

Visual knowledge

Pietro Perona
California Institute of Technology

Parts and Attributes Workshop
Crete - 10 Sept 2010

[Joint work with Serge Belongie]







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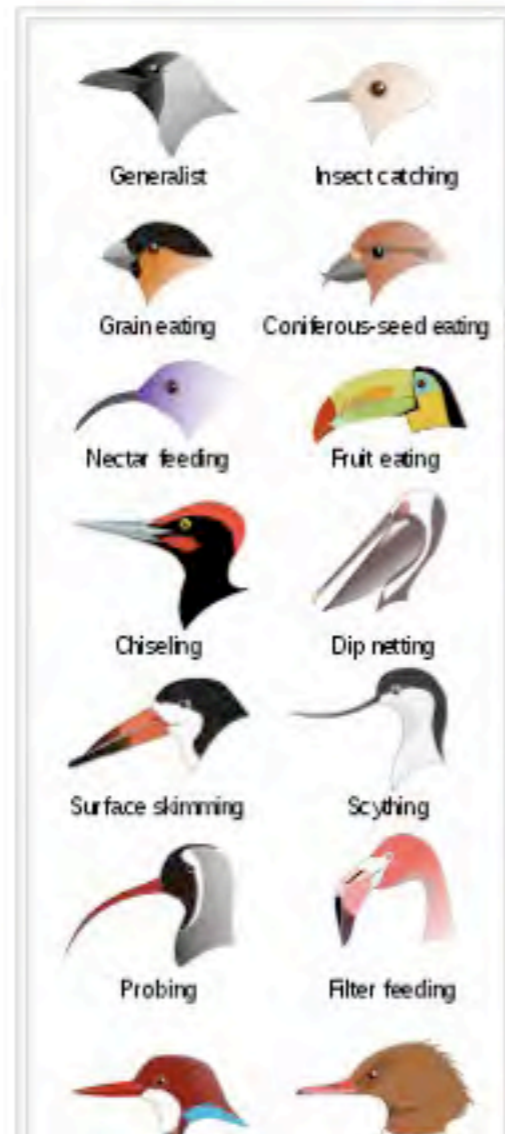
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Beak

From Wikipedia, the free encyclopedia

For other uses, see [Beak \(disambiguation\)](#).

The **beak**, **bill** or **rostrum** is an external anatomical structure of [birds](#) which, in addition to eating, is used for [grooming](#), manipulating objects, killing prey, probing for food, [courtship](#) and feeding their young. The term also refers to a similar mouthpart in some [cephalopods](#), [cetaceans](#), [pufferfishes](#), [turtles](#), [Anuran tadpoles](#) and [sirens](#).



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Anatomy [\[edit\]](#)

Beaks can vary significantly in size and shape from species to species. The beak is composed of an upper jaw called the [maxilla](#), and a lower jaw called the [mandible](#). The jaw is made



The bill of a scavenger—the [vulture](#).



The bill and knob of a [domesticated Chinese goose](#), highly exaggerated by farm selection.





Cere

From Wikipedia, the free encyclopedia

The **cere** (from the Latin *cera*: wax)^[1] or **operculum**^[2] is a soft, fleshy swelling found on the beaks of certain birds. [Hawks](#), [parrots](#), [doves](#), [skuas](#) and [budgerigars](#) are among the birds that have ceres. The word 'cere' is often used synonymously with 'beak', although the two are not identical. The cere plays a role in indicating the reproductive stage of certain [dimorphic](#) birds, and also has a key function in respiration.

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Physical characteristics [\[edit\]](#)

The cere is located at the top of the beak,^{[2][3]} and is often waxy in texture. The colour of the cere may vary from species to species, and also depends on the season.^[4] The cere contains the [nares](#) (nostrils). The shape of the cere varies from species to species. In falcons, the opening⁴ of the nares is roughly circular in shape.^[2]



The [Rock Pigeon](#), *Columba livia*. The cere is located at the top of the beak, and is a distinctive white-grey colour.

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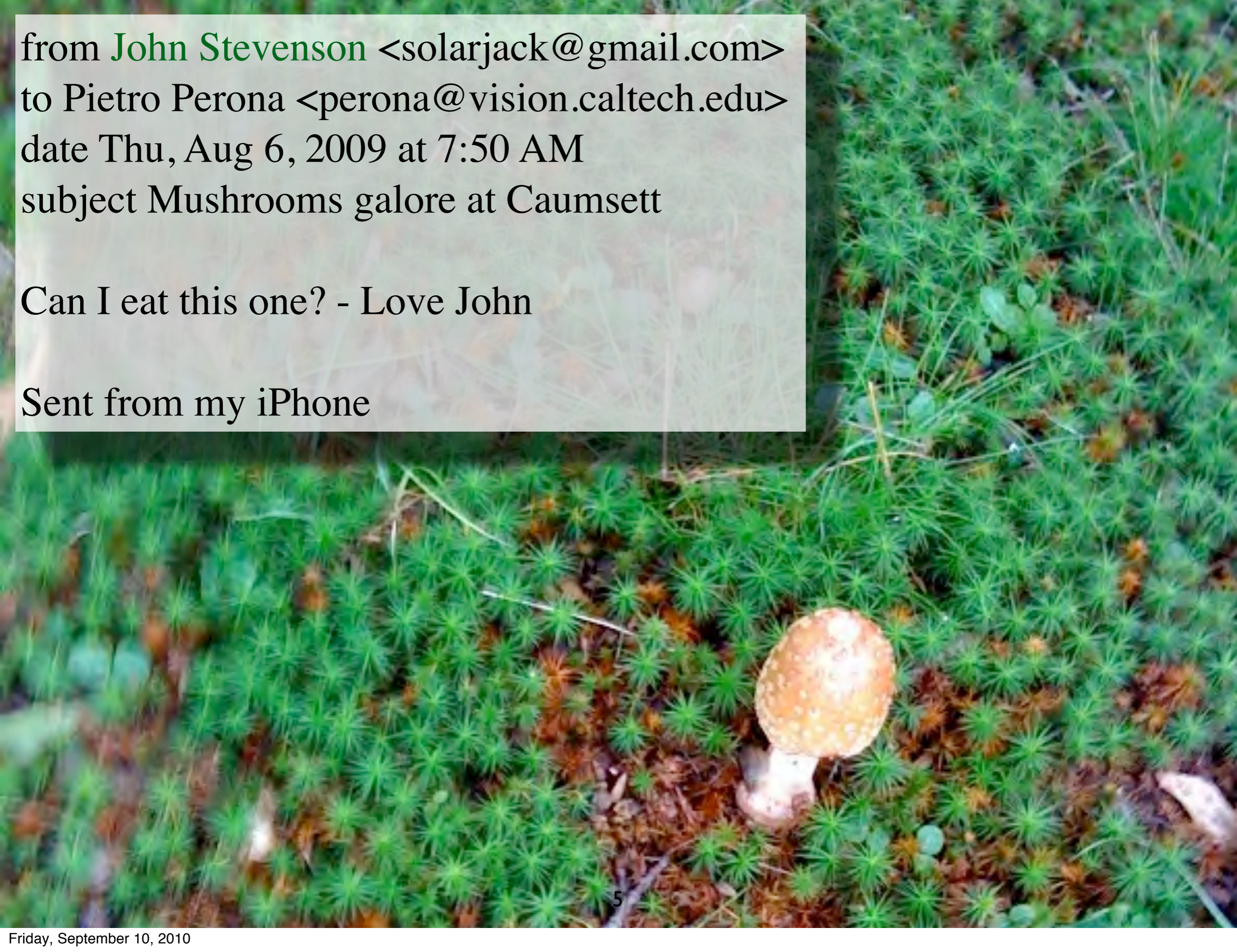
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from **John Stevenson** <solarjack@gmail.com>
to Pietro Perona <perona@vision.caltech.edu>
date Thu, Aug 6, 2009 at 7:50 AM
subject Mushrooms galore at Caumsett

Can I eat this one? - Love John

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Mushroom

From Wikipedia, the free encyclopedia

For other uses, see [Mushroom \(disambiguation\)](#).

A **mushroom** is the fleshy, [spore-bearing fruiting body](#) of a [fungus](#), typically produced above ground on soil or on its food source. The standard for the name "mushroom" is the cultivated white button mushroom, *Agaricus bisporus*, hence the word mushroom is most often applied to those fungi ([Basidiomycota](#), [Agaricomycetes](#)) that have a stem (*stipe*), a cap (*pileus*), and gills (lamellae, sing. [lamella](#)) on the underside of the cap, just as do store-bought white mushrooms.

The word "mushroom" can also be used for a wide variety of gilled fungi, with or without stems, and the term is used even more generally, to describe both the fleshy fruiting bodies of some [Ascomycota](#) and the woody or leathery fruiting bodies of some [Basidiomycota](#)



The mushroom *Amanita muscaria*, commonly

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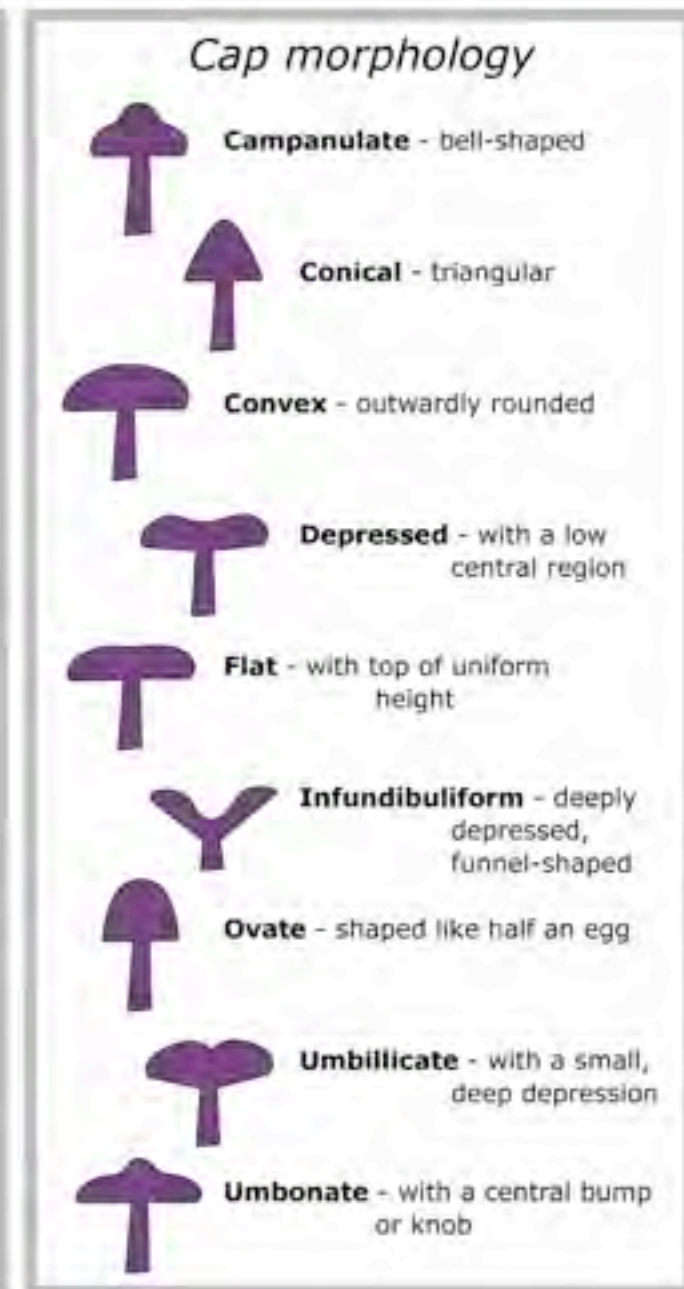
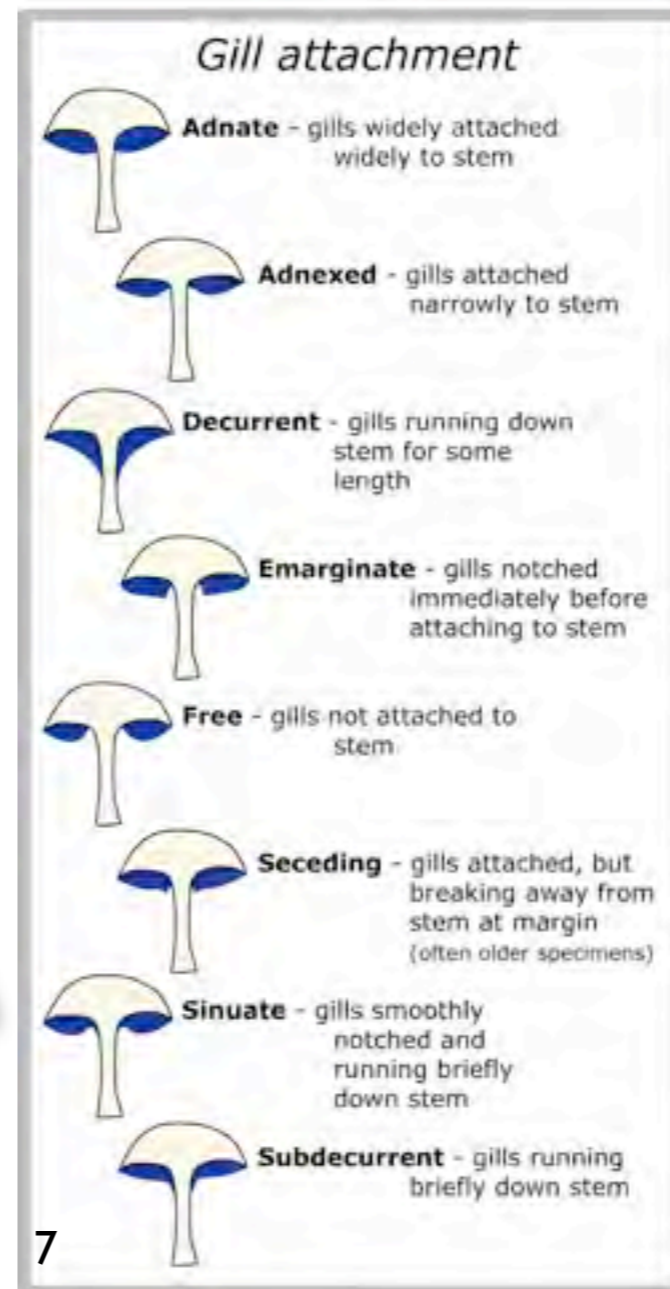
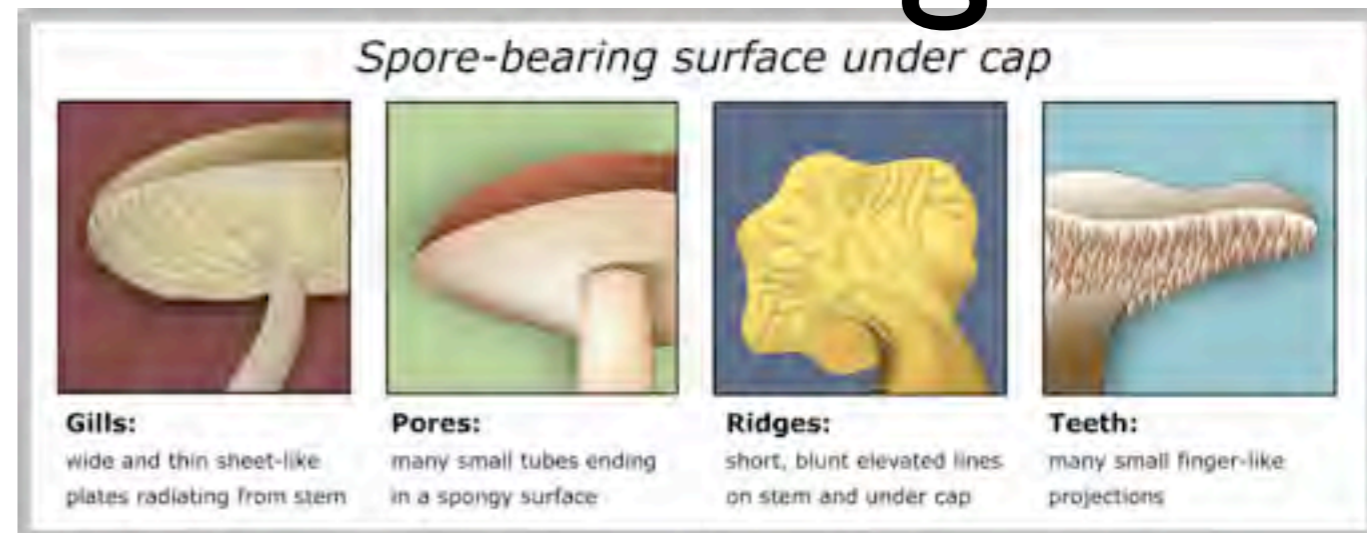
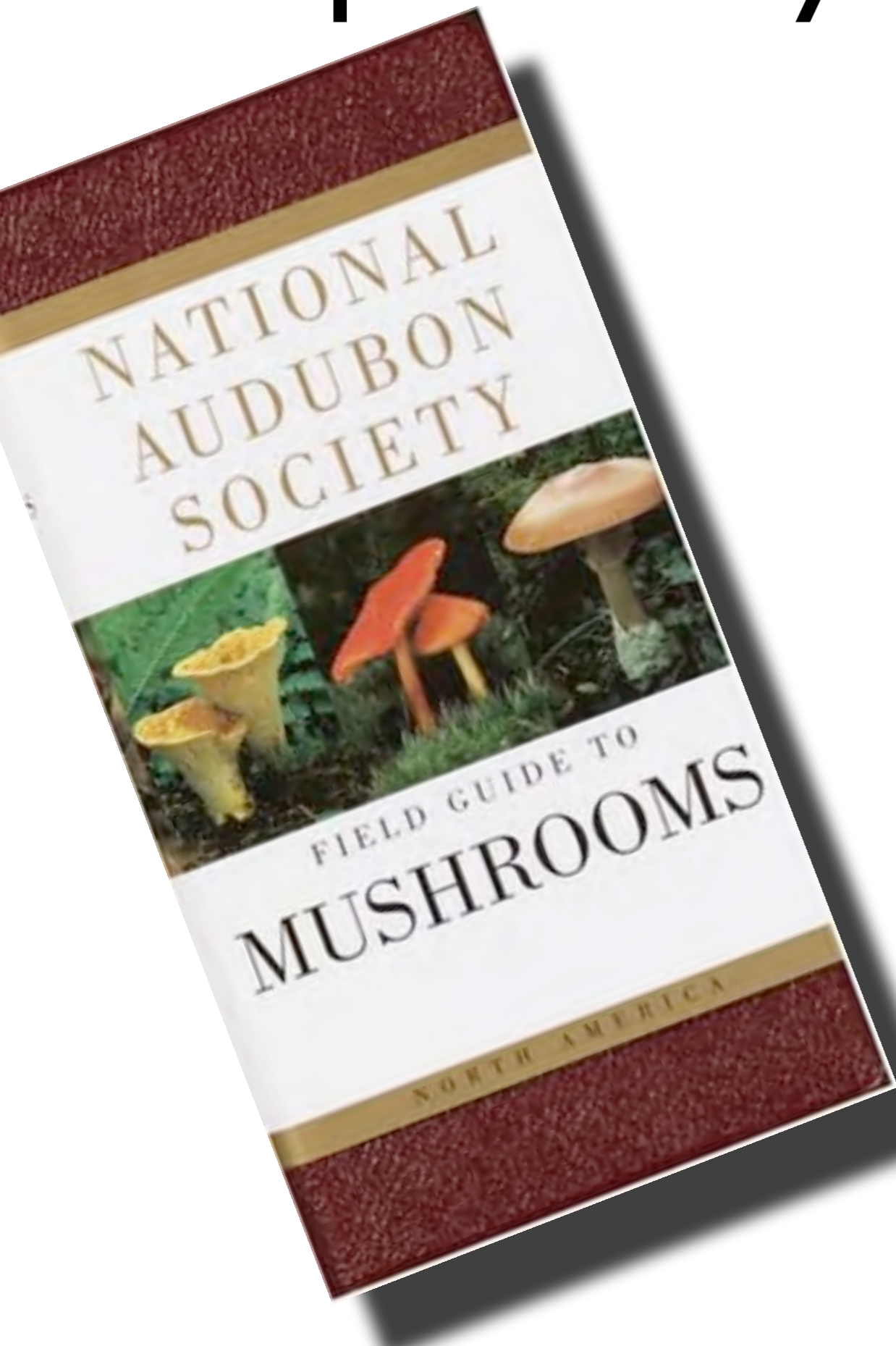
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Wikipedia says: use a field guide



Yet, the info is there...

Amanita pantherina var. *pantherina*

From Wikipedia, the free encyclopedia

(Redirected from [Amanita pantherina](#))

Amanita pantherina var. ***pantherina***, also known as the "*European Panther*" and "*False Blusher*" due to its similarity to the true Blusher (*Amanita rubescens*), is a species of [Europe](#) and western Asia. Material described as *A. pantherina* in the [Americas](#) seems to belong to a number of distinct taxa only some of which have been described.

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European Panther



**Visual info mostly
not there...**

Femur

From Wikipedia, the free encyclopedia

For the [invertebrate femur](#), see [Arthropod leg](#).

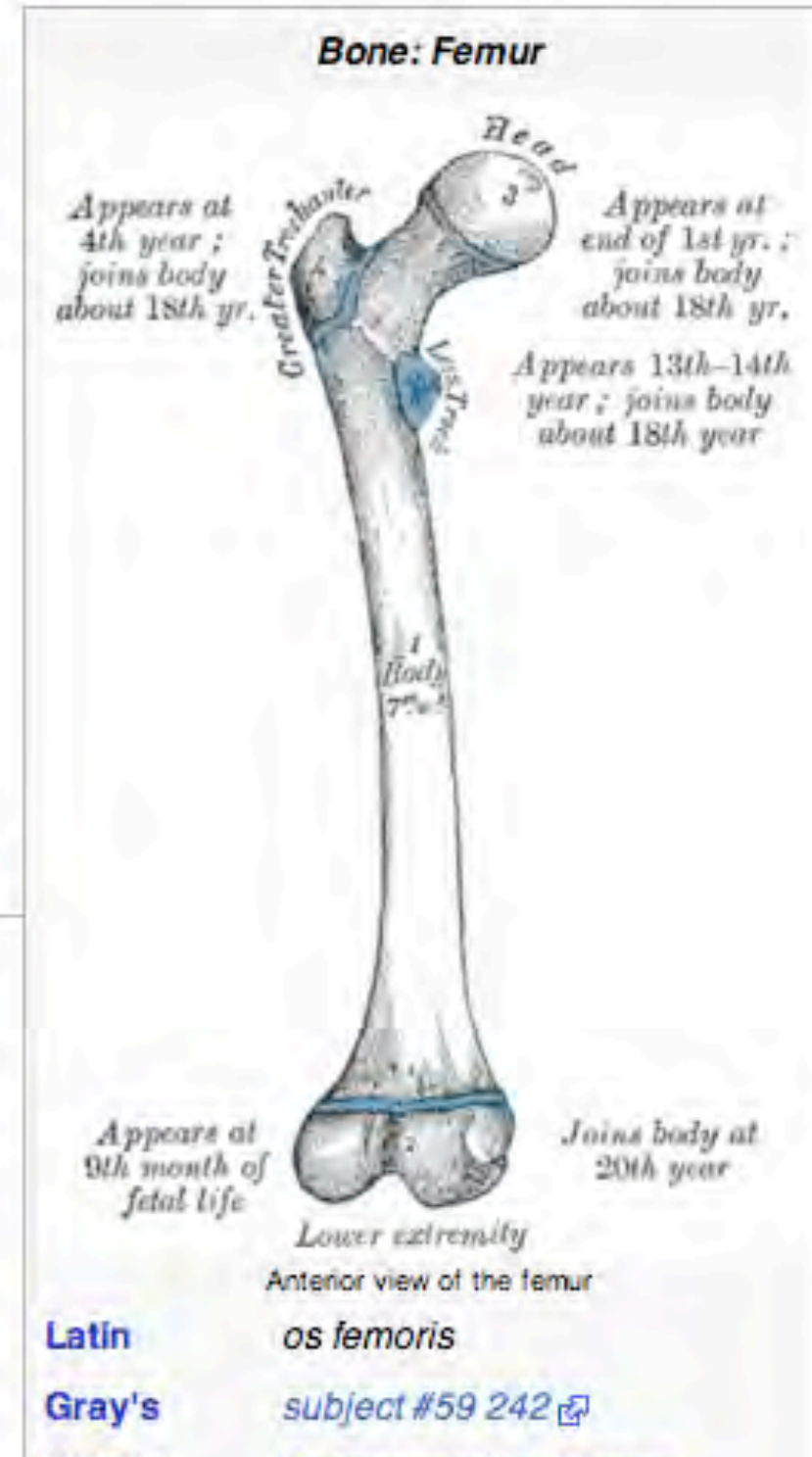
The **femur**, or **thigh bone**, is the most **proximal** (closest to the body) **bone** of the **leg** in **vertebrates** capable of **walking** or **jumping**, such as most **land mammals**, **birds**, many **reptiles** such as **lizards**, and **amphibians** such as **frogs**. In vertebrates with four legs such as **dogs** and **horses**, the femur is found only in the rear legs.

