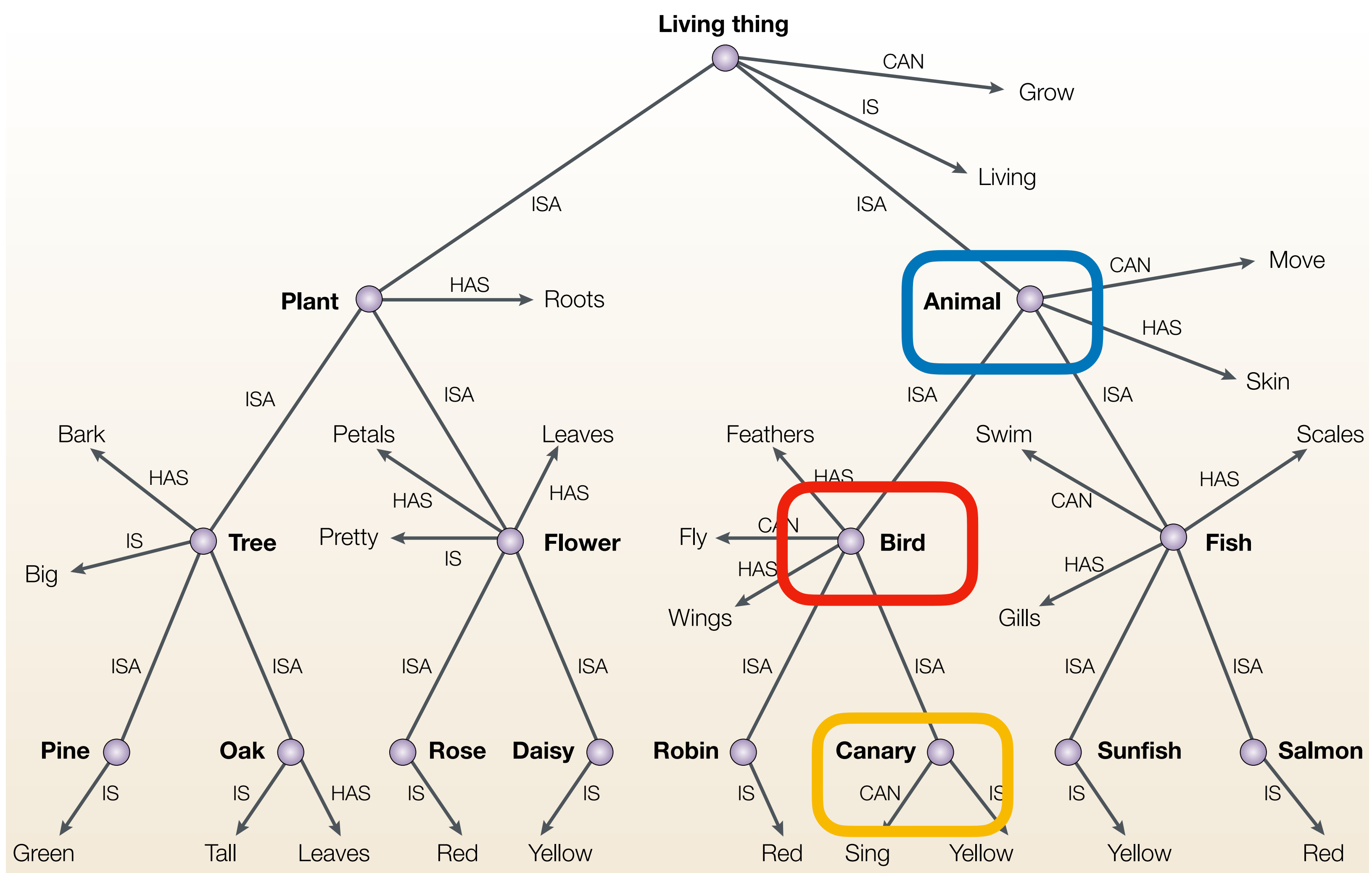
- Proposal that concepts are represented in a hierarchy organized from specific to general.
- Features true of all members of specific categories are stored only once, at the higher-level
- Appealing factor was "economy of storage"



(Collins & Quillian, 1968)