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Human anatomy [\[edit\]](#)

In **human anatomy**, the femur is the **longest** and largest bone. Along with the **temporal bone** of the **skull**, it is one of the two strongest bones in the body. The average adult male femur is 48 centimeters (18.9 in) in length and 2.34 cm (0.92 in) in diameter and can support up to 30 times the weight of an adult.^[1] It forms part of the **hip** (at the **acetabulum**) and part of the **knee**, which is located above. There are four eminences, or protuberances, in the human femur: the **head**, the **greater trochanter**, the **lesser trochanter**, and the **lower extremity**. They appear at various times from just before birth to about age 14. Initially, they are joined to the main body of the femur with **cartilage**, which gradually



Latin os femoris
Gray's subject #59 242 [\[↗\]](#)



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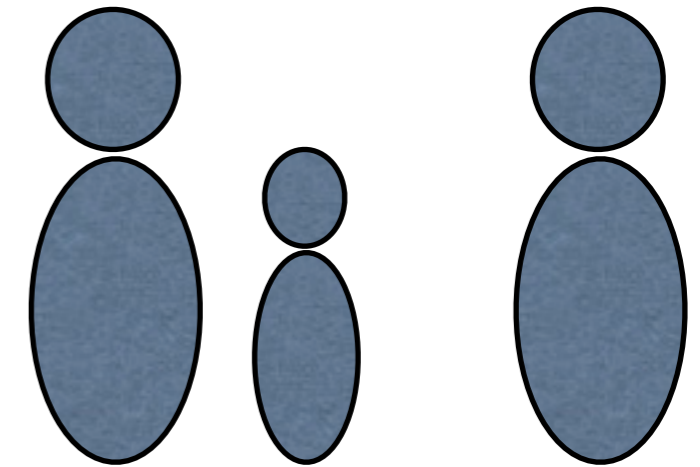
Lessons:

- *Visual queries*
 - Easy for humans
 - Difficult for machines
- Much information is available on line
- Pictures are *digital dark matter*
- Experts not providing visual knowledge

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Physical characteristics

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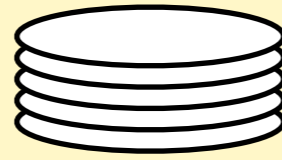
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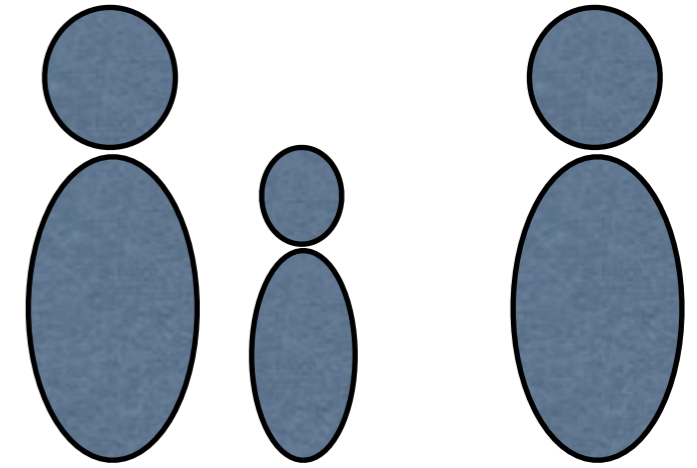
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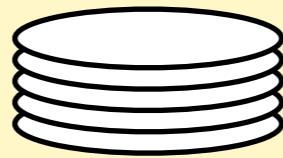
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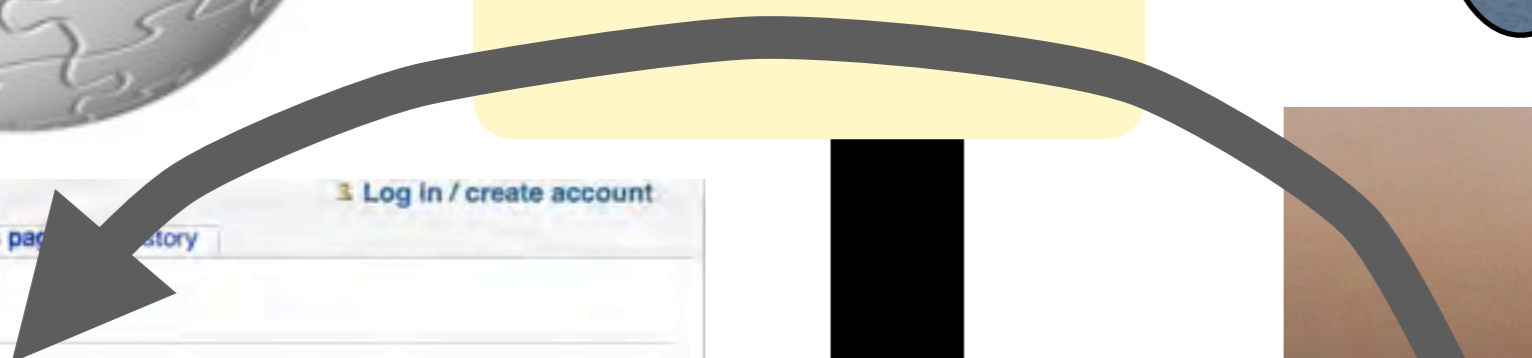
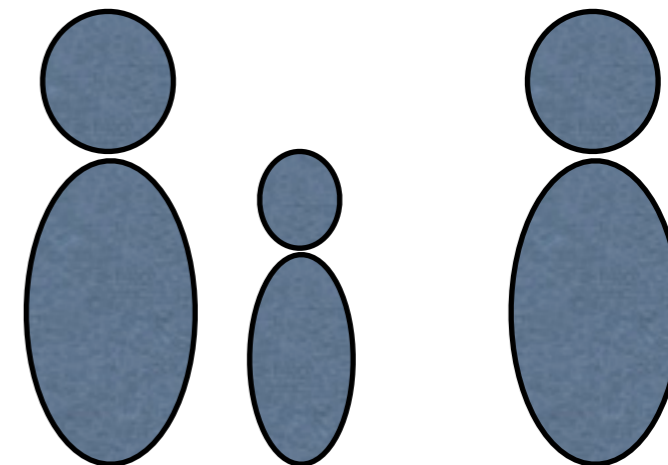
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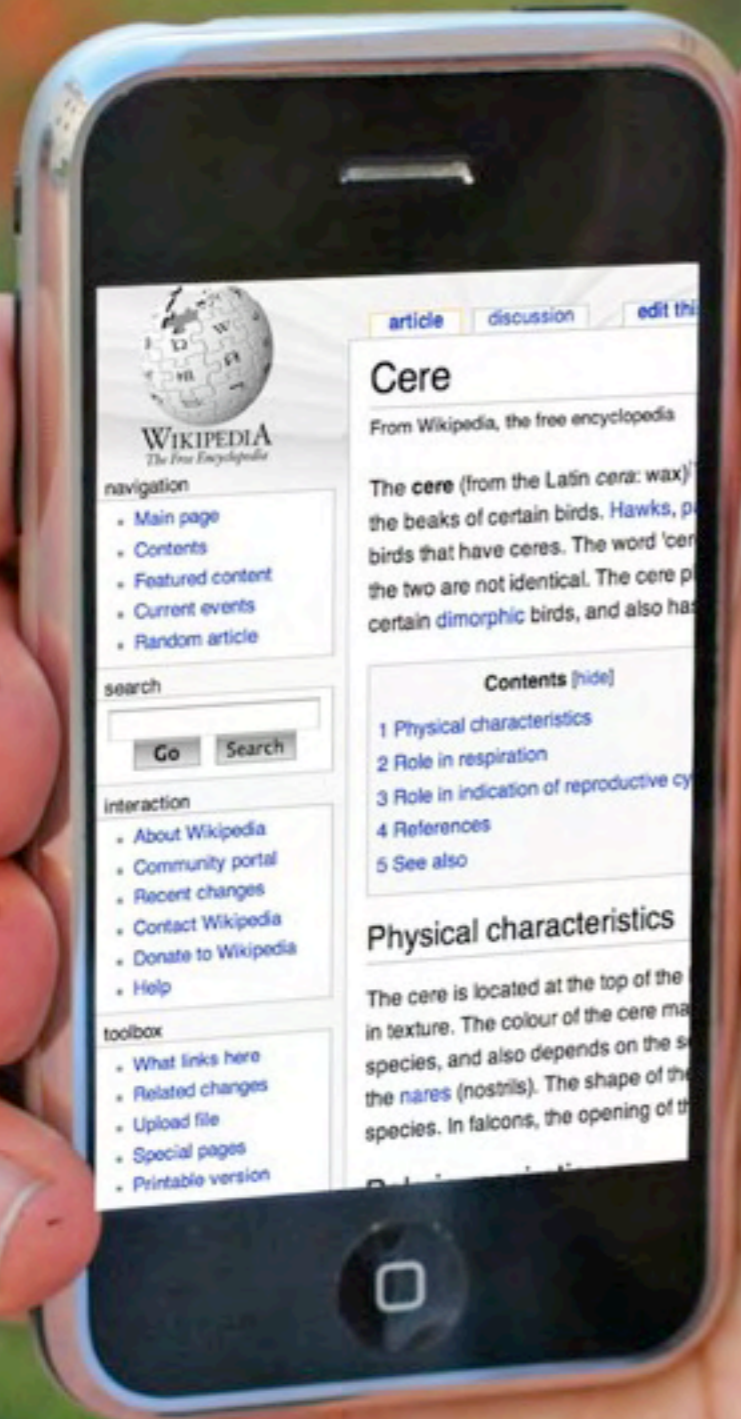
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happen?

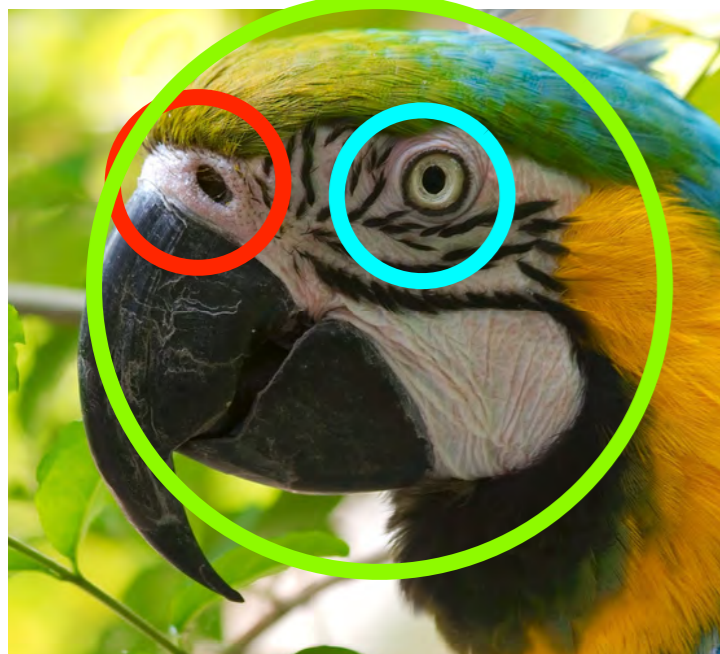
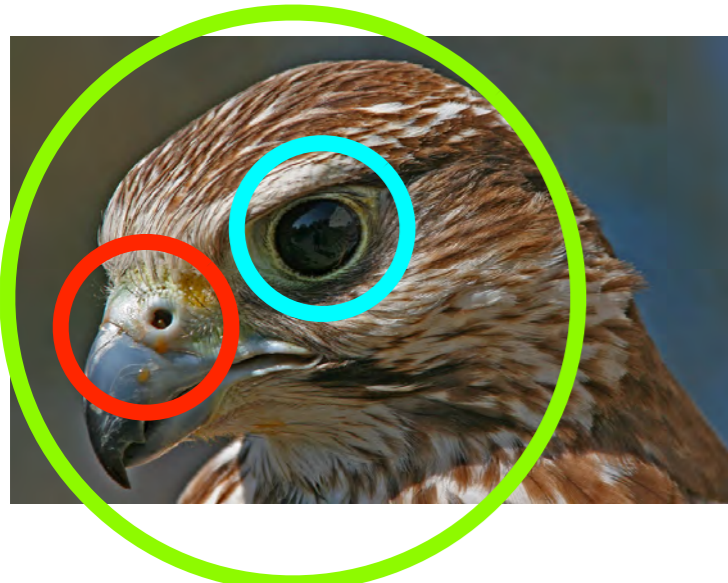
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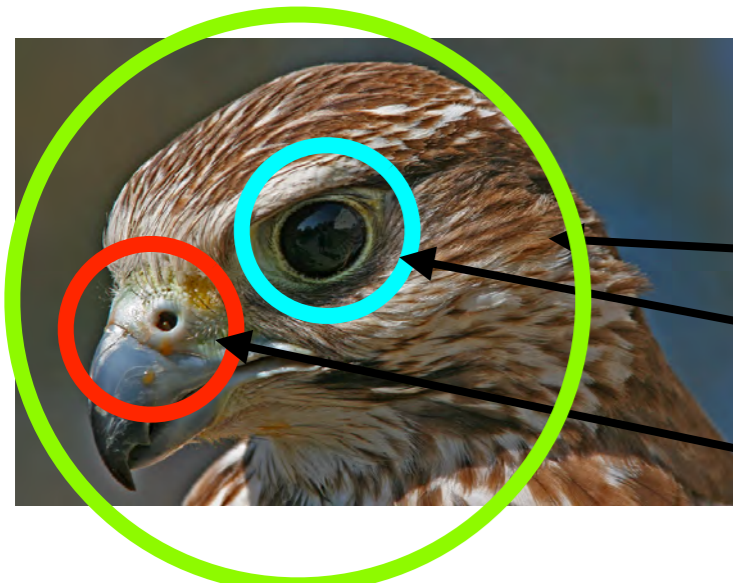


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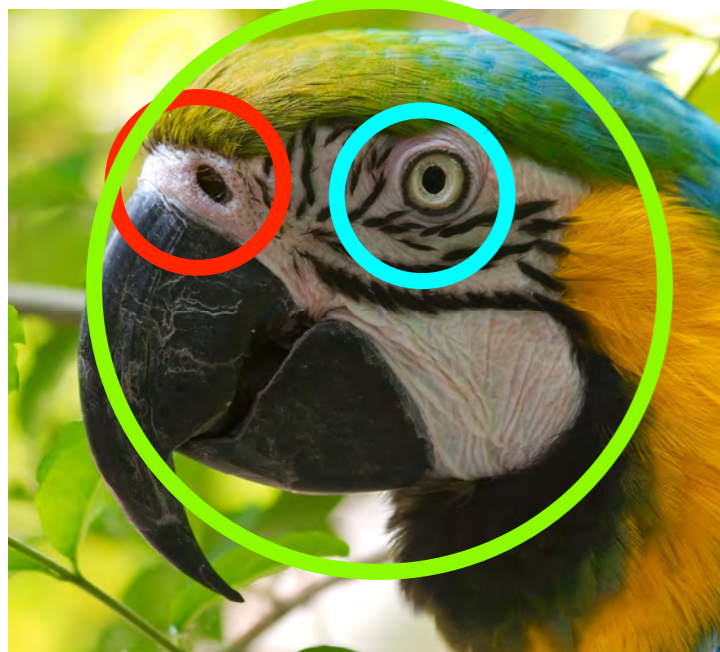
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Eye

Cere



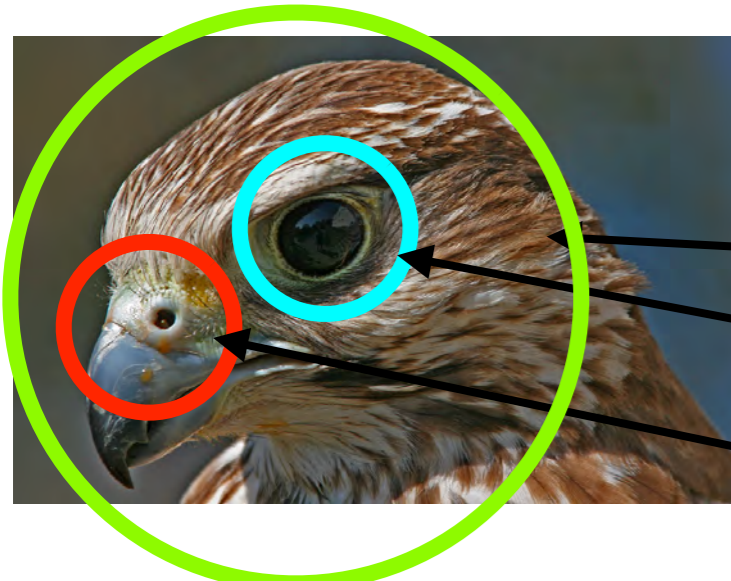
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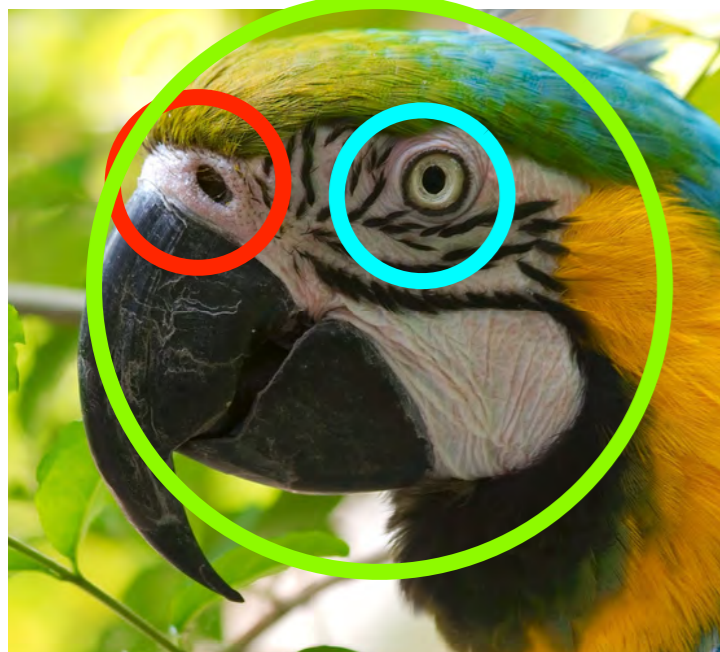
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Head

Eye

Cere



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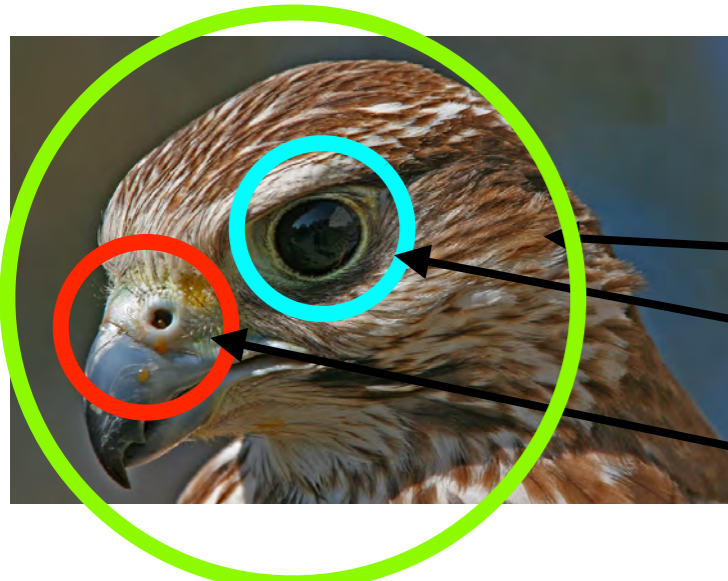


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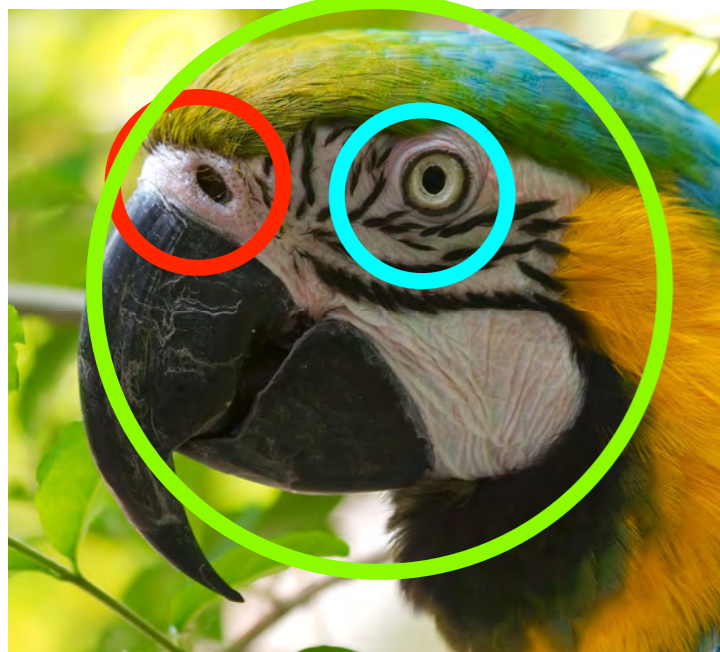
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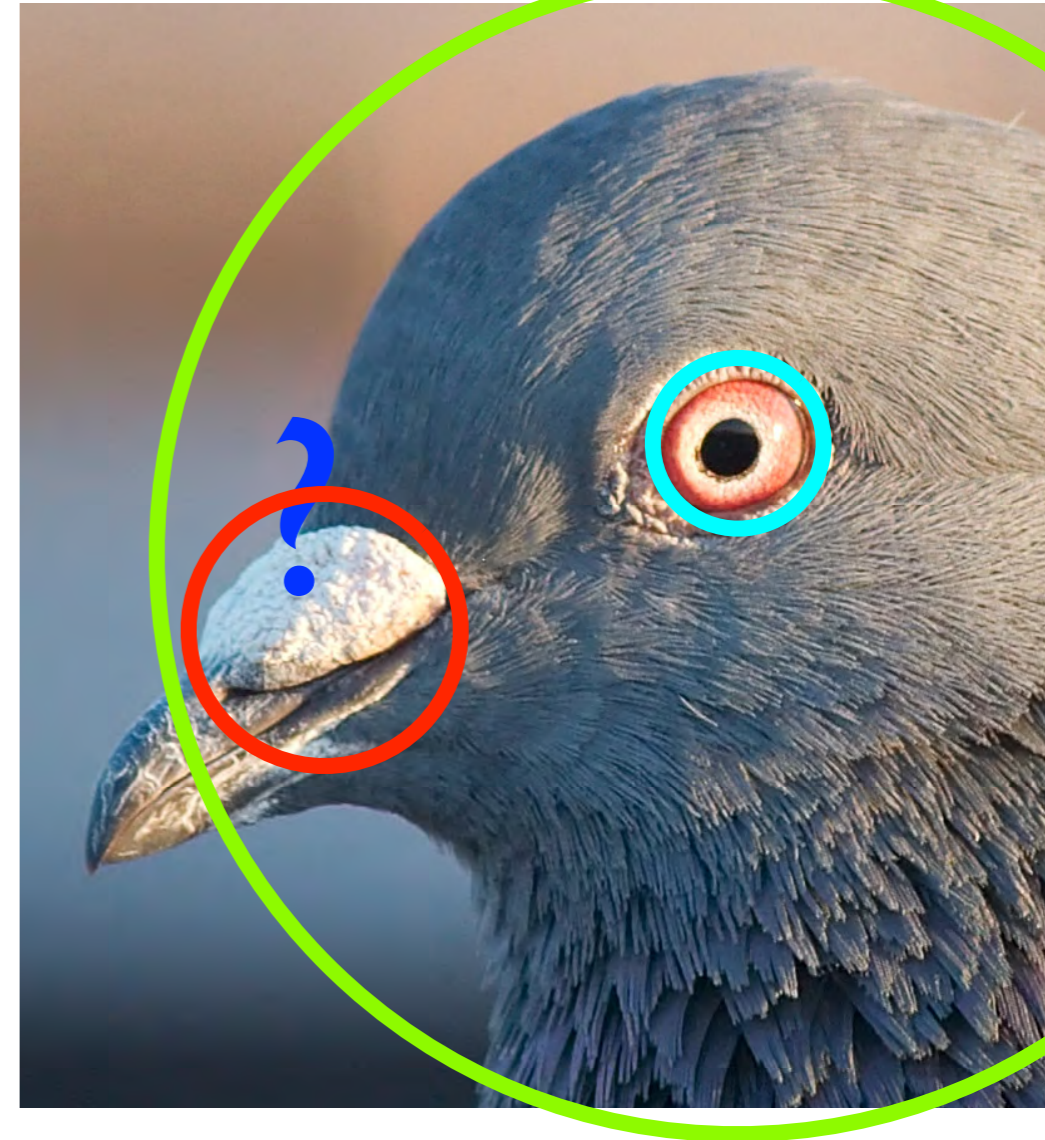
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Head
Eye
Cere