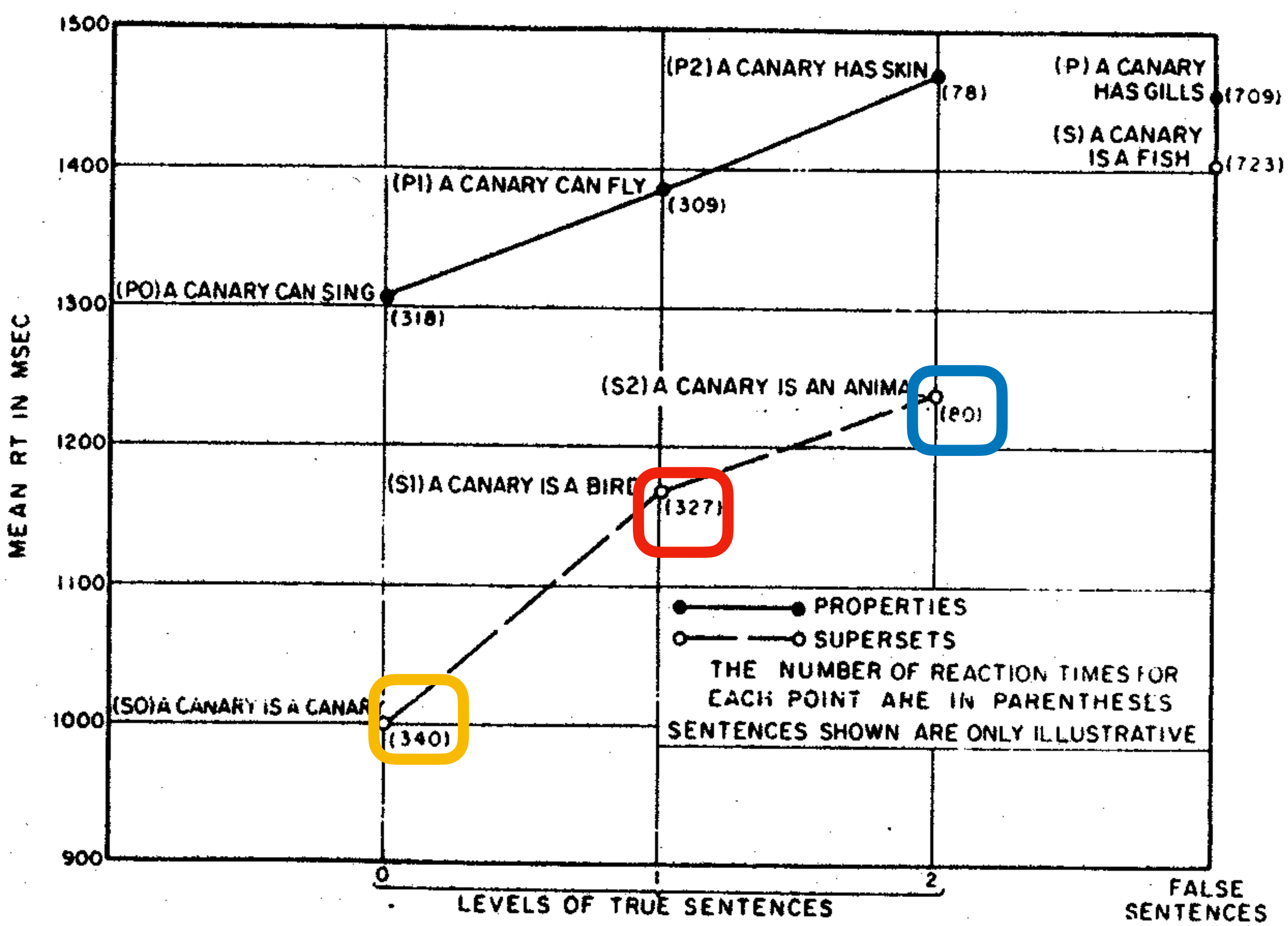
Collins and Quillian's hierarchical model of category representation

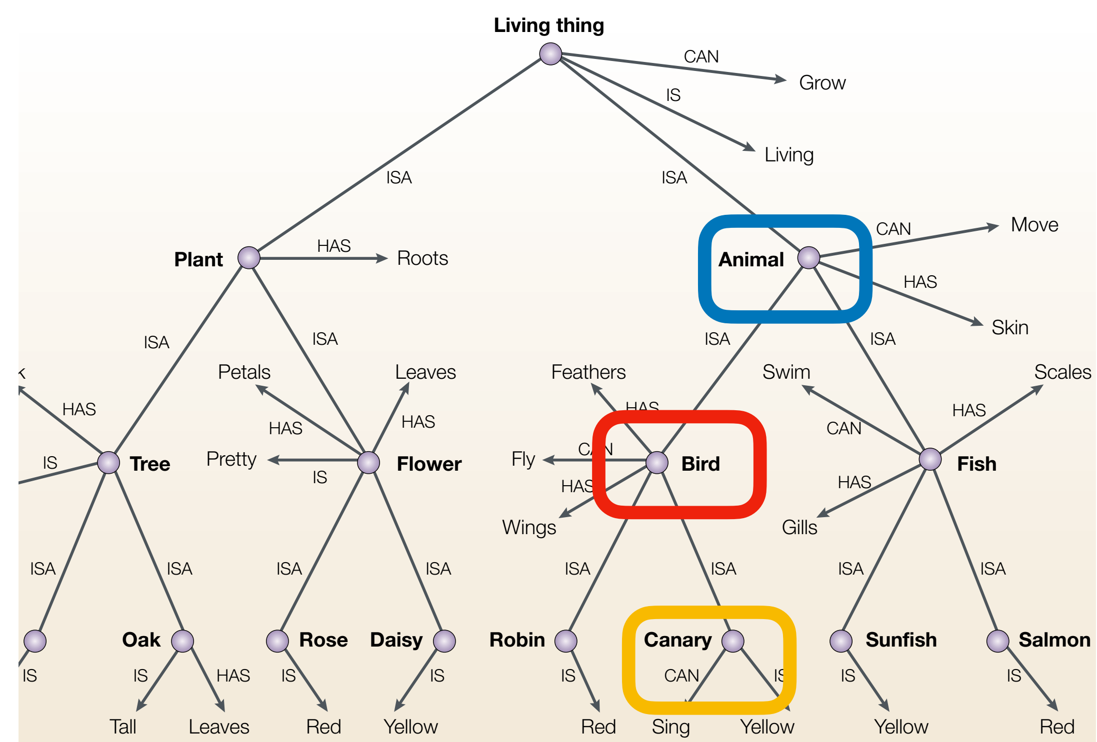
- As a model of human long term / semantic memory, let's assume that traversing an edge takes time
- Then, verifying that a "Canary is a bird" should be faster than "Canary is an animal"



Collins and Quillian's results

It's slower to retrieve facts from long term/semantic memory that are further in the network

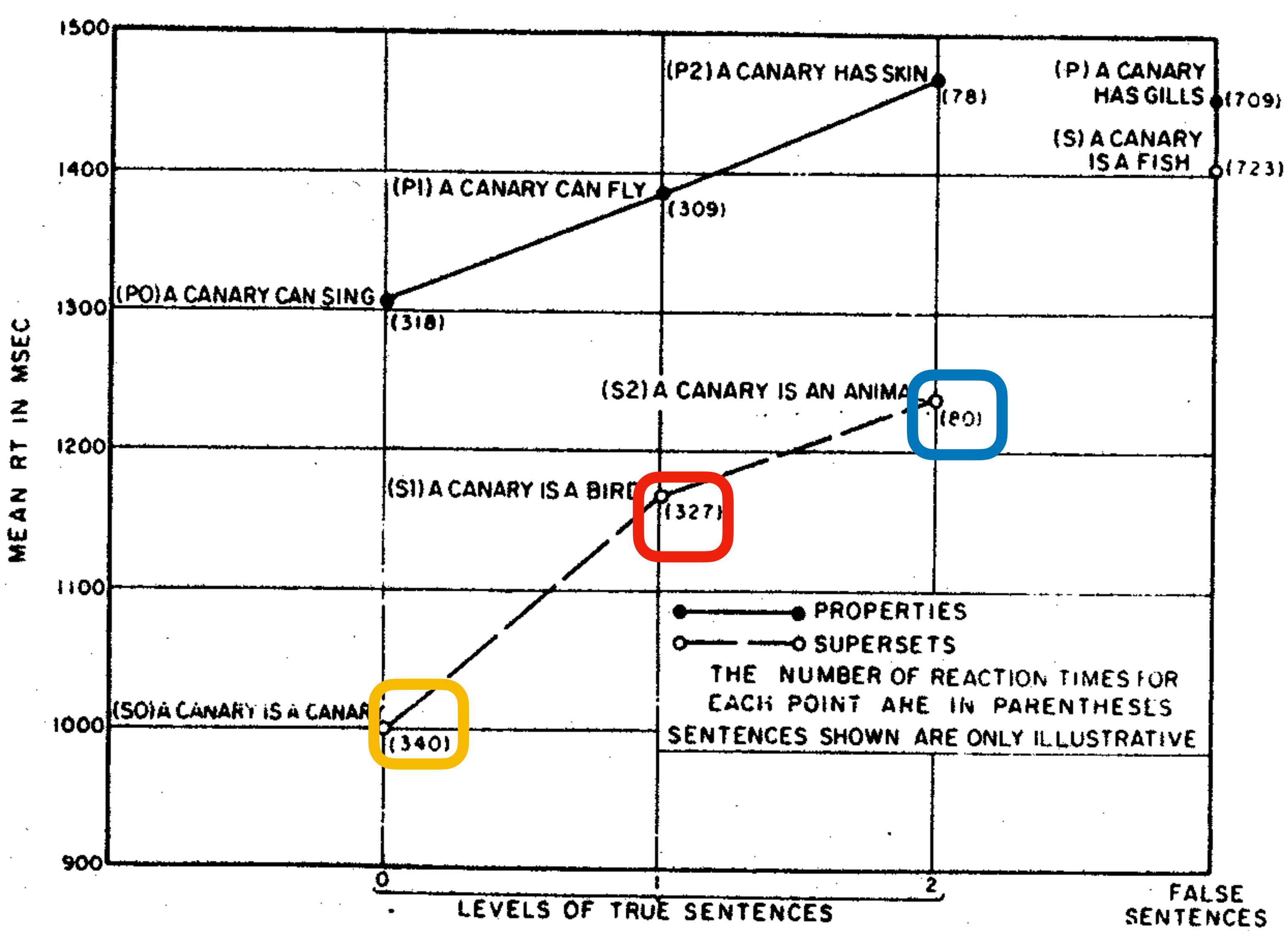




Alternative feature-based accounts

(e.g., Rips, Shoben, & Smith, 1973)