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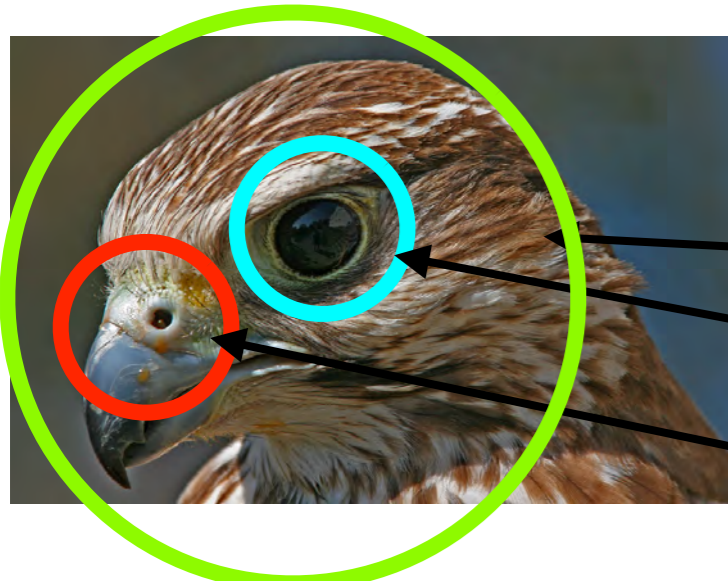


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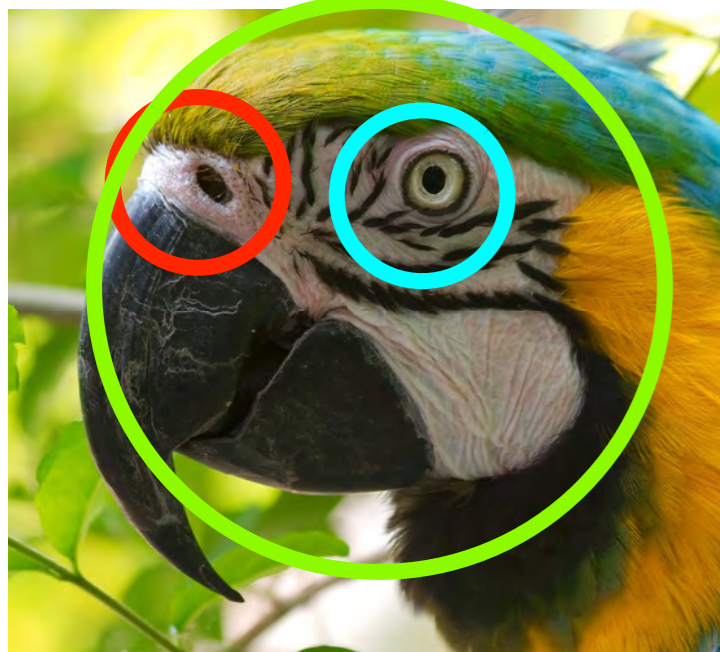
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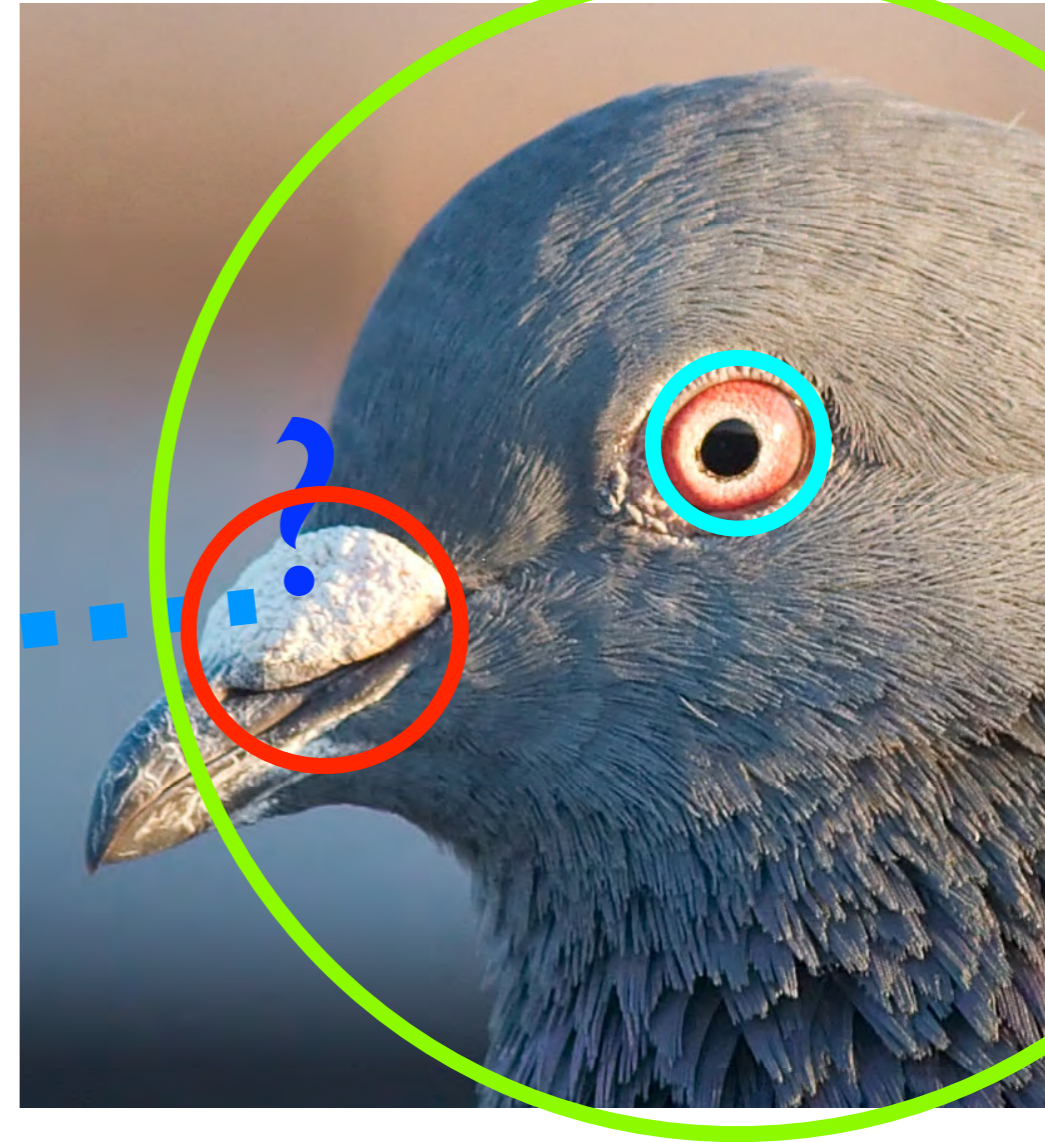
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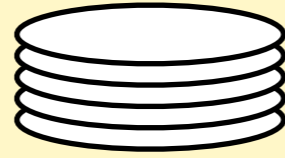
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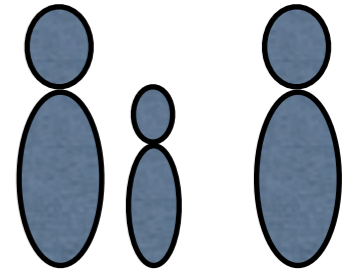
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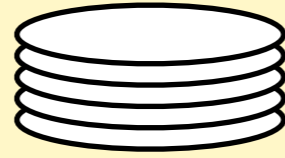
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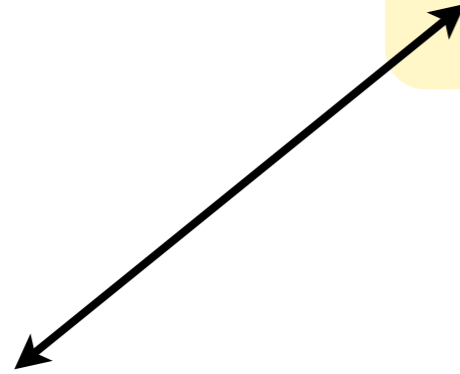
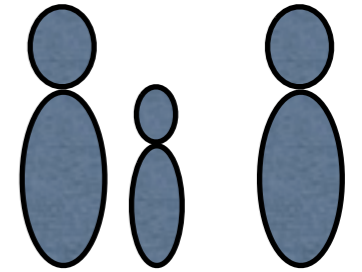
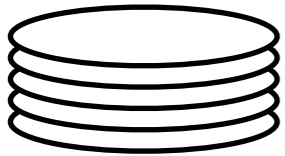


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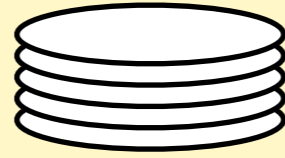
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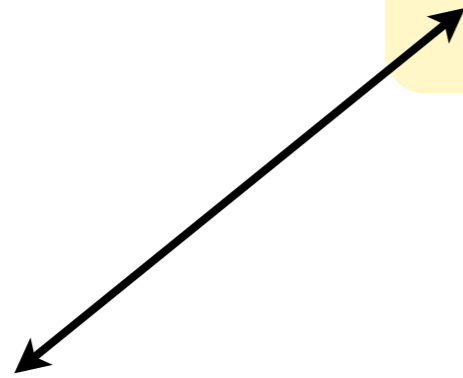
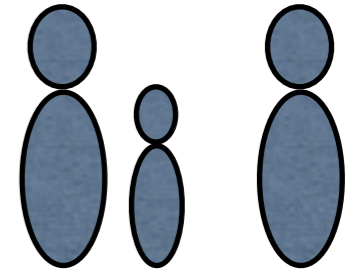
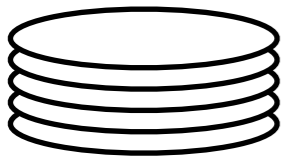


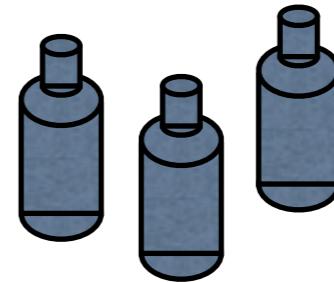
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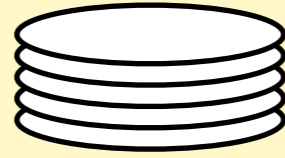
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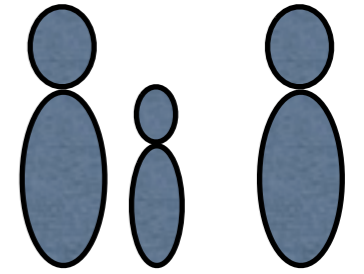


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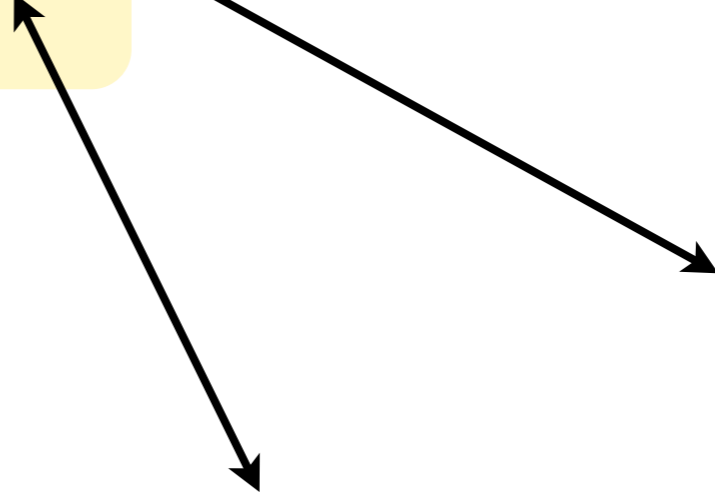
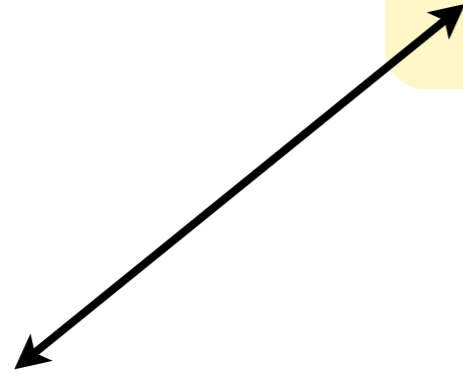
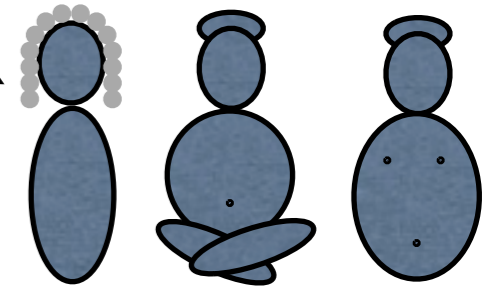
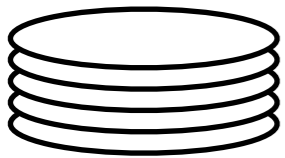
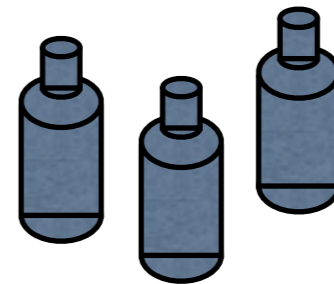


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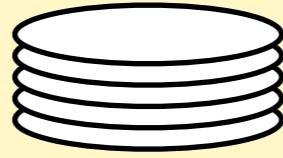
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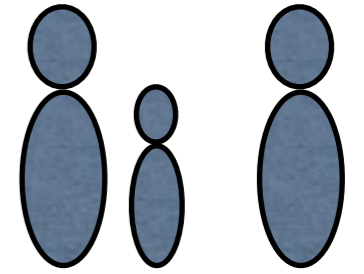


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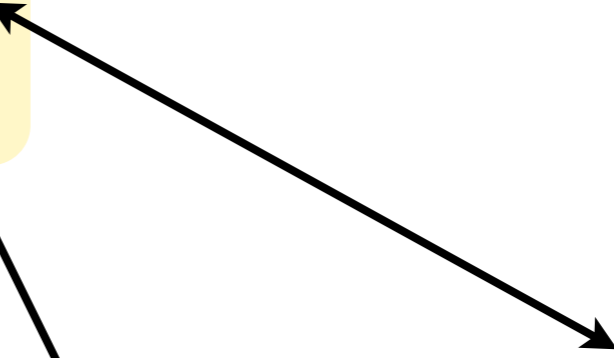
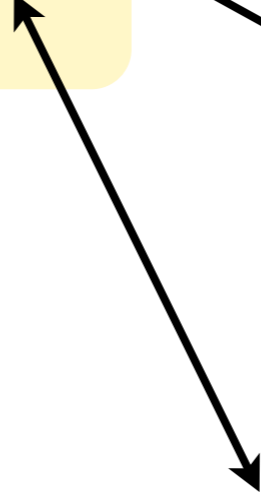
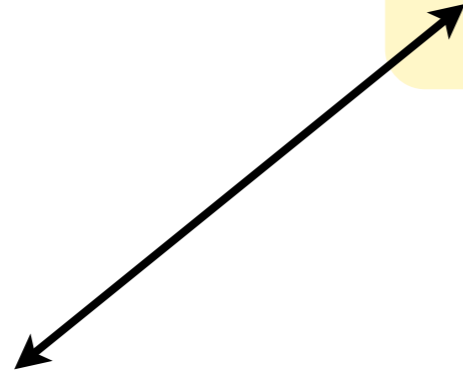
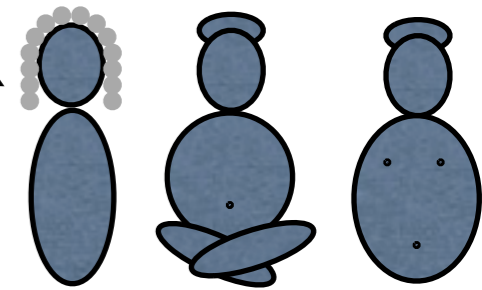
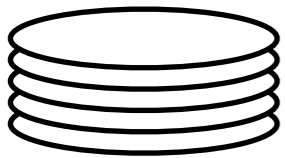
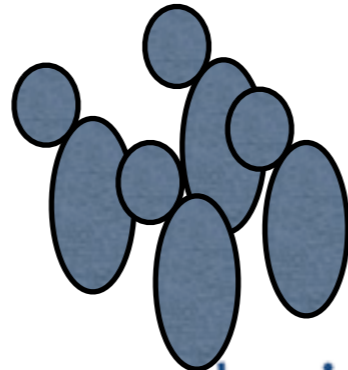