- Hierarchies aren't stored, but are computed using the degree to which prototypes overlap in their features.
- Also predicts "canary is an animal" is slower to verify.
- Failures of transitivity speak against hierarchies: car seat is a chair, chairs are furniture, but car seat is not furniture



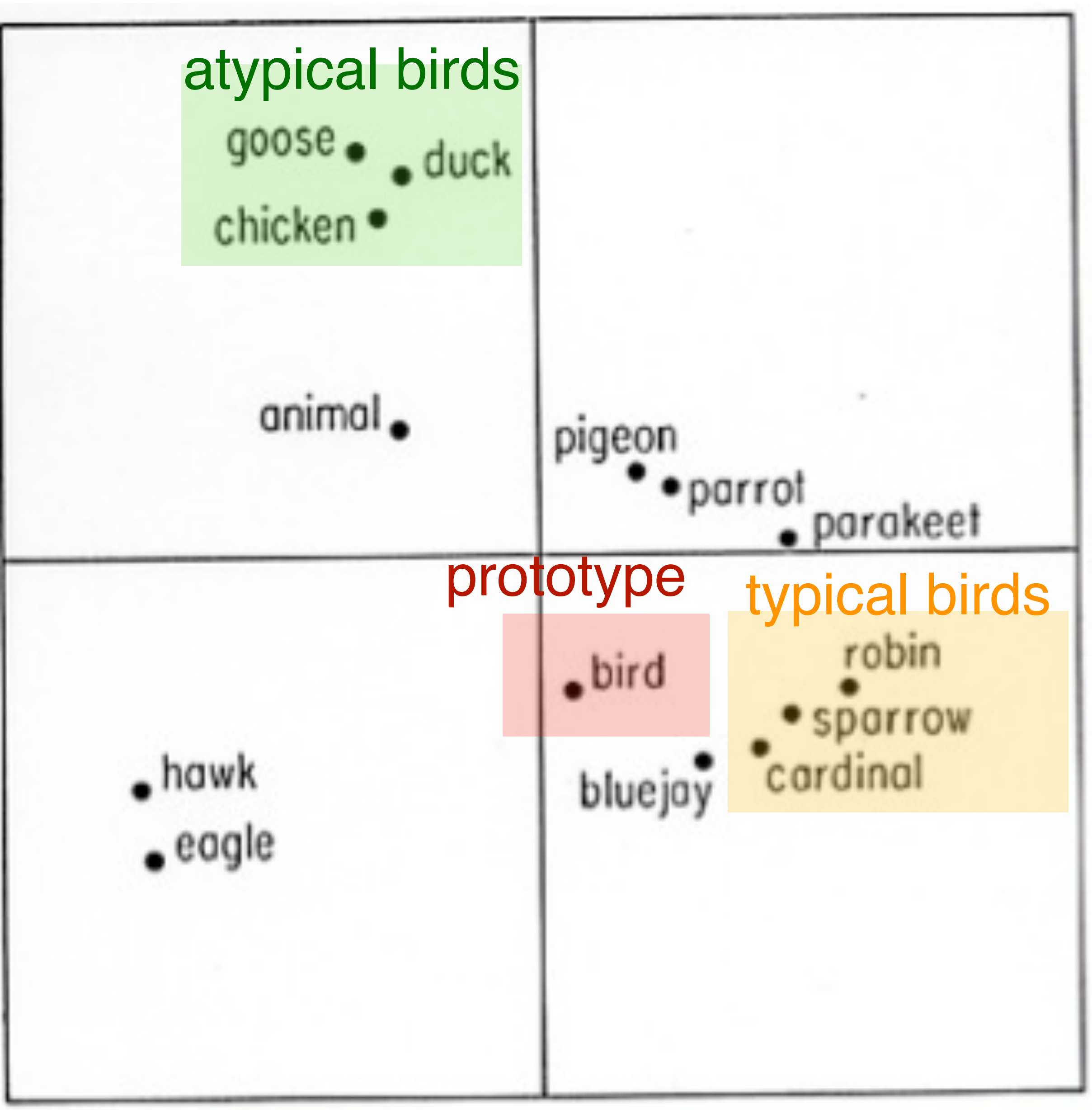
animal prototype

bird prototype