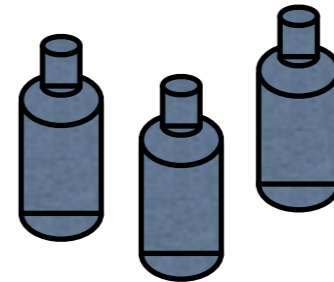
Image databases

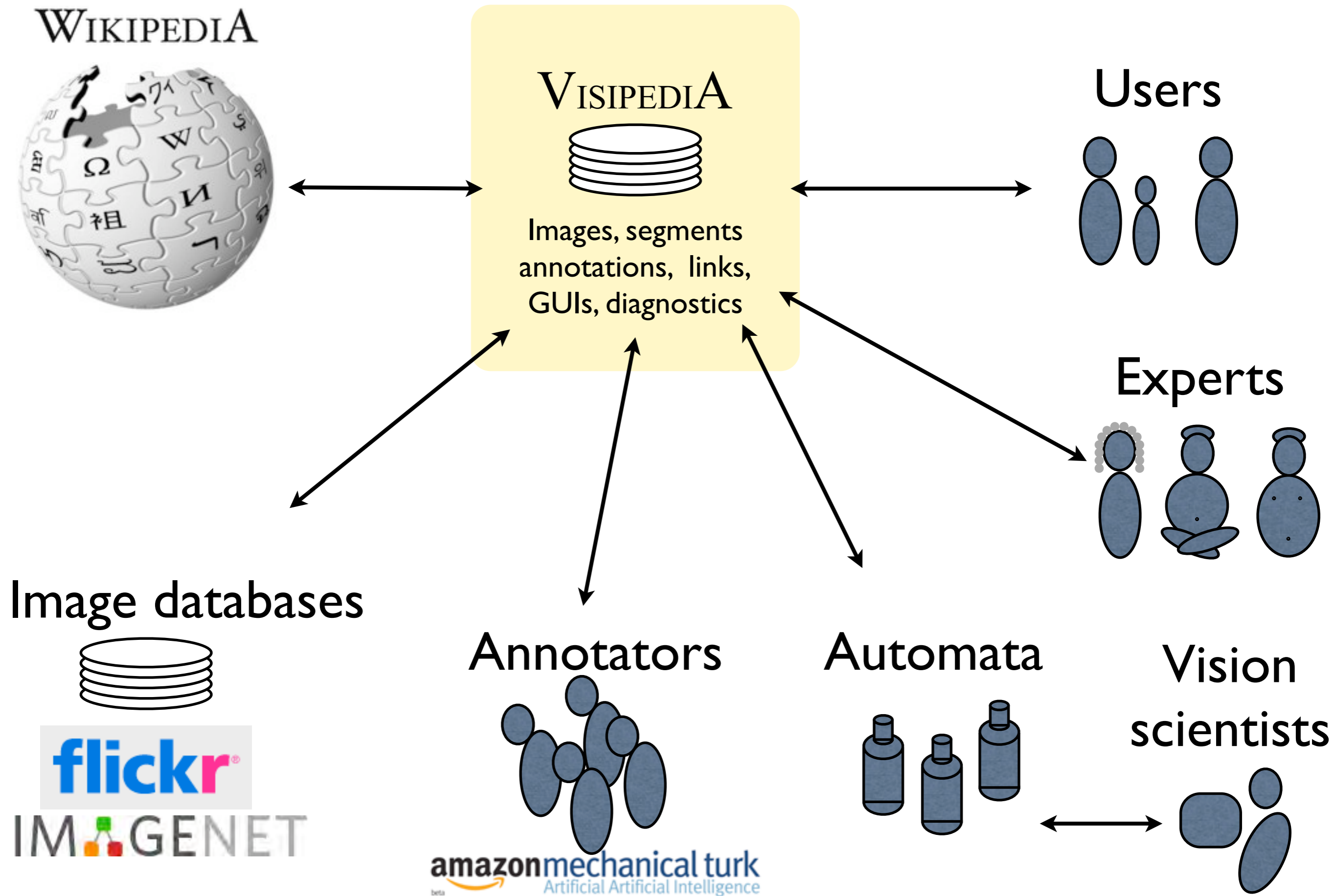


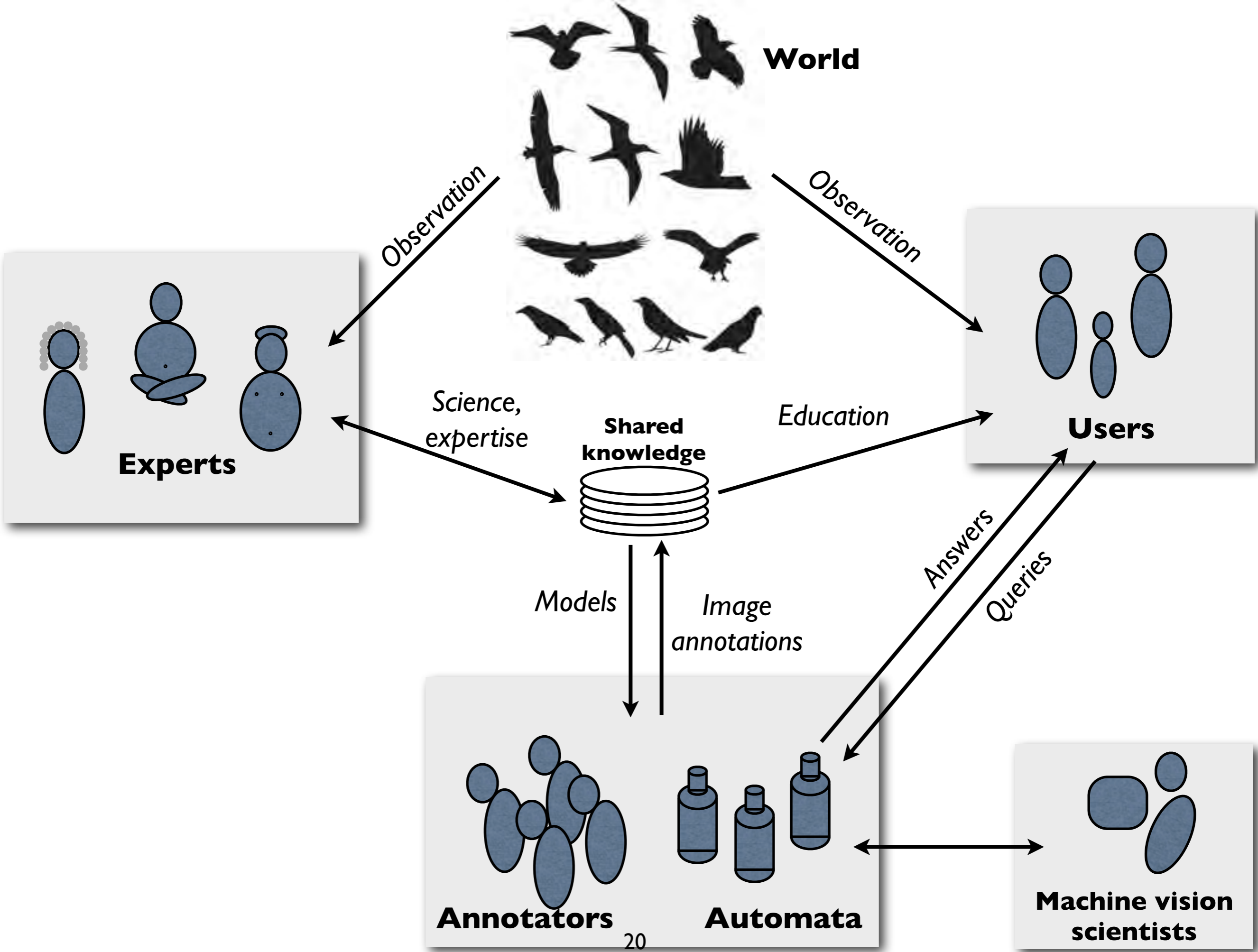
Annotators

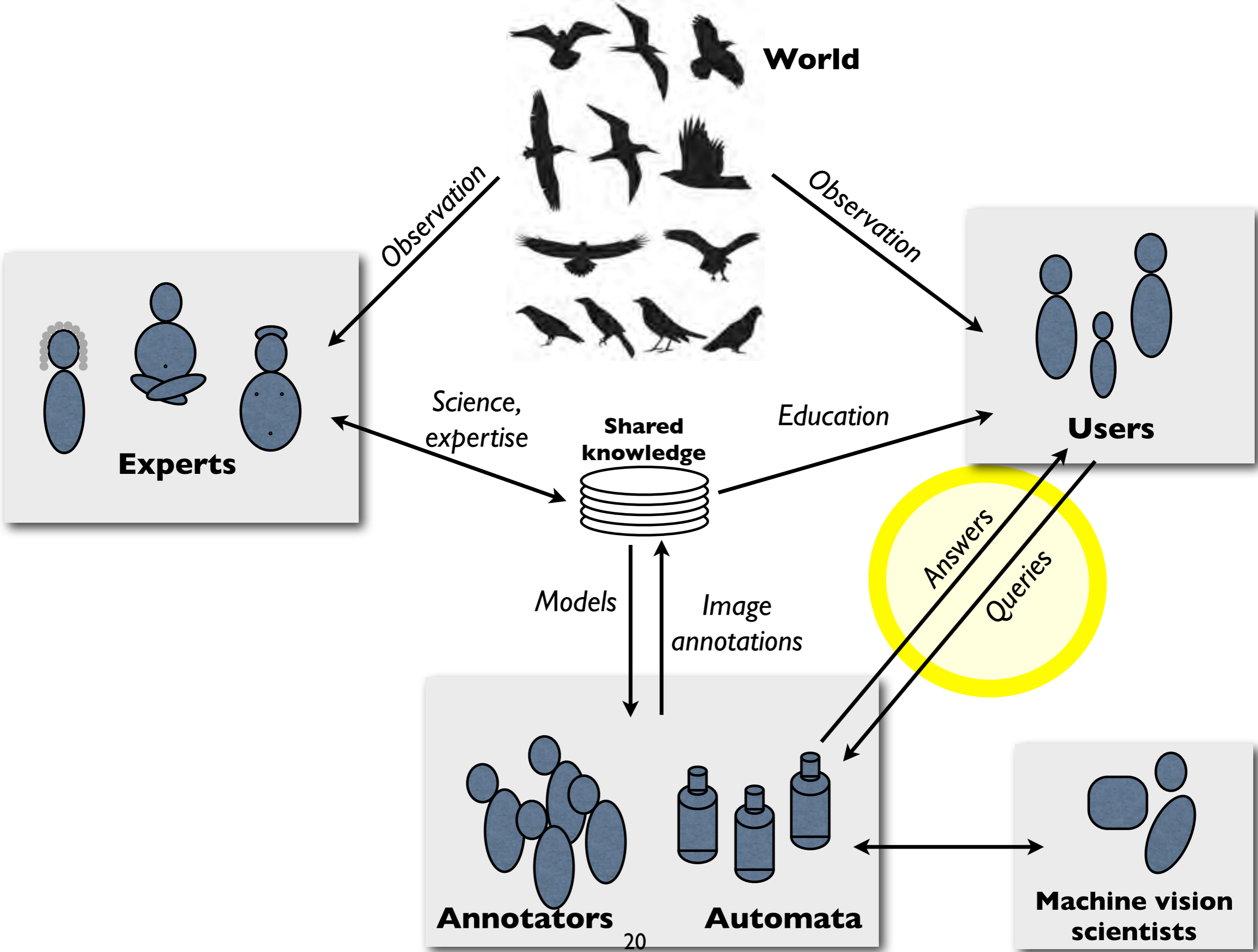


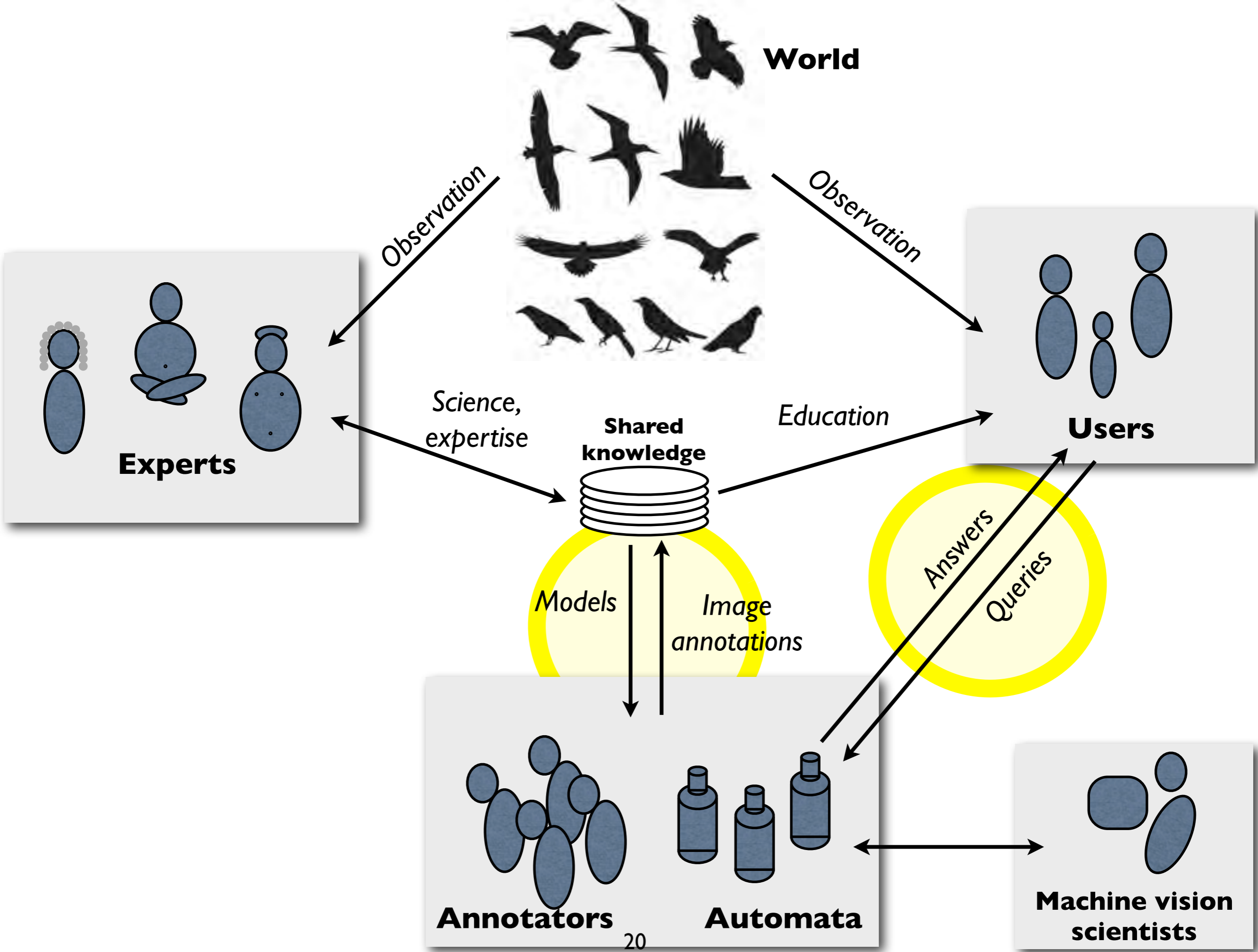
Automata

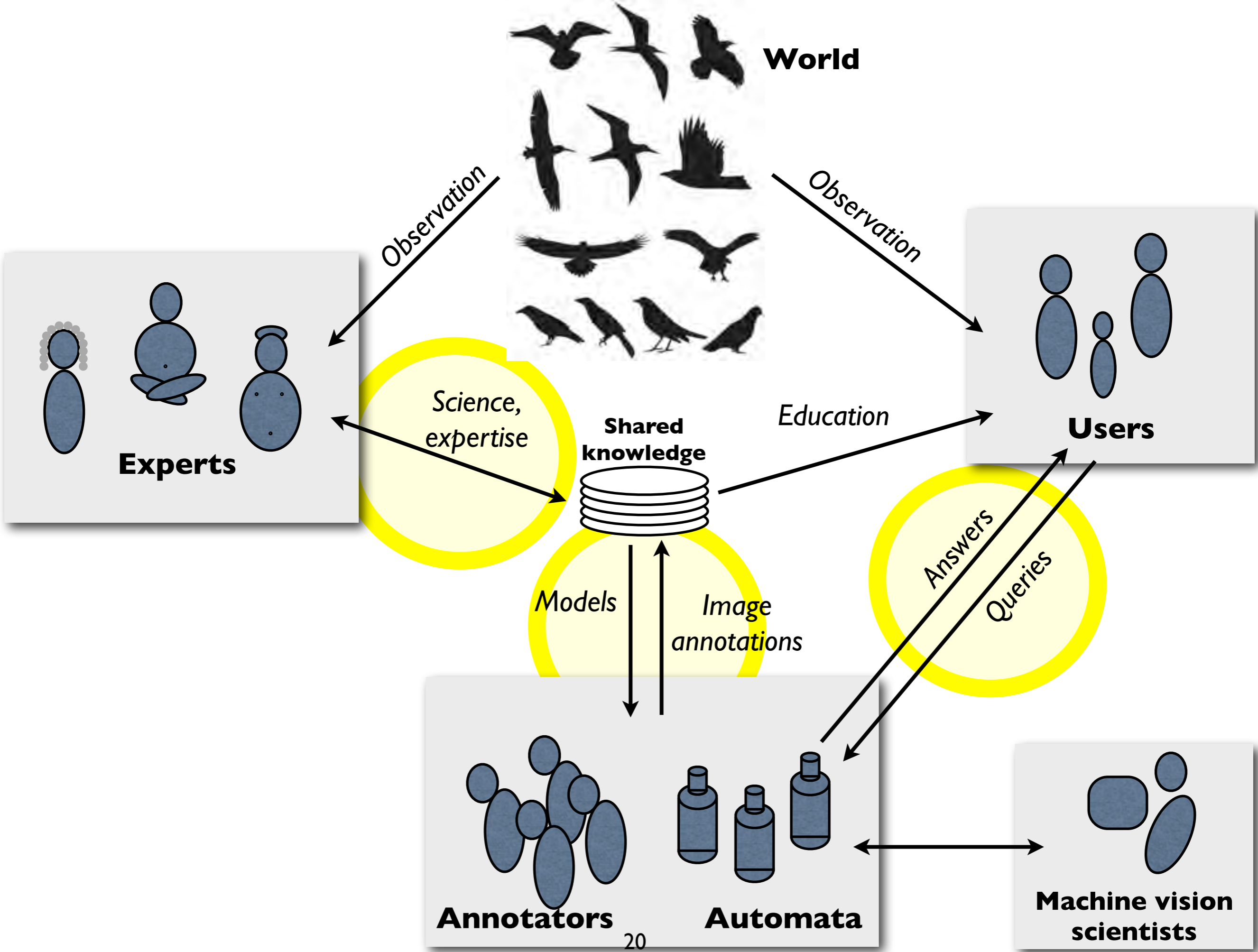












Today's focus

- Visual queries
- Image annotation
- Obtaining visual knowledge

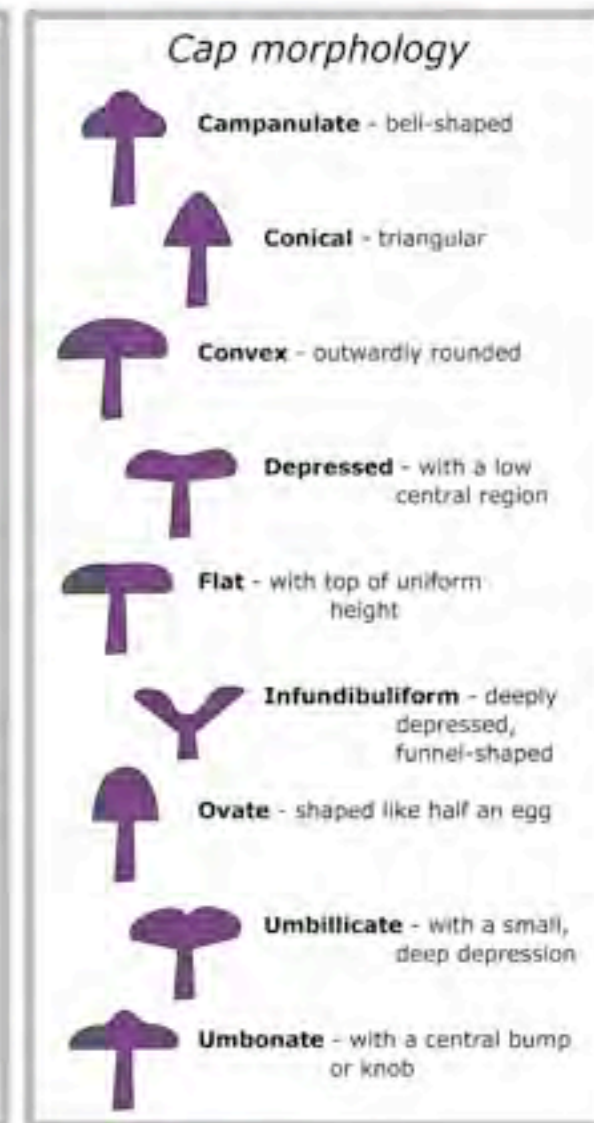
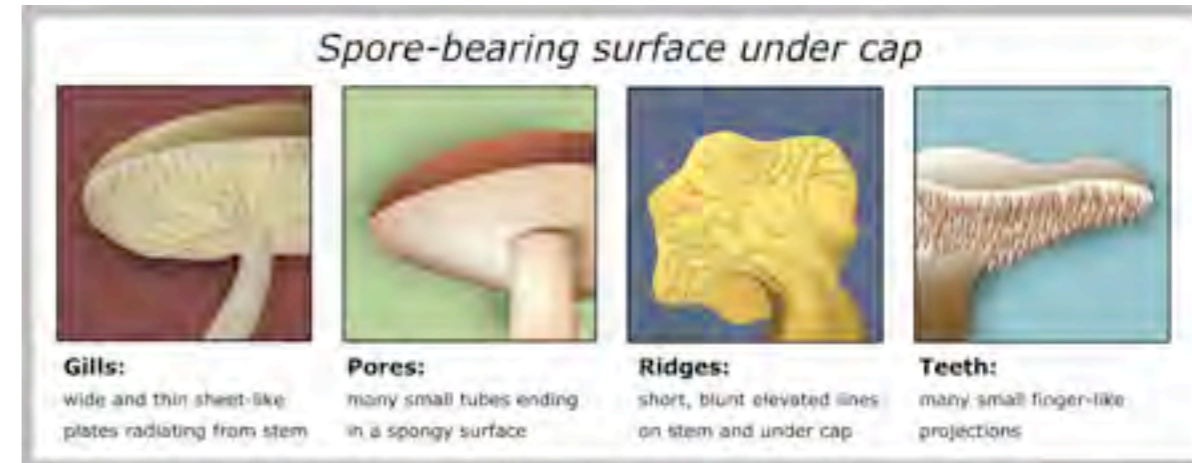
Visual knowledge

Visual knowledge



Task-oriented (practitioners)₂

Visual knowledge



Task-oriented (practitioners)₂

Categorical (experts)

Obtaining visual knowledge from experts

Femur

From Wikipedia, the free encyclopedia

For the [invertebrate femur](#), see [Arthropod leg](#).

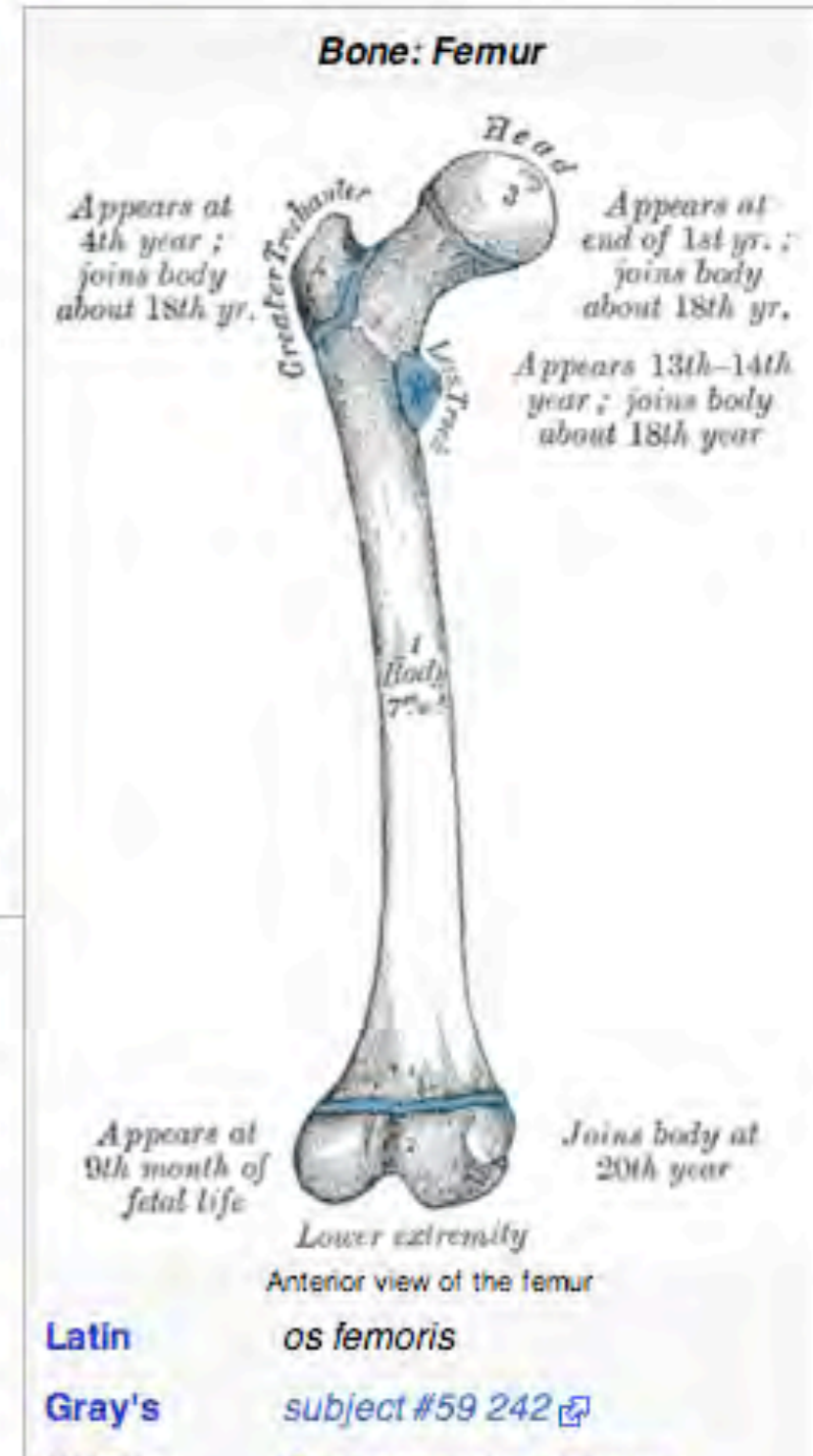
The **femur**, or **thigh bone**, is the most **proximal** (closest to the body) **bone** of the **leg** in **vertebrates** capable of **walking** or **jumping**, such as most **land mammals**, **birds**, many **reptiles** such as **lizards**, and **amphibians** such as **frogs**. In vertebrates with four legs such as **dogs** and **horses**, the femur is found only in the rear legs.

Contents [\[hide\]](#)

- 1 Human anatomy
- 2 Evolutionary variation
- 3 Etymology
- 4 Additional images
- 5 References
- 6 External links

Human anatomy [\[edit\]](#)

In **human anatomy**, the femur is the **longest** and largest bone. Along with the **temporal bone** of the **skull**, it is one of the two strongest bones in the body. The average adult male femur is 48 centimeters (18.9 in) in length and 2.34 cm (0.92 in) in diameter and can support up to 30 times the weight of an adult.^[1] It forms part of the **hip** (at the **acetabulum**) and part of the **knee**, which is located above. There are four eminences, or protuberances, in the human femur: the **head**, the **greater trochanter**, the **lesser trochanter**, and the **lower extremity**. They appear at various times from just before birth to about age 14. Initially, they are joined to the main body of the femur with **cartilage**, which gradually



Latin *os femoris*
Gray's *subject #59 242* [\[ⓘ\]](#)

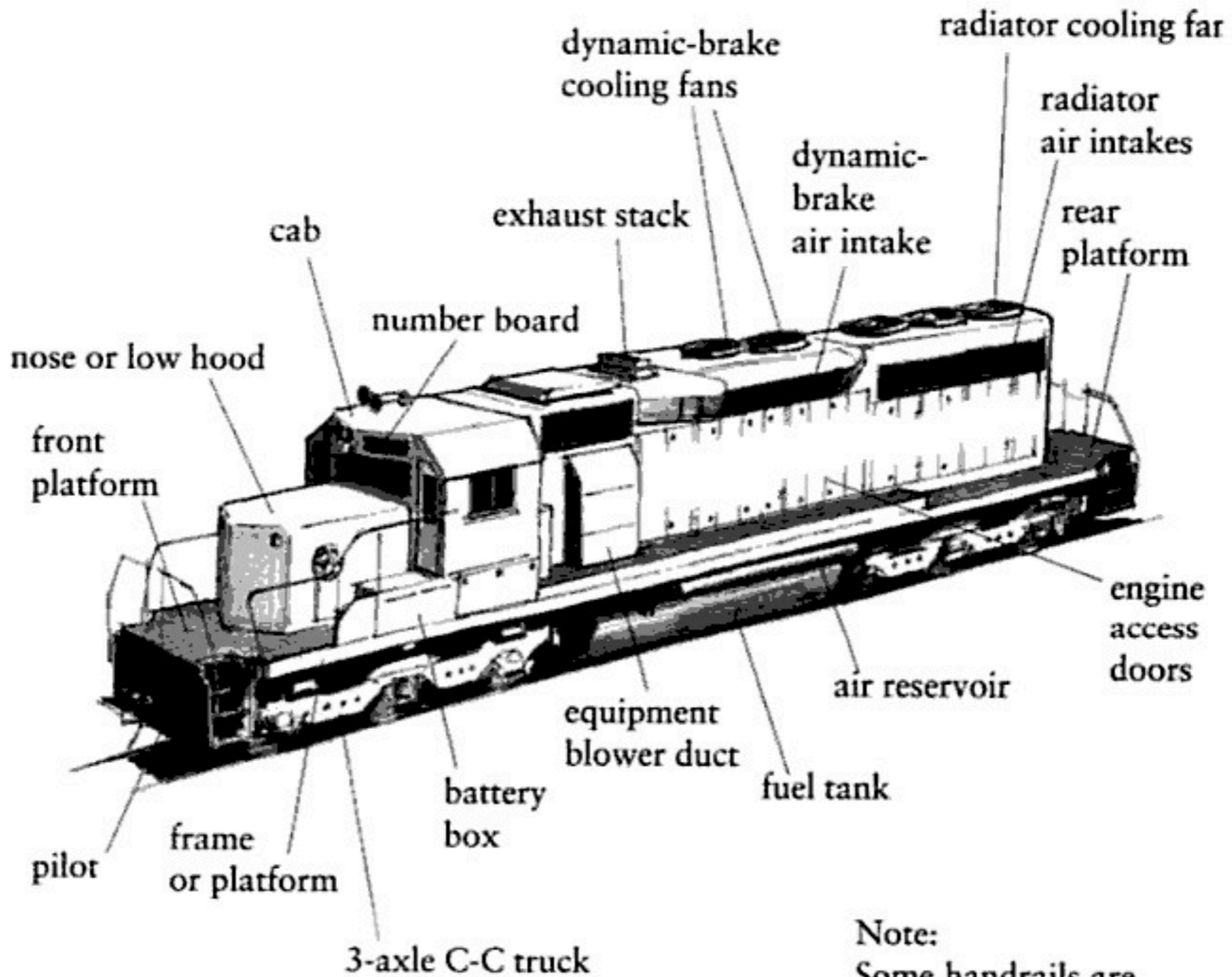


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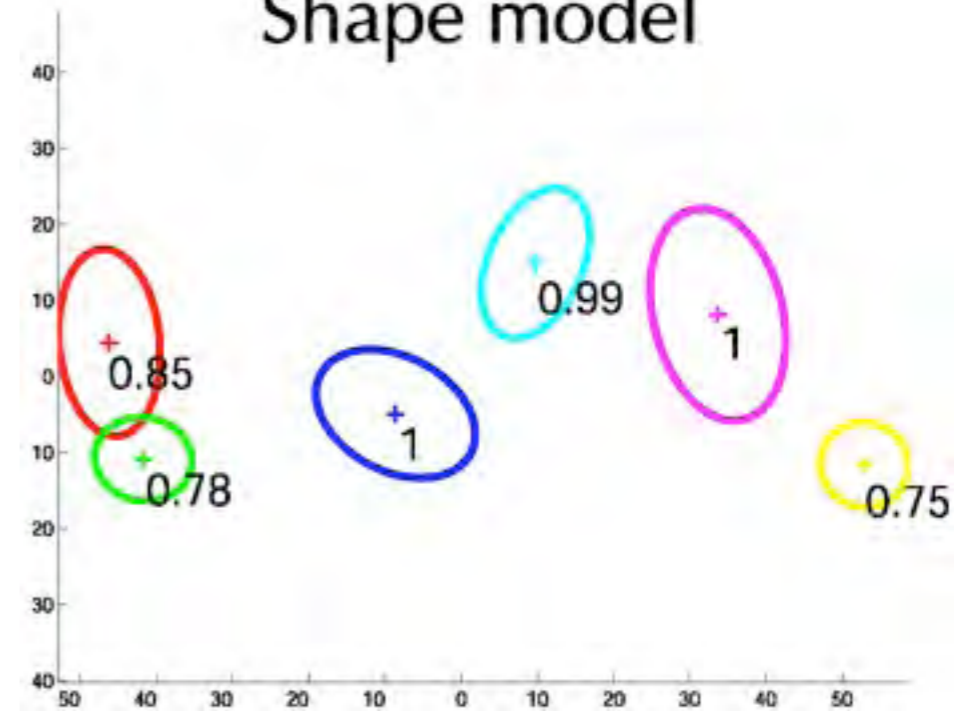


THE PARTS OF A LOCOMOTIVE

Unsupervised learning?



Shape model



[Fergus et al., CVPR03]

Unsupervised Learning?

Shape model

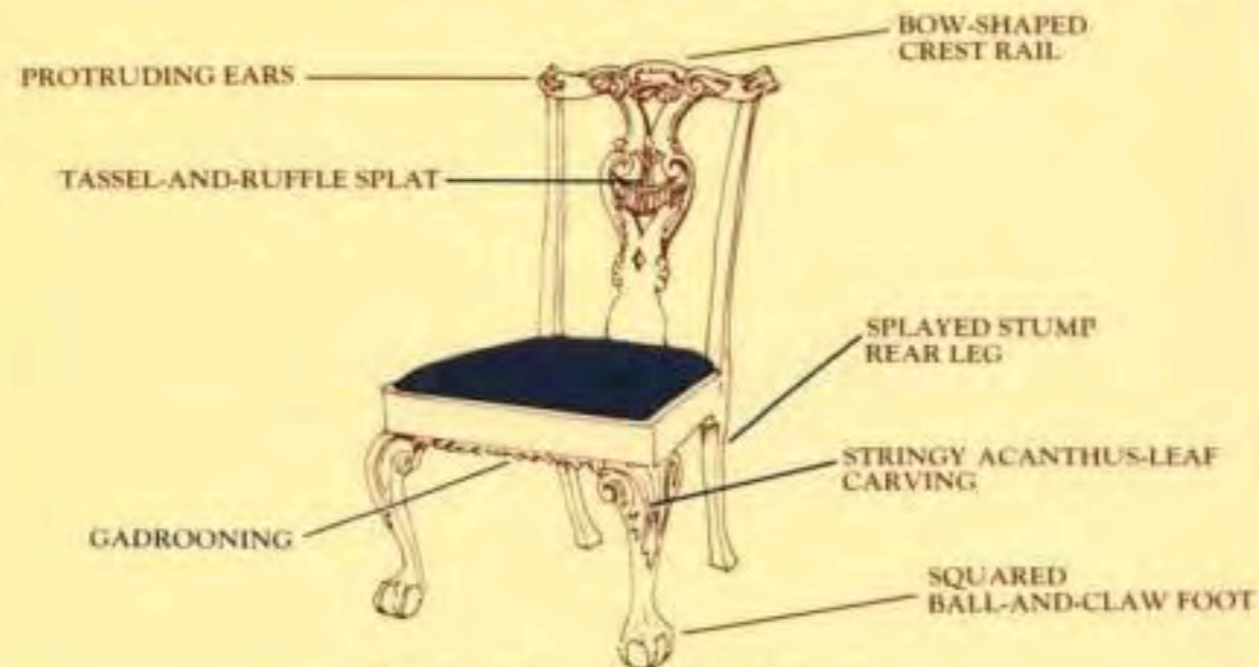


[Fergus et al., CVPR05]

FIELD GUIDE TO

AMERICAN ANTIQUUE FURNITURE

A UNIQUE VISUAL SYSTEM FOR
IDENTIFYING THE STYLE OF VIRTUALLY ANY
PIECE OF AMERICAN ANTIQUE FURNITURE

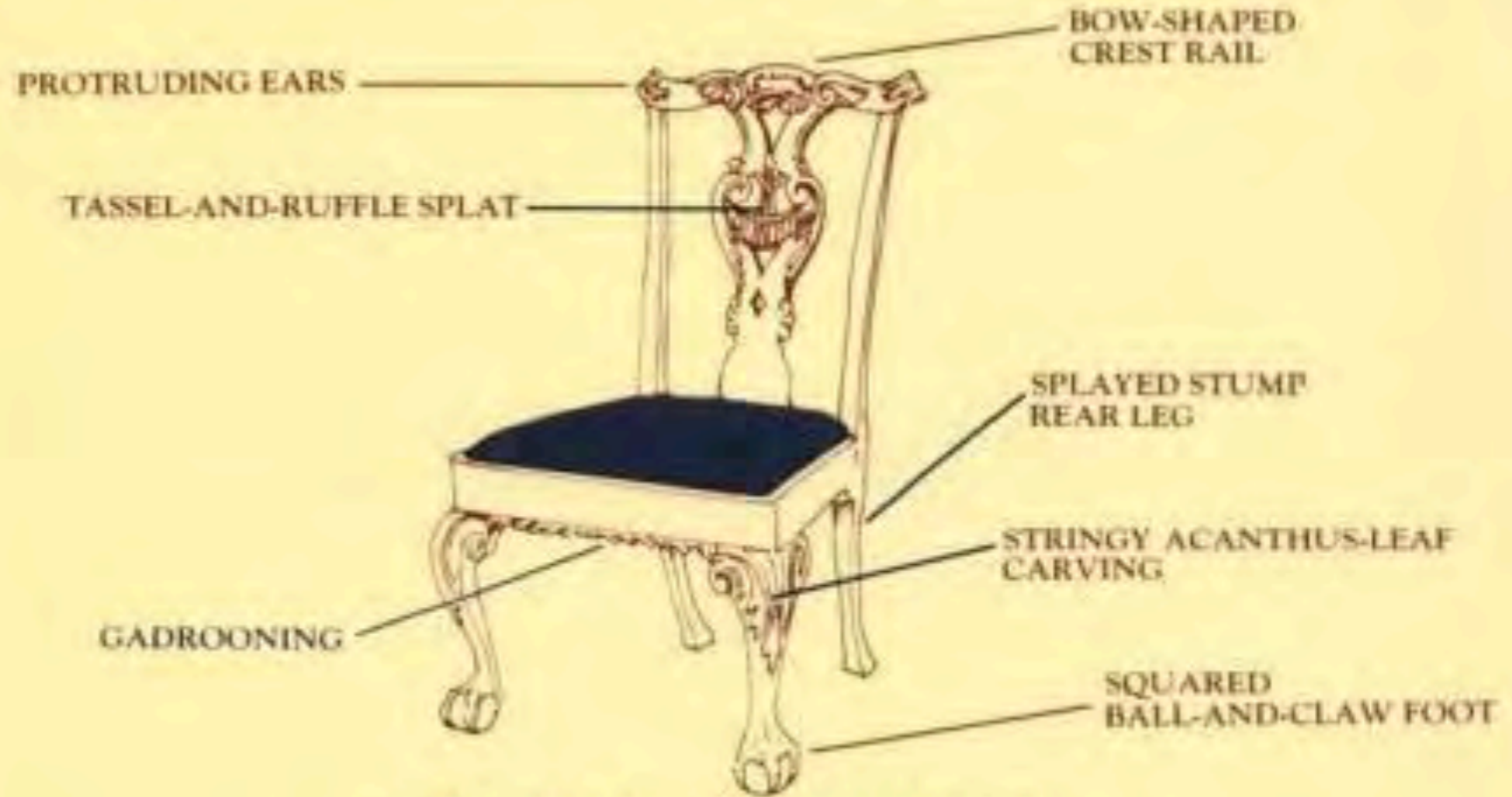


NEW YORK CHIPPENDALE SIDE CHAIR

JOSEPH T. BUTLER
ILLUSTRATIONS
RAY SKIBINSKI

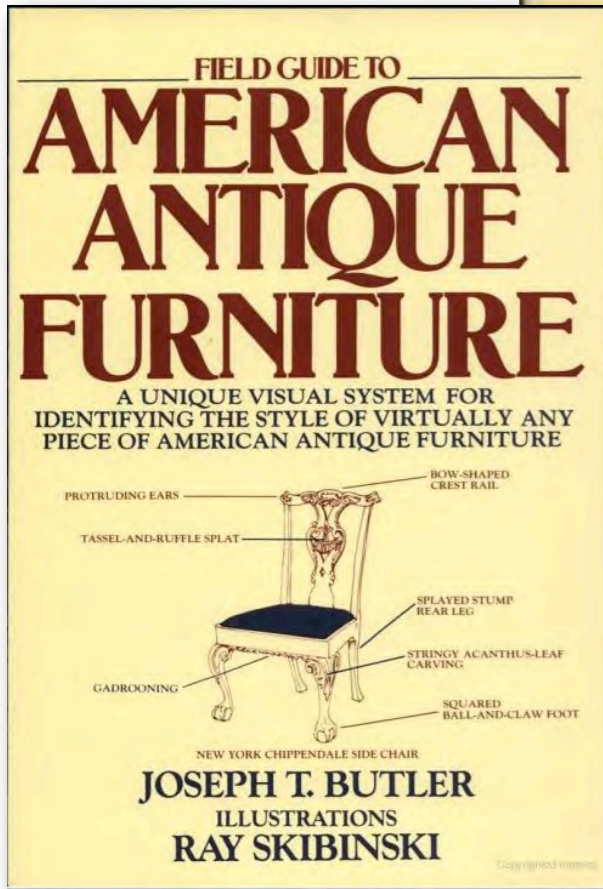
FURNITURE

A UNIQUE VISUAL SYSTEM FOR IDENTIFYING THE STYLE OF VIRTUALLY ANY PIECE OF AMERICAN ANTIQUE FURNITURE

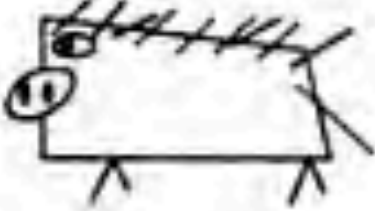

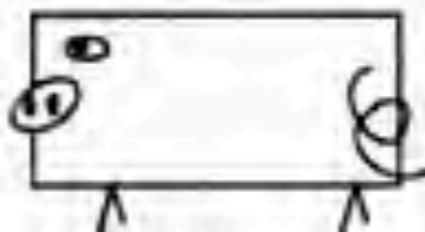
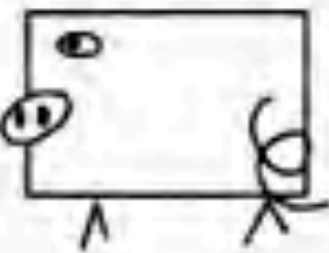


NEW YORK CHIPPENDALE SIDE CHAIR

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ILLUSTRATIONS
RAY SKIBINSKI



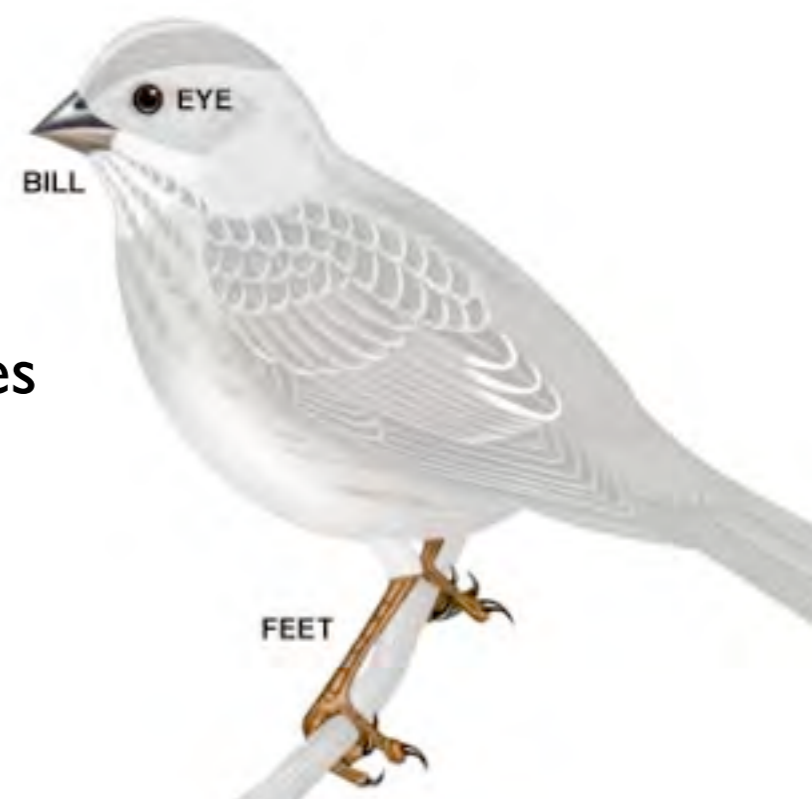
PIG TYPES

Wild/Feral	Domesticated		
Eurasian 	Lard 	Bacon 	Porker/Meat 
<p>Slight hindquarters, long tusks, long straight snout, straight tail, coarse bristles, small prick ears, and striped piglets.</p>	<p>Chuffy, fat, low, and square-shaped body. A type bred mostly in the U.S. during the early and mid-1800s. Fine hair. Shorter face with an angled profile.</p>	<p>Lean, long body. A type developed in Europe. Fine hair.</p>	<p>Cross between lard and Bacon types. Bigger muscles, big hams. A type developed in the 1930s for the American market. Fine hair.</p>
<p>Razor back, Hawaiian feral, wild/feral hybrids, and Eurasian Wild Boar.</p>	<p>They went on a diet and are no longer seen.</p>	<p>These pig breeds are used mostly for bacon: Gloucestershire Old Spot, Tamworth, British Lop, Landrace, Large Black, and Yorkshire.</p>	<p>These pig breeds are used mostly for pork: Lacombe, Spotted, Duroc, Hereford, Piétrain, Chester White, Hampshire,</p>

Topography of a bird's body



Constant features



Curved-shaped Bill



Hook-shaped Bill



Cone-shaped bill



Needle-shaped Bill



Spatulate-shaped Bill



Dagger-shaped Bill

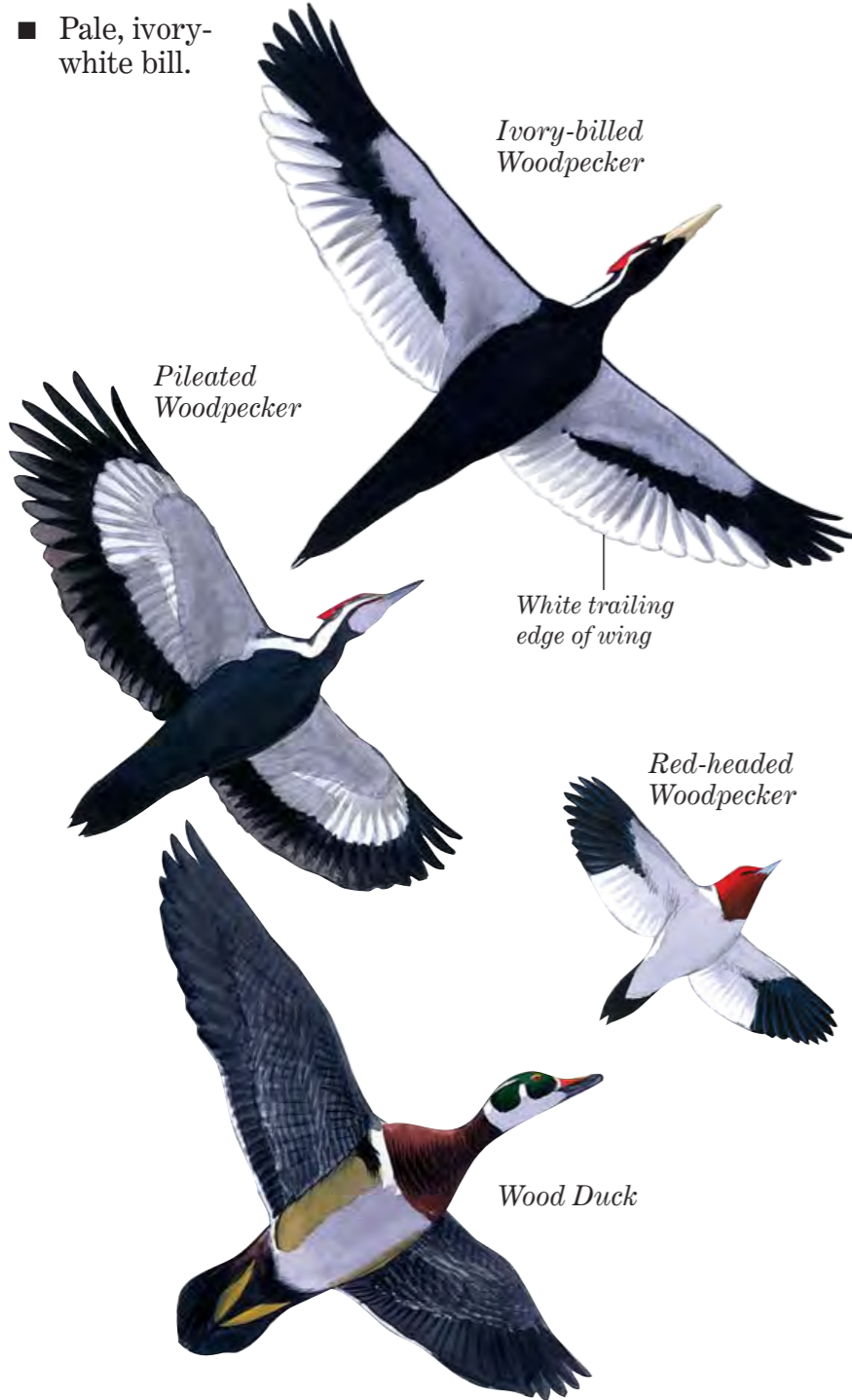


Identifying Field Marks of an Ivory-billed Woodpecker and Similar Birds

In flight - view from below

Distinct Ivory-billed Woodpecker characteristics:

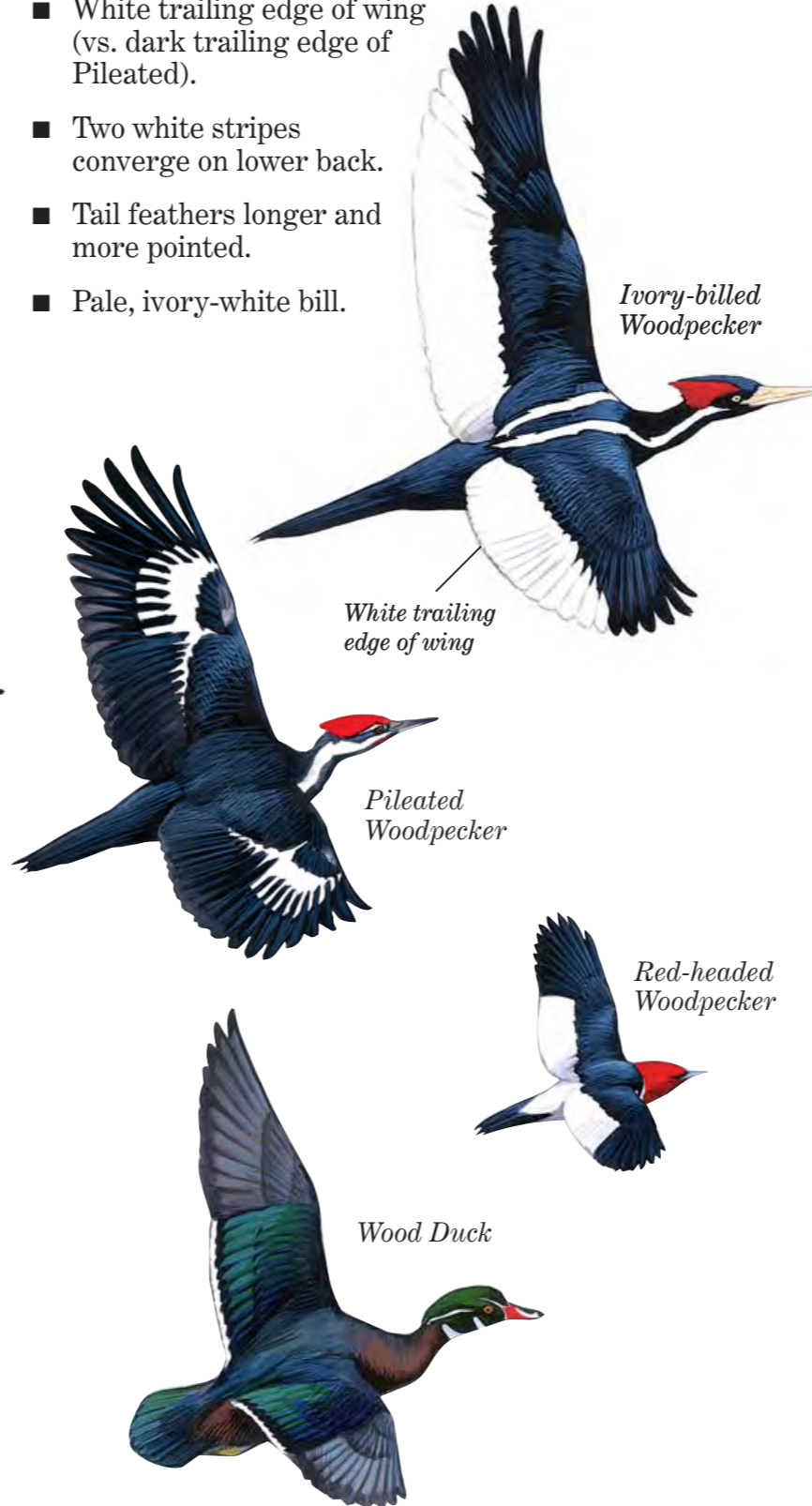
- White trailing edge of wing (vs. dark trailing edge of Pileated).
- Wing more slender than Pileated.
- Tail feathers longer and more pointed.
- Pale, ivory-white bill.