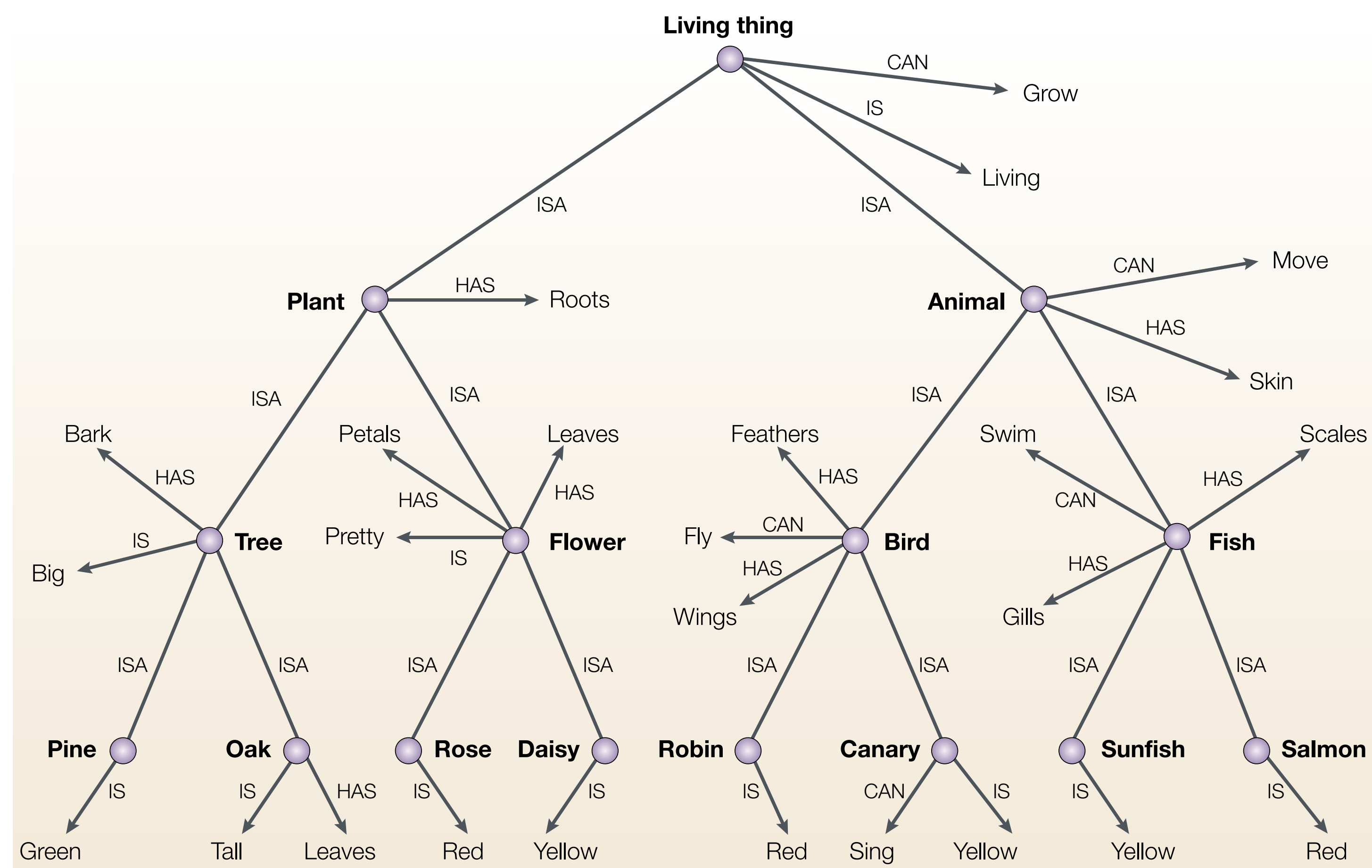
canary prototype

Typicality also influences verification (of course)

- People are slower to verify "A penguin is a bird" than "A robin is a bird"
- Not clear how the hierarchical model can account for this, or how they can account for property exceptions (that penguin's can't fly)



(Rips, Shoben, & Smith, 1973)

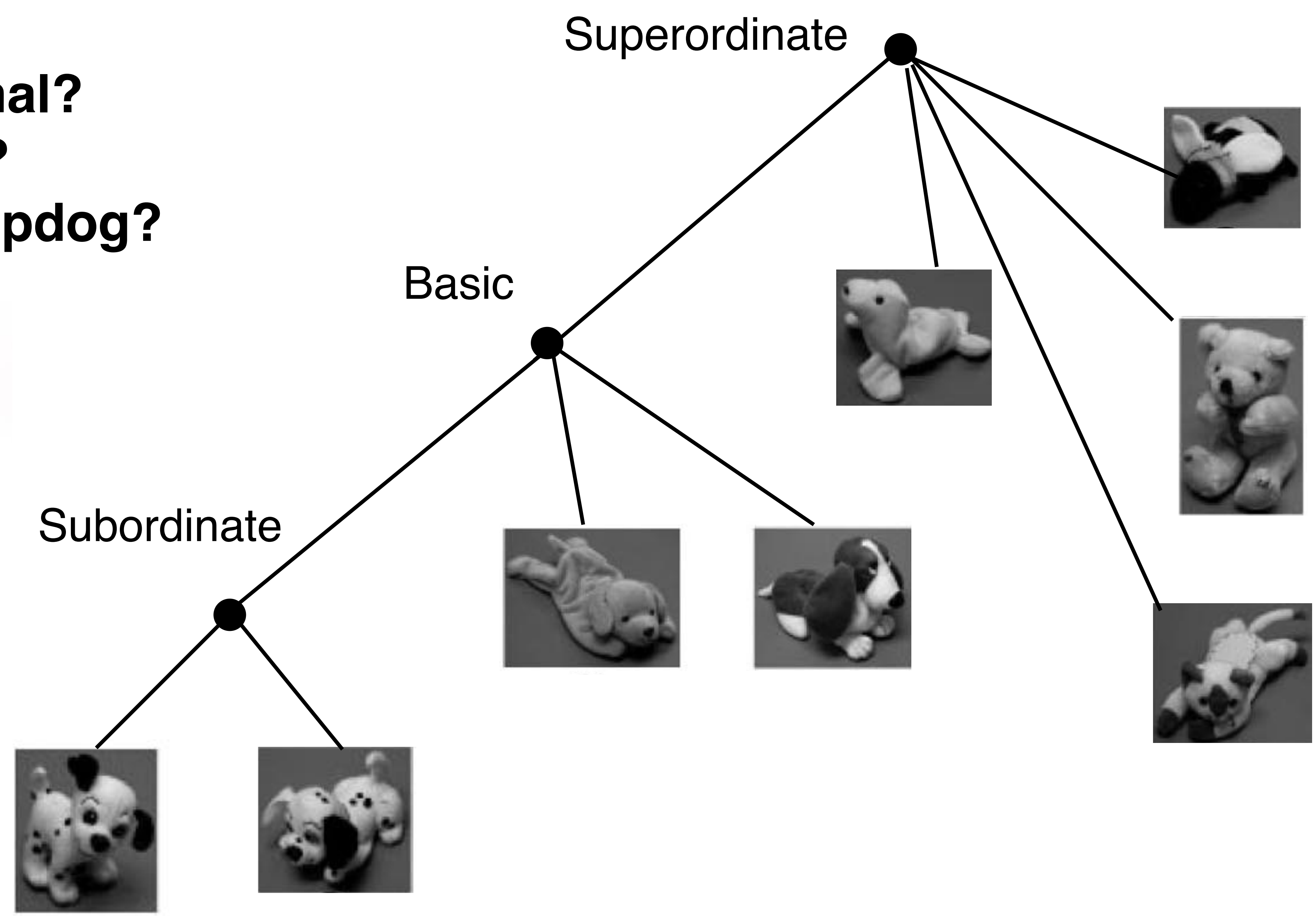


(Collins & Quillian, 1968)

How does the mind represent and use hierarchies?

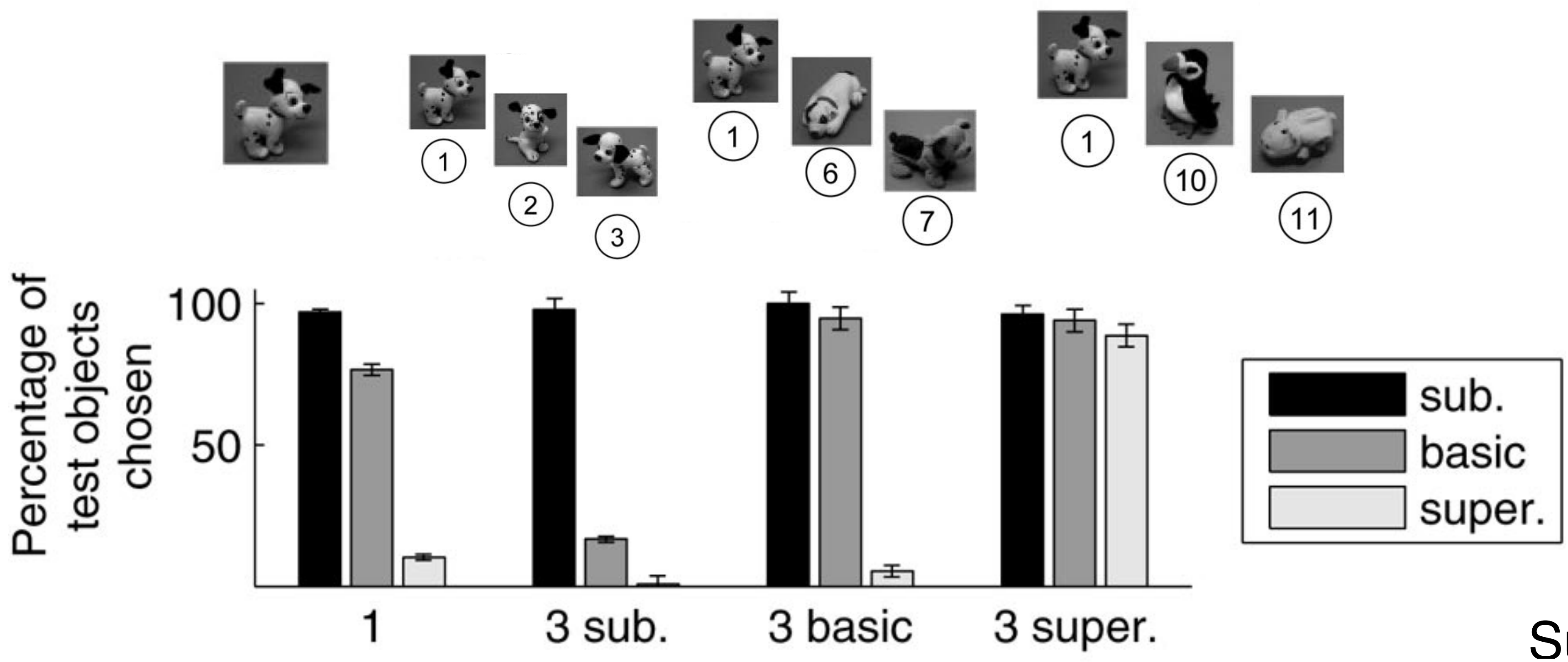
- Clearly our concepts are organized as hierarchies, and the basic level is favored for name use, same-different judgments, priming, verification, etc.
- Unresolved debate of whether these hierarchies are used for storage and retrieval, but the feature-based accounts have an edge (Murphy)