In flight - view from above

Distinct Ivory-billed Woodpecker characteristics:

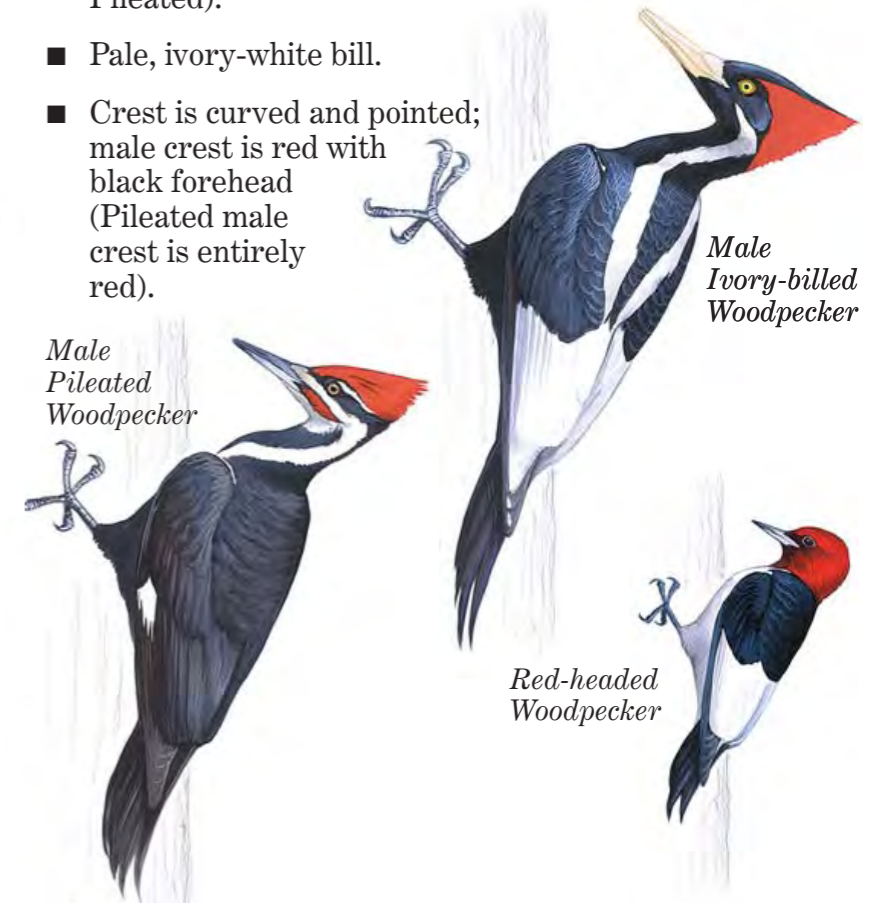
- White trailing edge of wing (vs. dark trailing edge of Pileated).
- Two white stripes converge on lower back.
- Tail feathers longer and more pointed.
- Pale, ivory-white bill.



At rest

Distinct Ivory-billed Woodpecker characteristics:

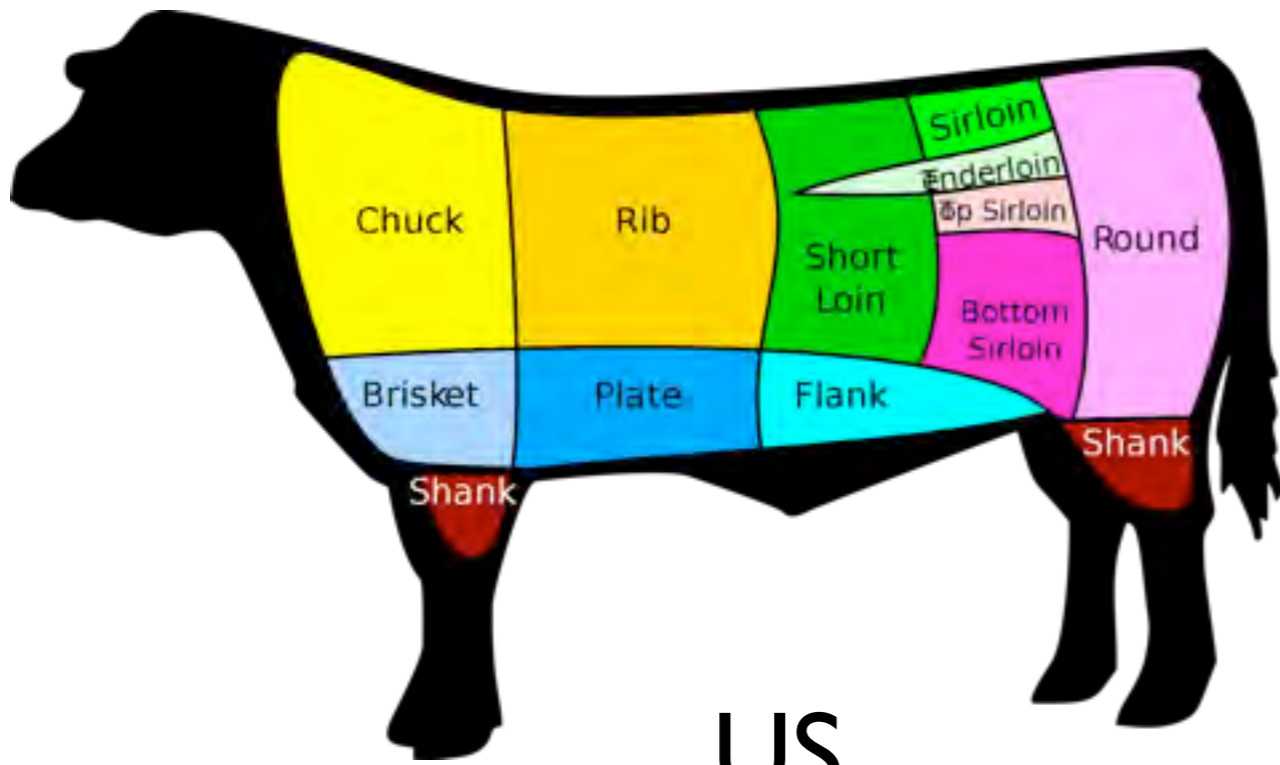
- Two white stripes converge on lower back.
- Entirely white secondary feathers give appearance of white "saddle" on back.
- Largely dark face and dark chin (vs. white chin of Pileated).
- Pale, ivory-white bill.
- Crest is curved and pointed; male crest is red with black forehead (Pileated male crest is entirely red).



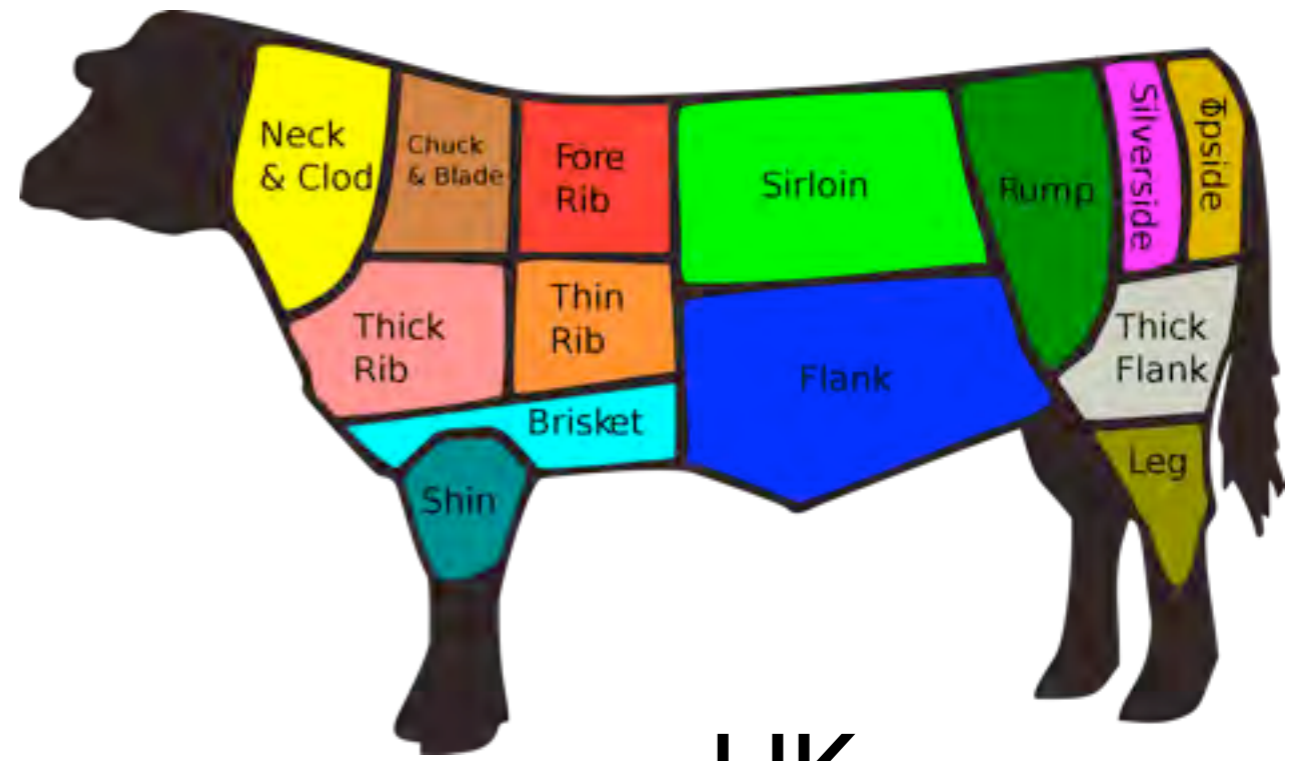
Female Head

- Female Ivory-bill crest is entirely black (female Pileated crest resembles male ivory-billed red crest with black forehead – use chin color as distinguishing feature)

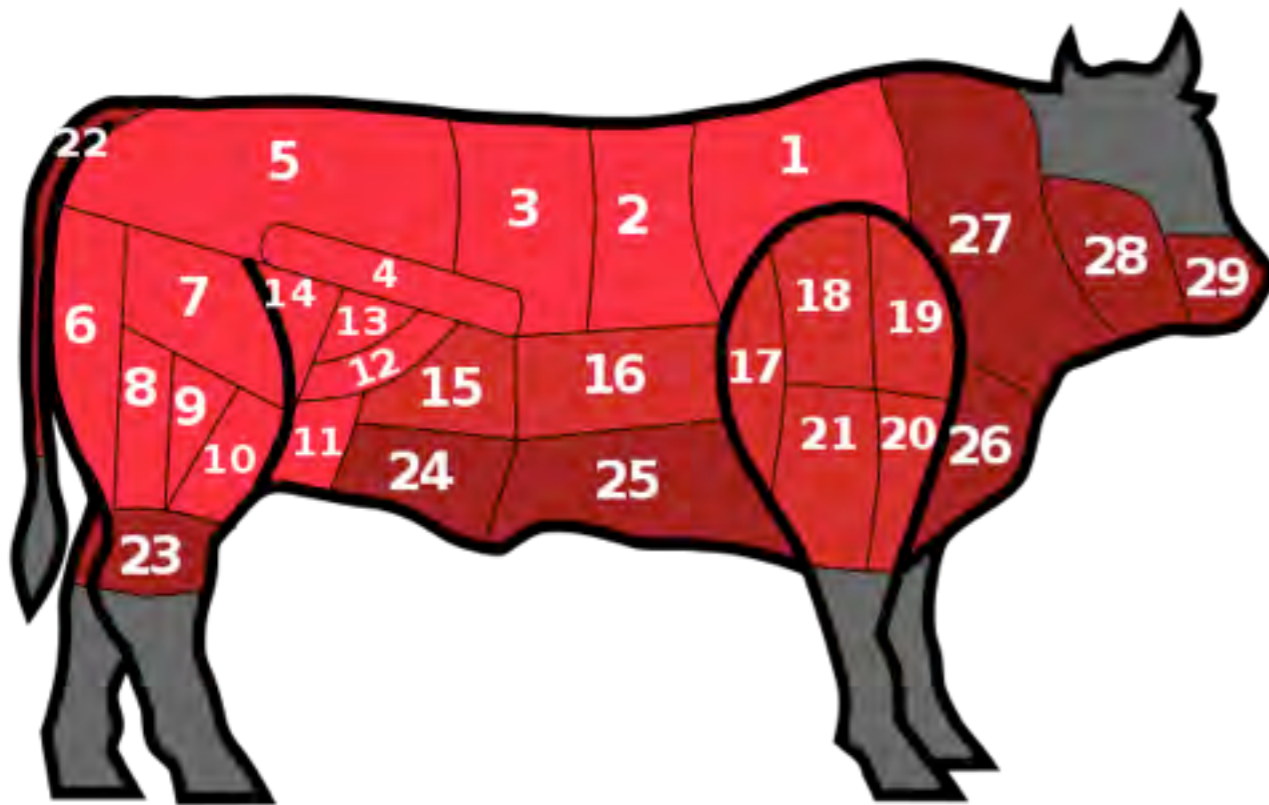




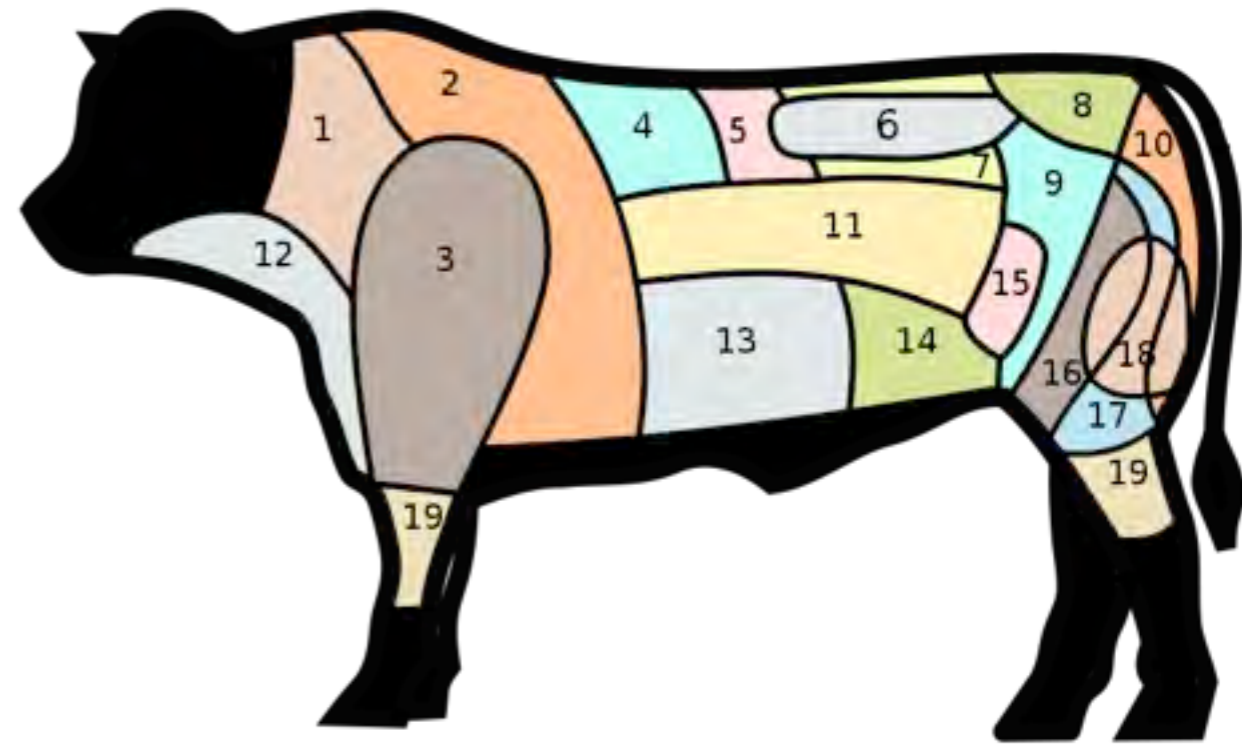
US



UK



France



Brazil

Thoughts

- Goal: computationally tractable models
- Expert involvement is essential
- Empower the experts with tools
- Generative and discriminative knowledge
- Ties with language (parts/attributes)
- Accommodate `dialects`

Image annotation

1. Welinder & Perona - Workshop on Advancing Computer Vision with Humans in the Loop at CVPR'10
2. Welinder et al. - NIPS 2010

Annotation hierarchy

Present/absent

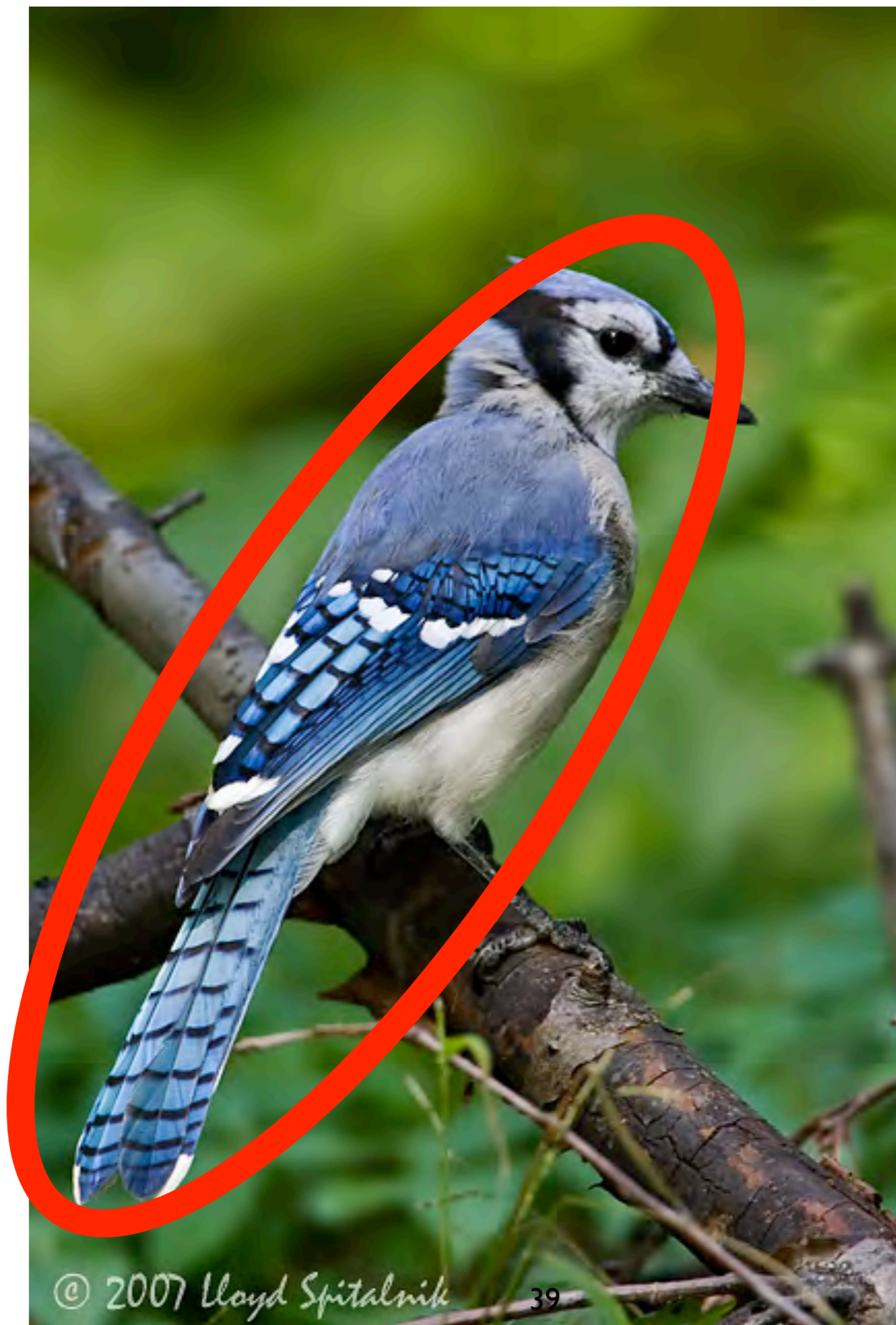


Bounding box



© 2007 Lloyd Spitalnik

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Bounding box
with orientation