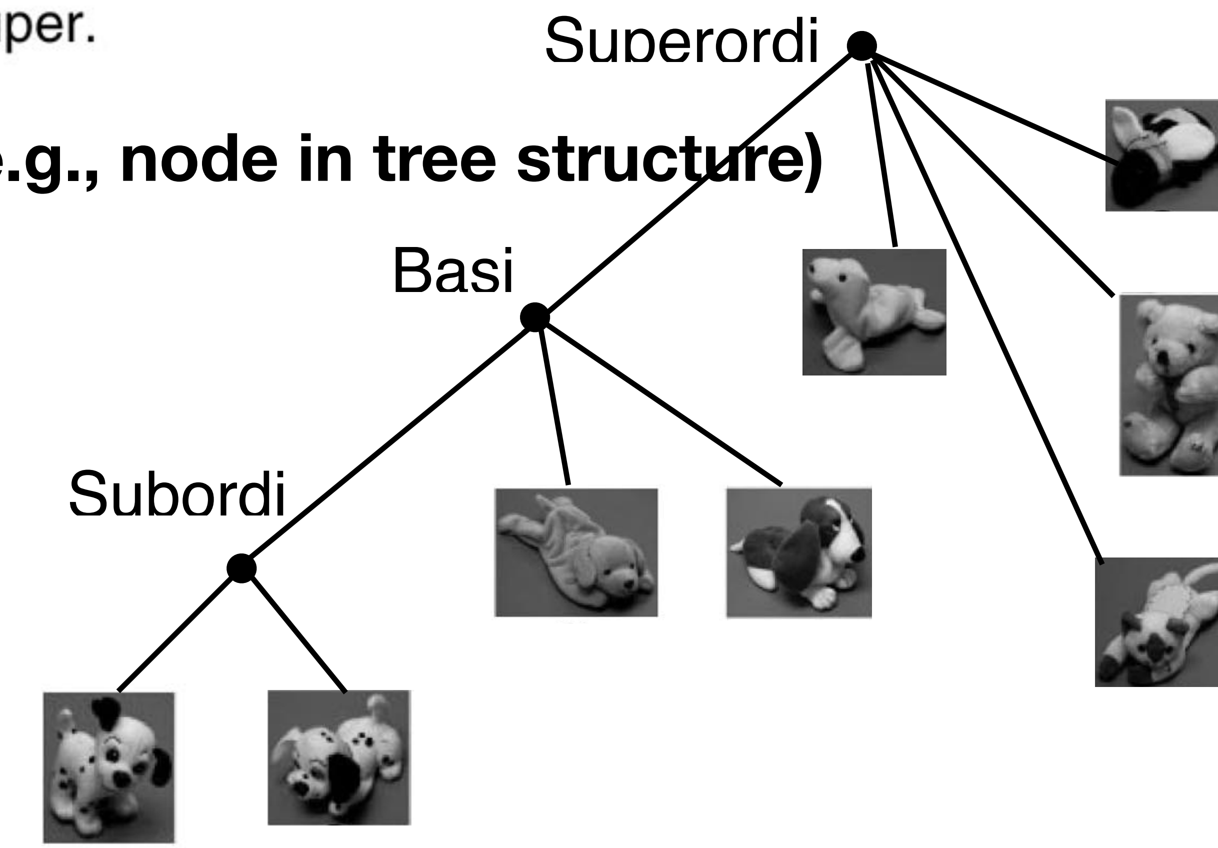
Animal?
Dog?
Sheepdog?