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39



Contour

© 2007 Lloyd Spitalnik

40





Part blobs

© 2007 Lloyd Spitalnik

42

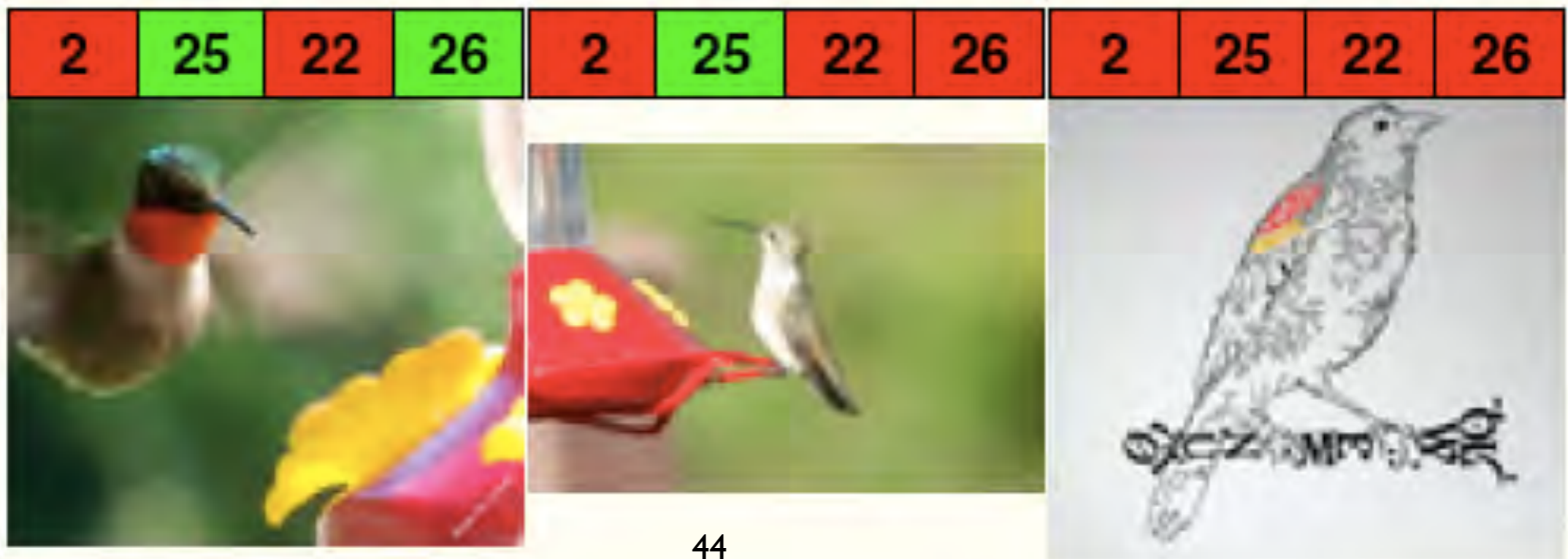


Segmented parts

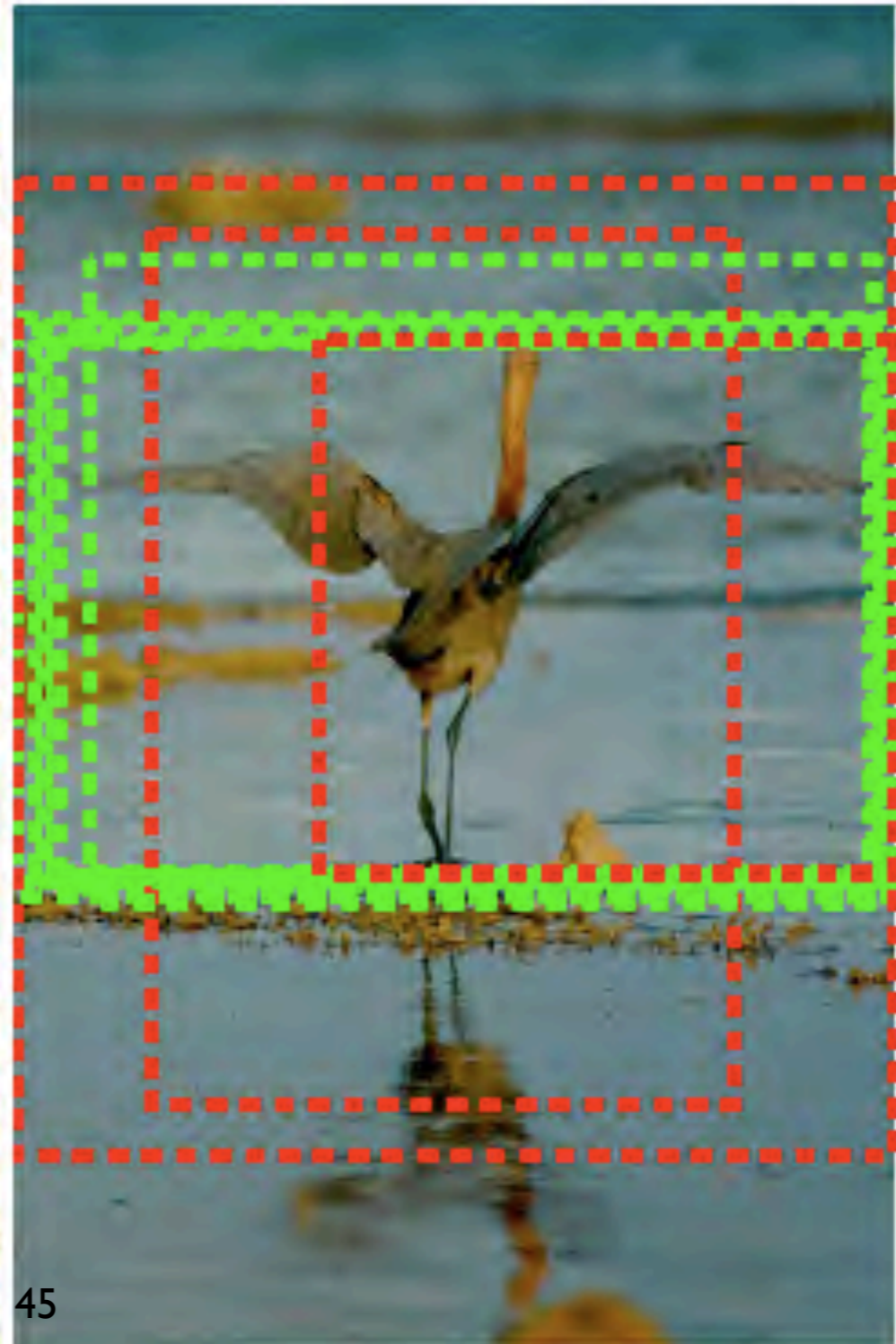
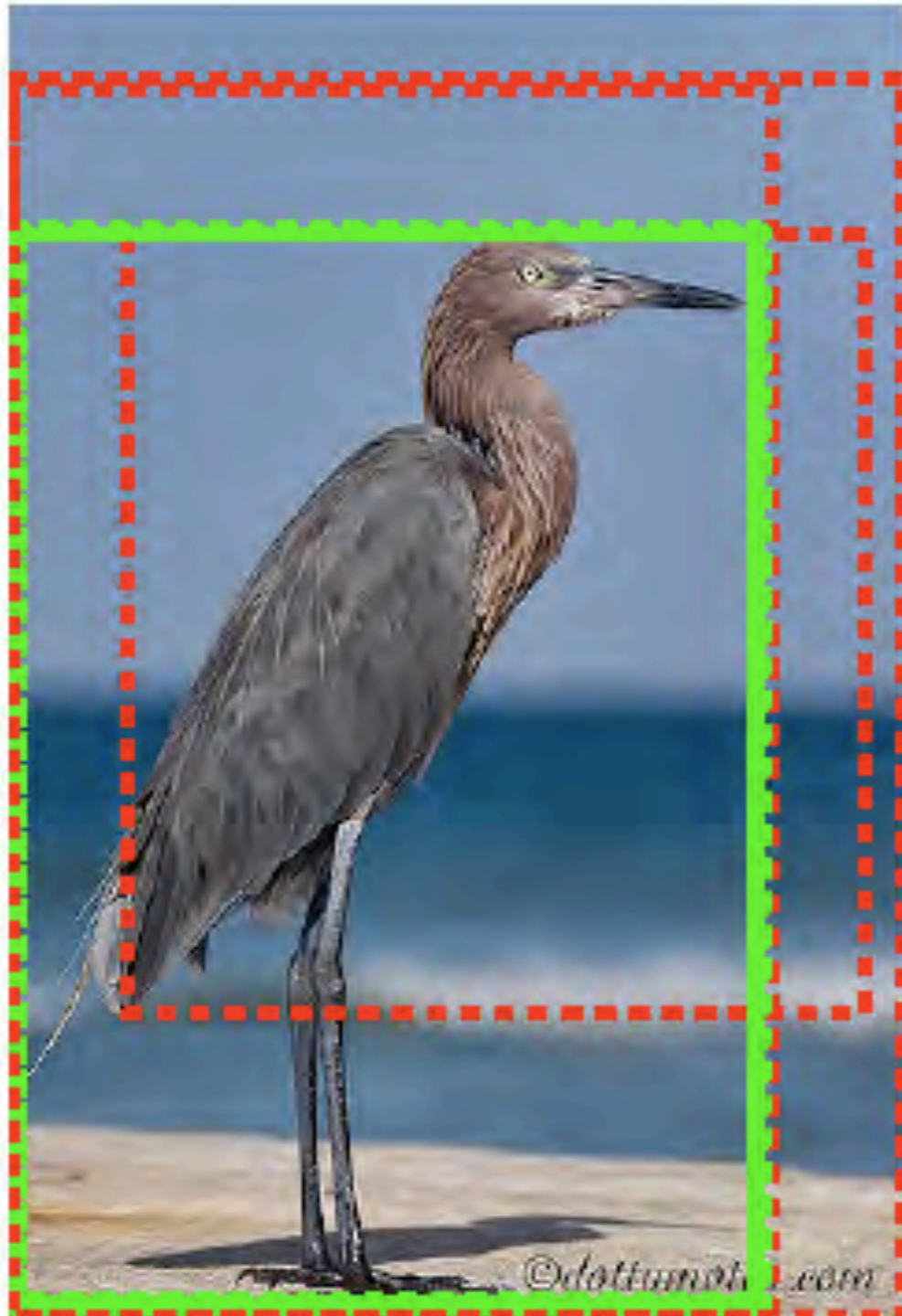
© 2007 Lloyd Spitalnik

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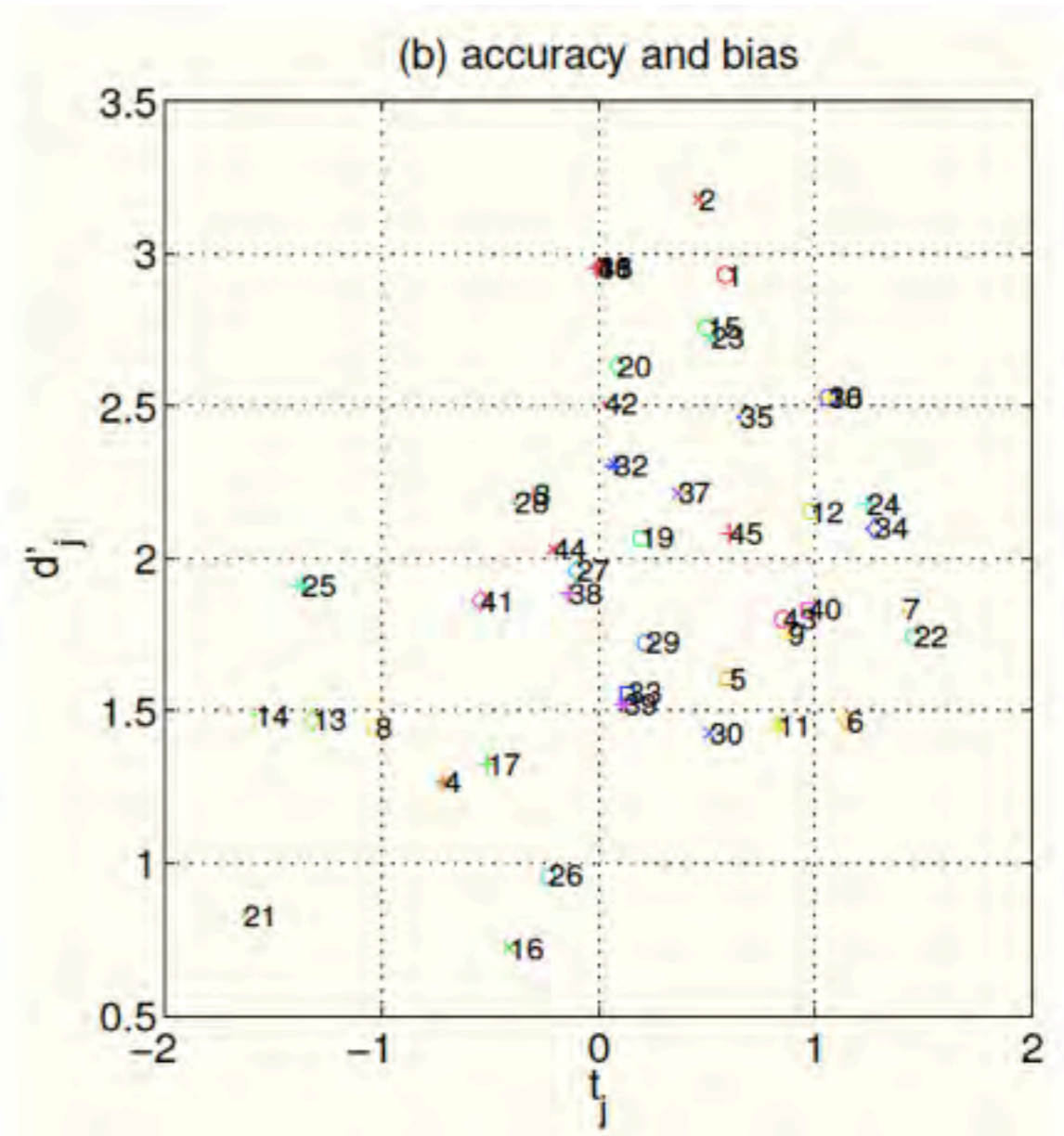
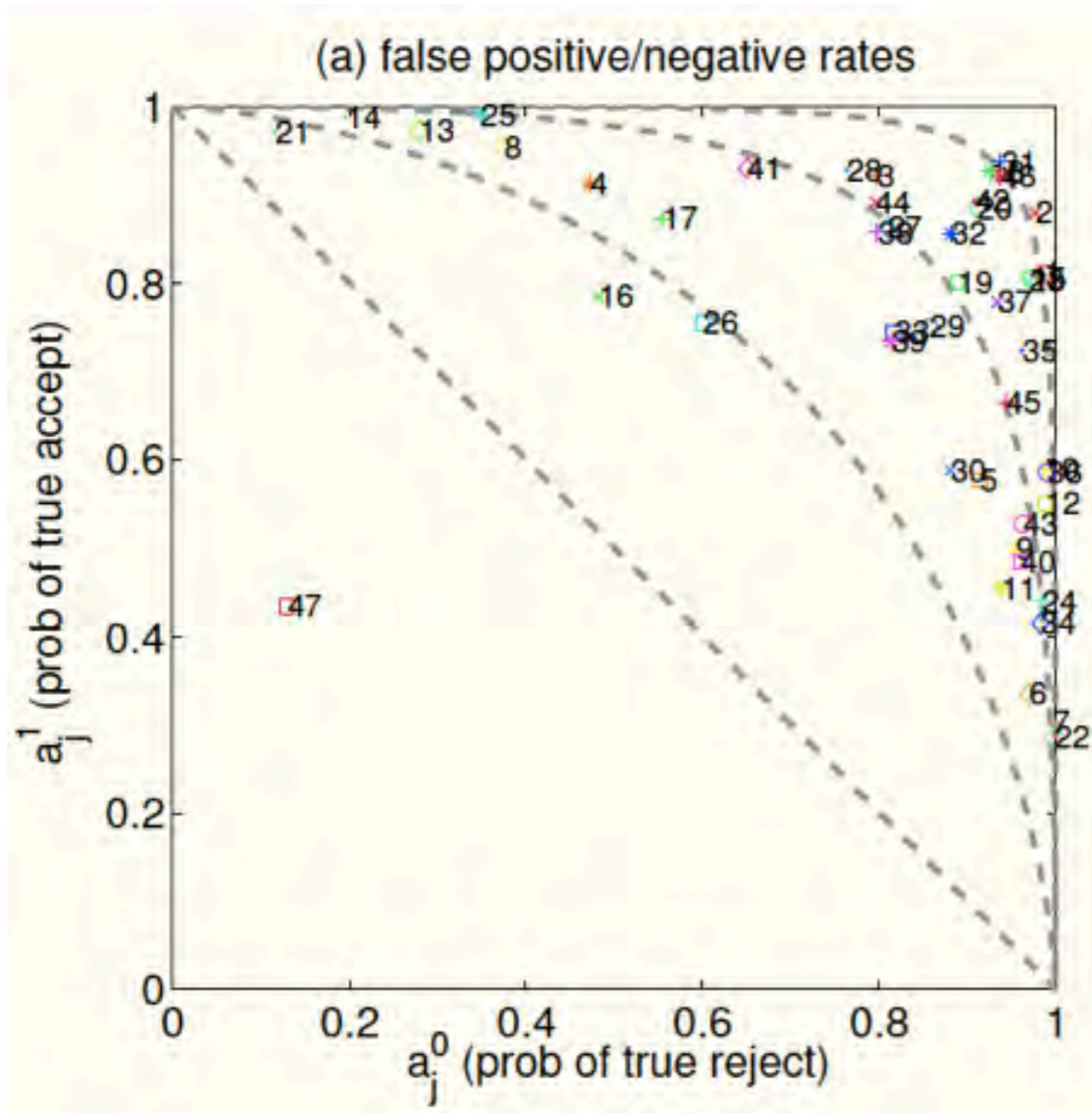
Binary labels