How does the mind represent and use hierarchies?

- Useful for understanding how new words are learned from just a few examples
- Xu and Tenenbaum’s Bayesian model of word learning relies on hierarchies





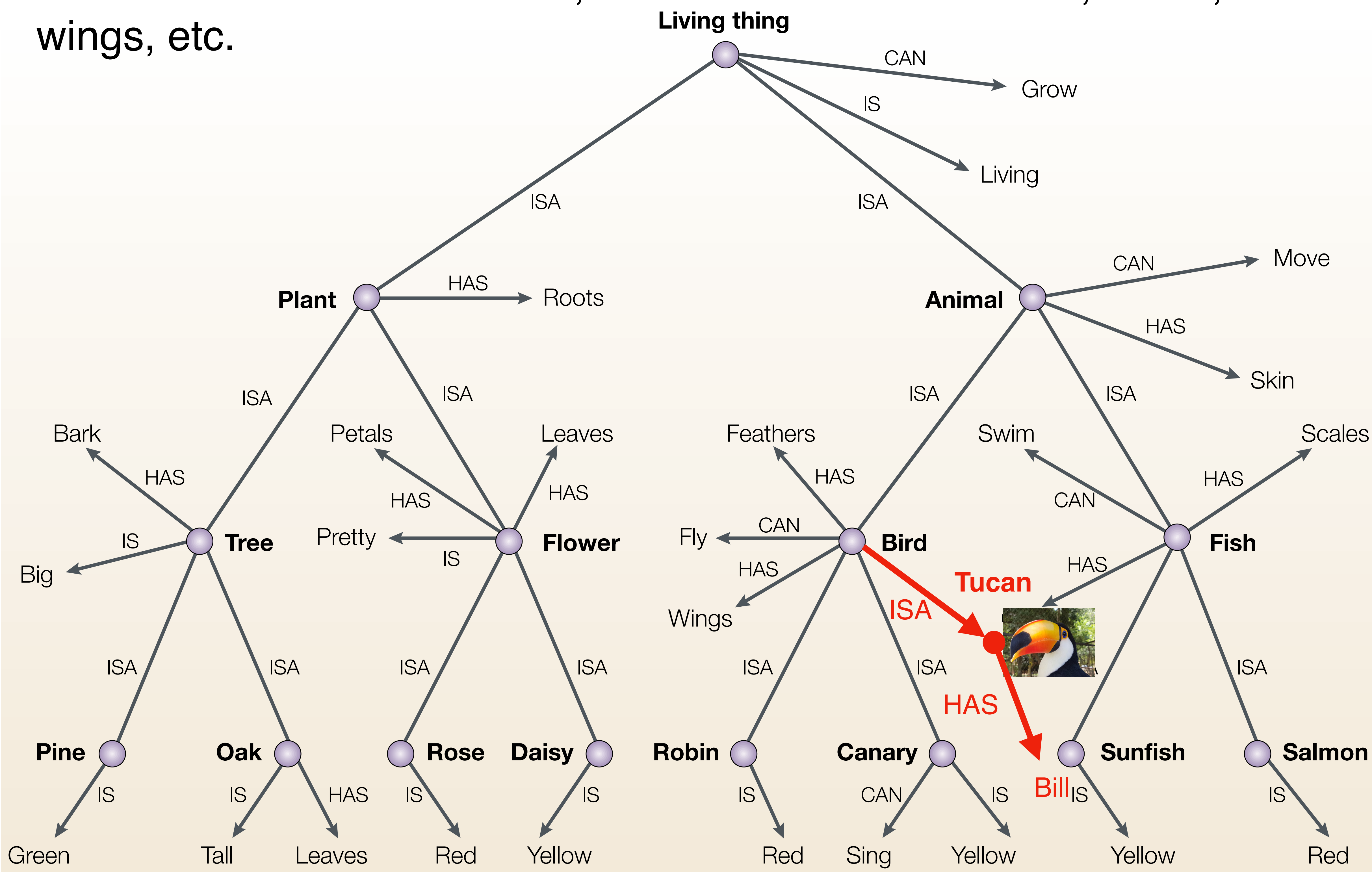
$h \in H$: **hypothesis about meaning of word (e.g., node in tree structure)**

Posterior over word meanings

$$p(h \mid X) = \frac{P(X \mid h) P(h)}{P(X)}$$

How does the mind represent and use hierarchies?

- Hierarchies are powerful representations for adding new concepts and making inferences
- If we know a “tucan is a bird”, we can infer that it is alive, it flies, has wings, etc.



Acknowledgements

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