Continuous labels



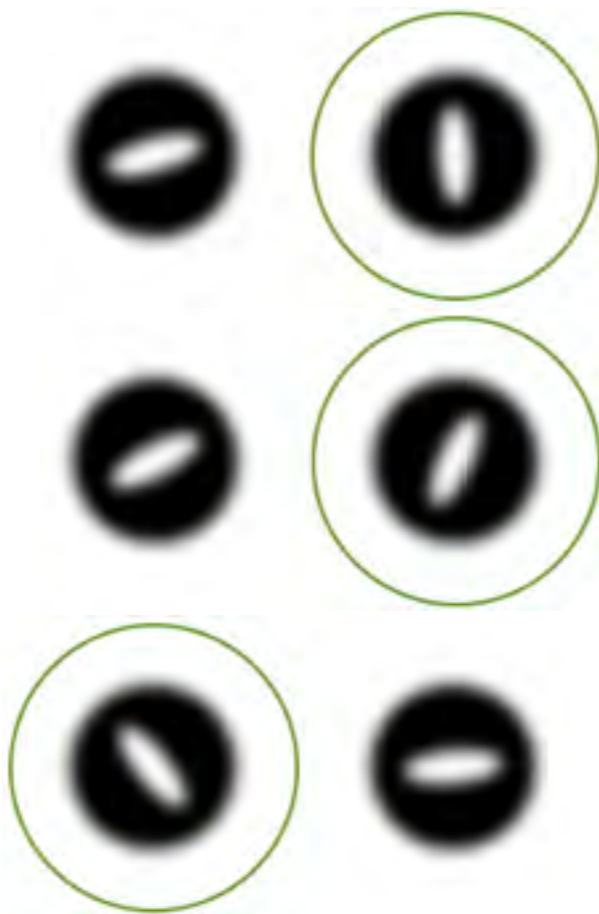
Annotators are multi-dimensional



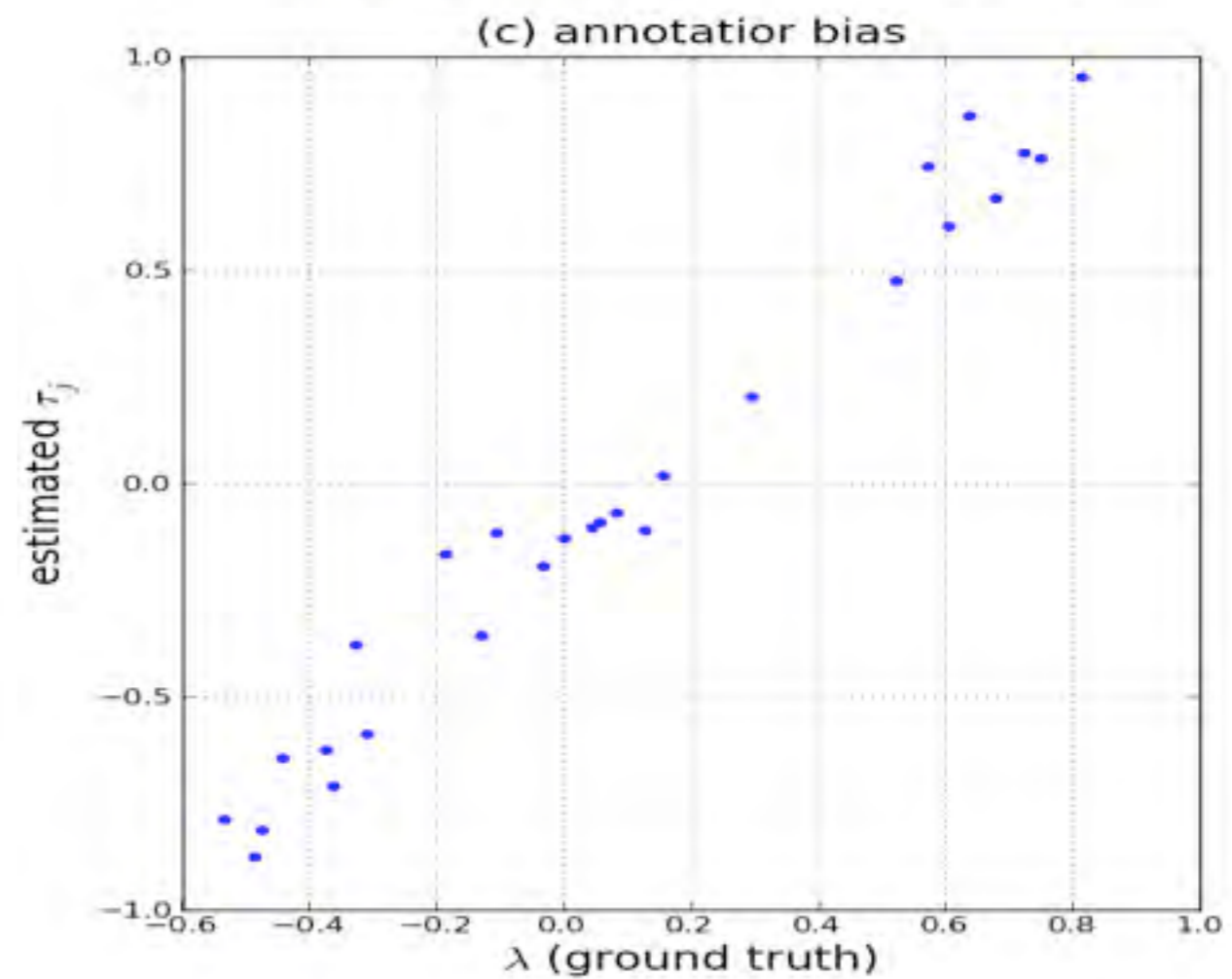
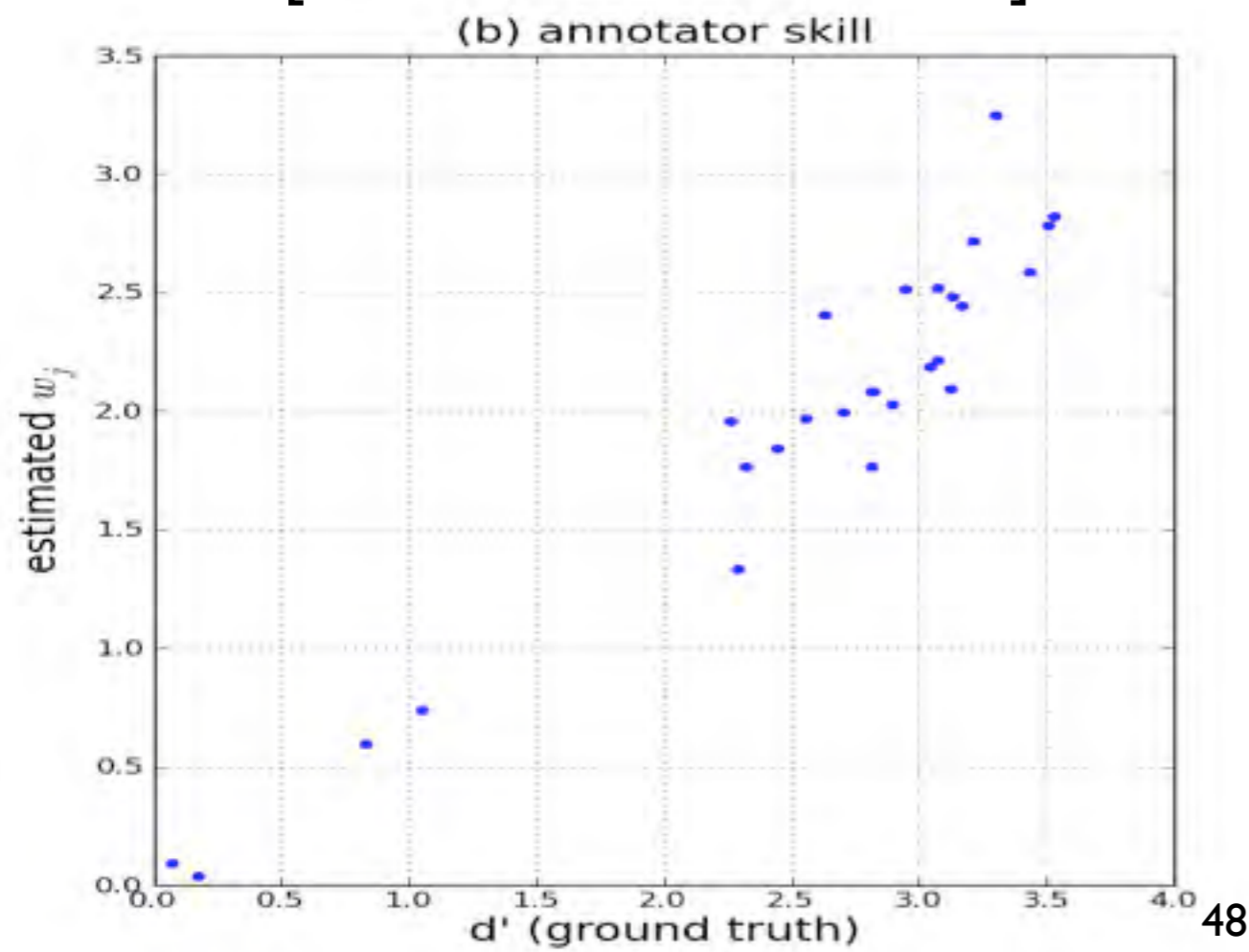
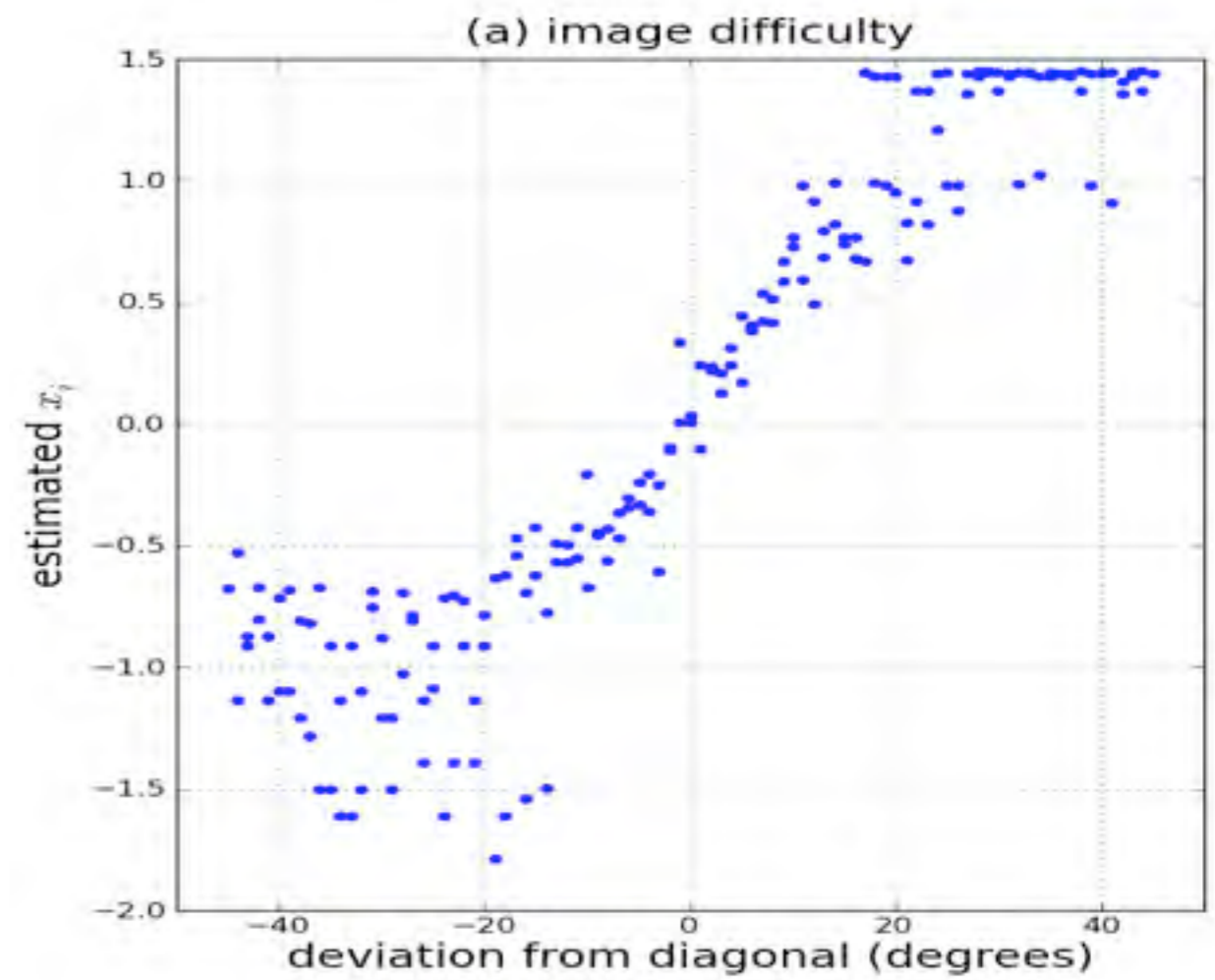
[Welinder & Perona - Workshop on Advancing Computer Vision with Humans in the Loop at CVPR'10]

Model of annotation

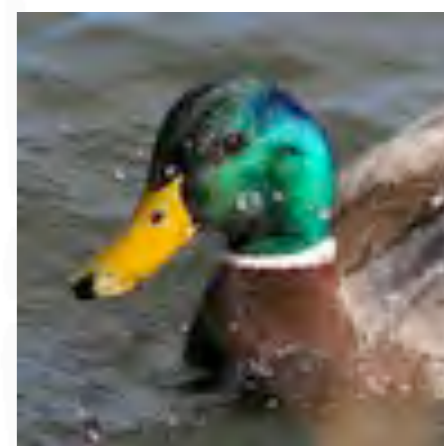
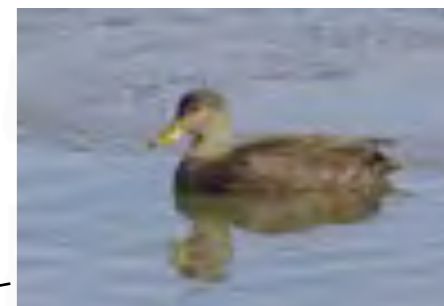
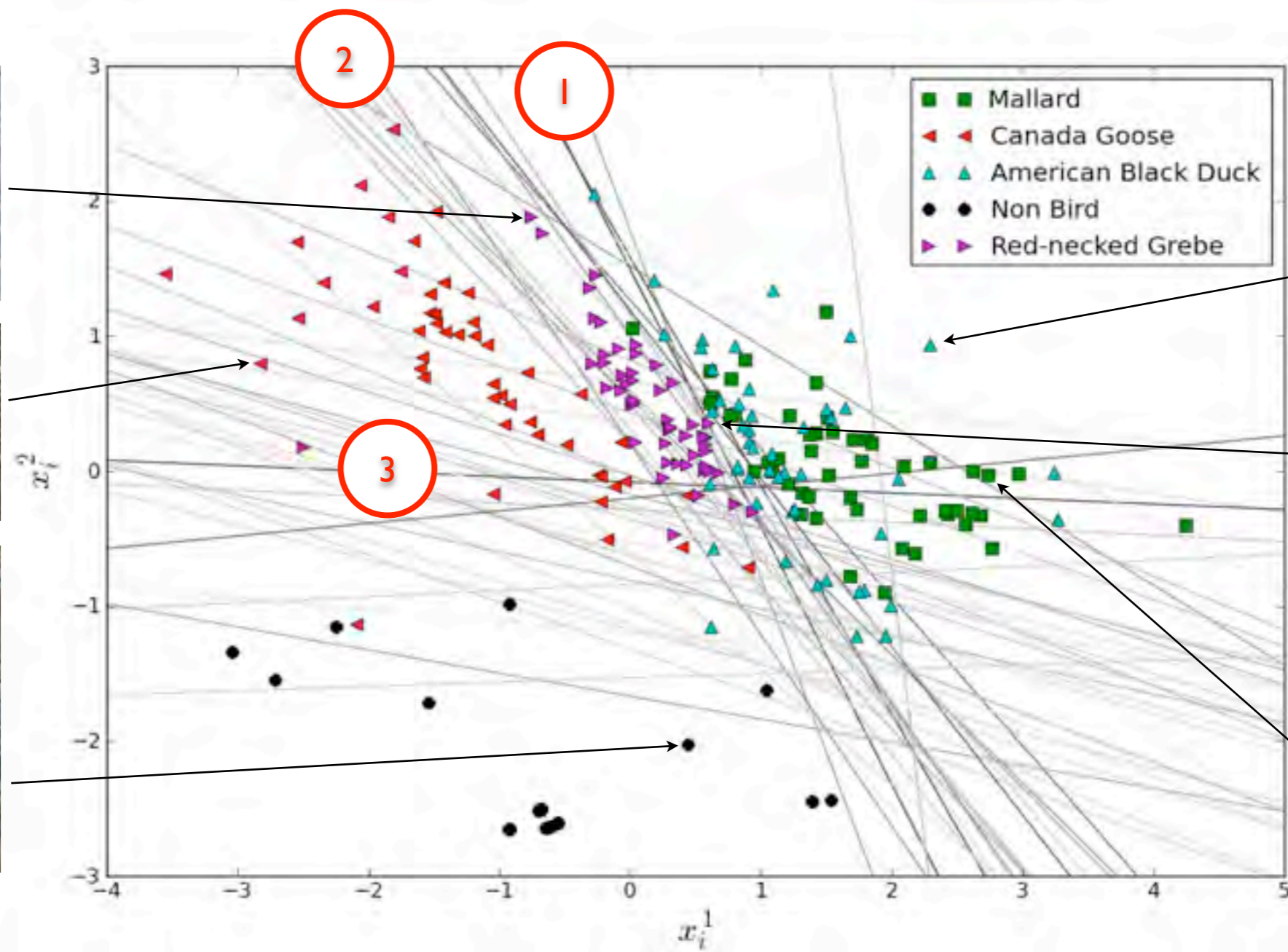
[See Welinder et al. - NIPS 2010]



[Welinder et al. - NIPS 2010]



Multidimensional expertise



[Welinder et al. - NIPS 2010]

Lessons learnt

- Multidimensional annotators
- Can obtain reliable labels
- Expertise, skill, bias
- Task difficulty

Automating field guides



?



Computer Vision





Computer Vision



Bottle



Computer Vision





Computer Vision



Bird

Field Guides

Attributes

Attribute Groups

- ◆ Basics
- Pattern
- Head
- Body
- Flight
- Illustrations
- Scientific Name
- Extras

Basics


 Location Common	 Location Uncommon	 Shape	 Size
 Color Primary	 Color Secondary	 Habitat	 Bill Shape


www.whatbird.com









Field Guides

Values

Select values and click
Next

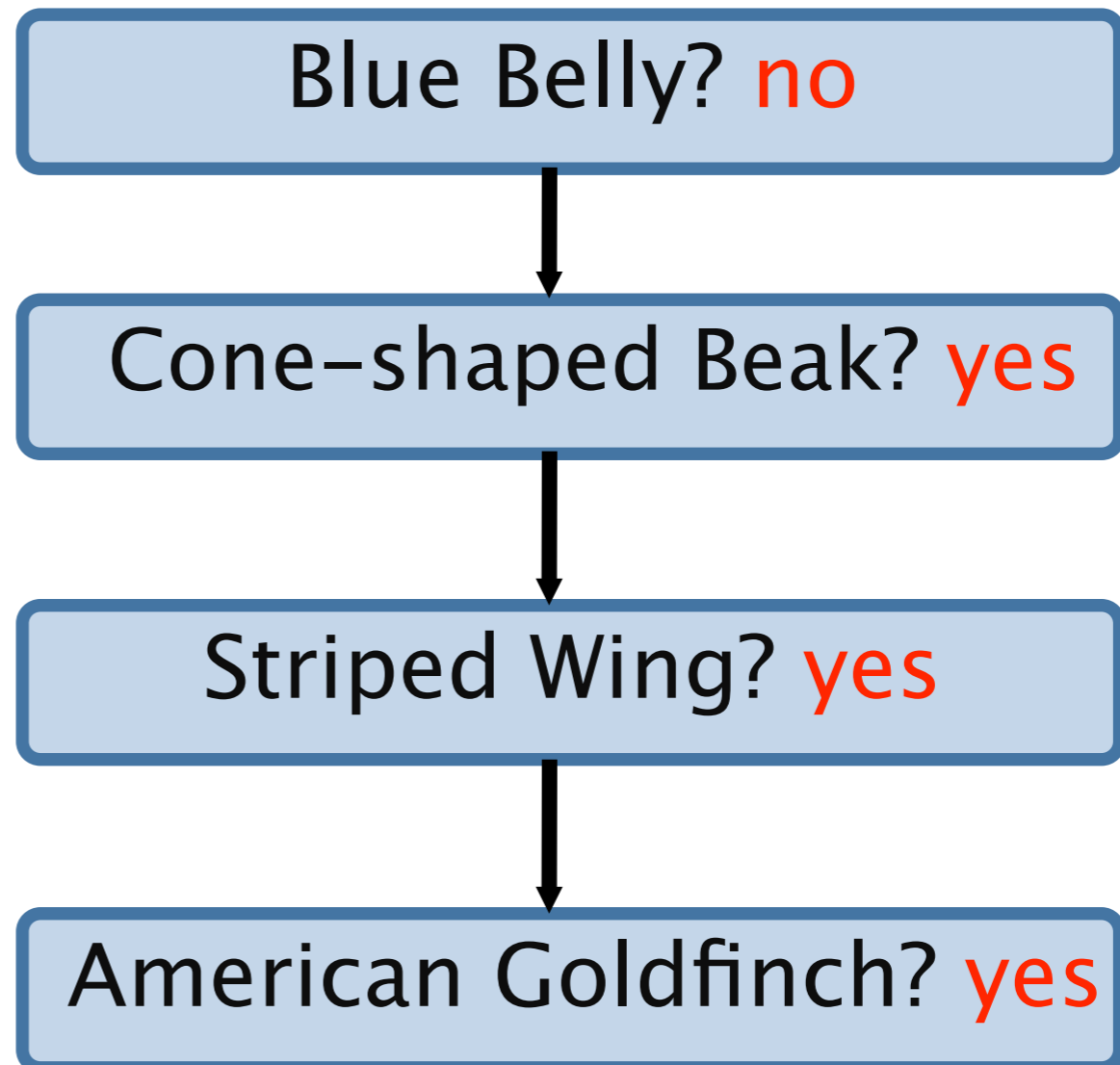
NEXT 

 **Shape**

<input type="checkbox"/>  Chicken- like-Marsh	<input type="checkbox"/>  Duck-like	<input type="checkbox"/>  Gull-like	<input type="checkbox"/>  Hawk-like
<input type="checkbox"/>  Hummingbird-like	<input type="checkbox"/>  Long-legged-like	<input type="checkbox"/>  Owl-like	<input type="checkbox"/>  Perching-like

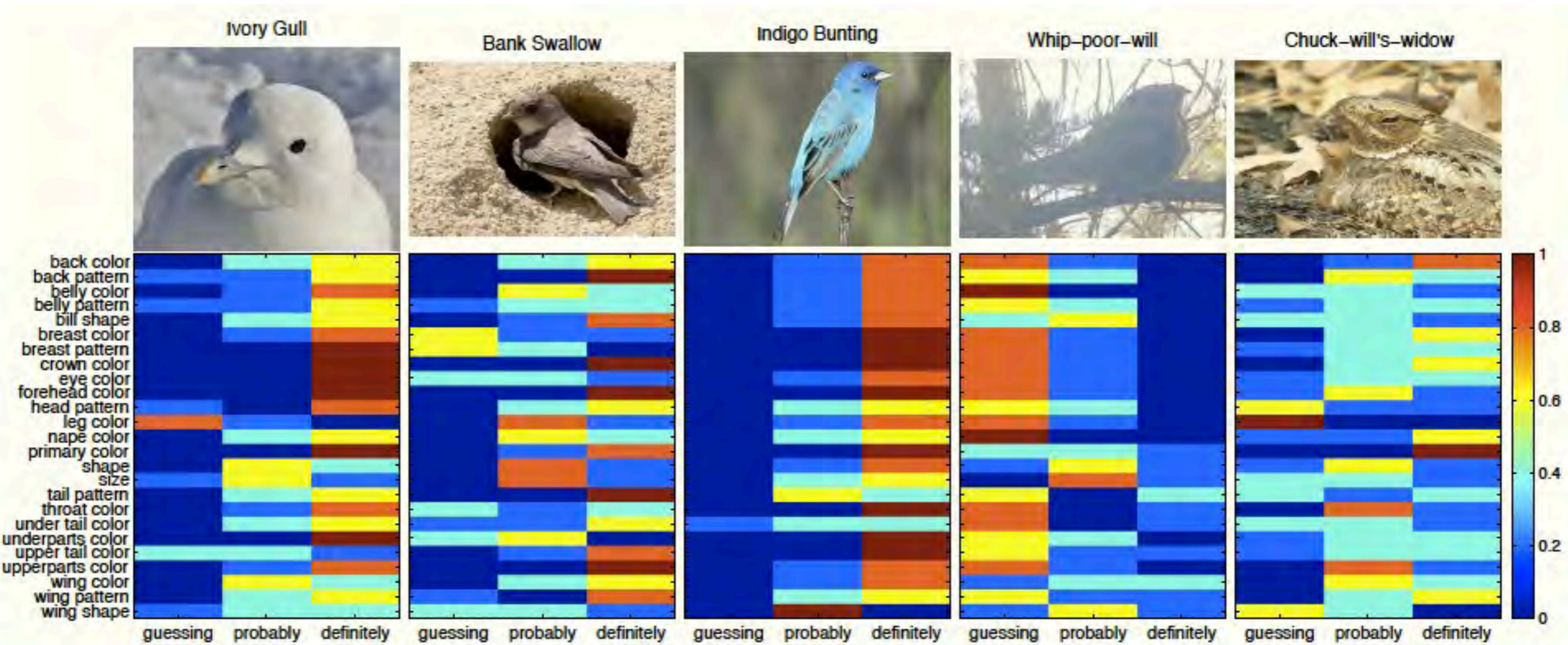
www.whatbird.com

Visual 20 Questions Game



Hard classification problems can be turned into a sequence of easy ones

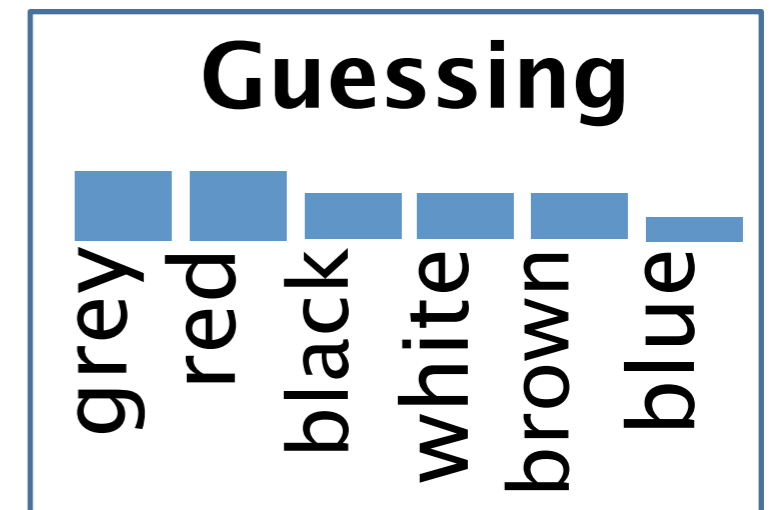
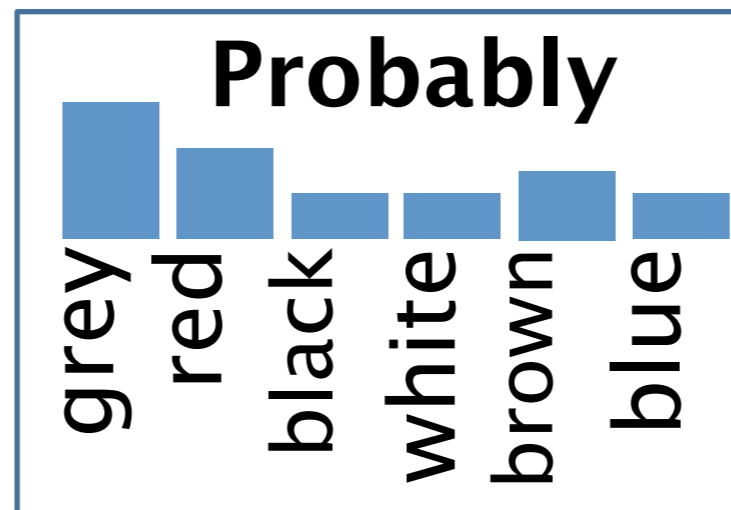
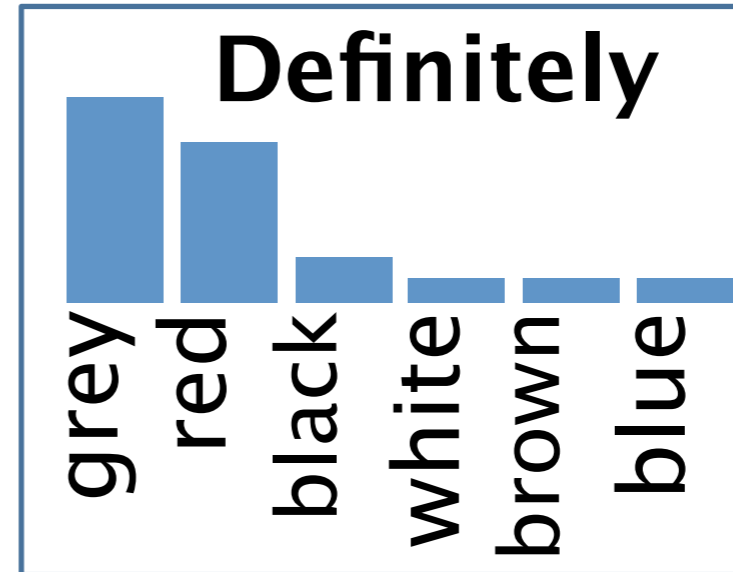
Unfortunately ...



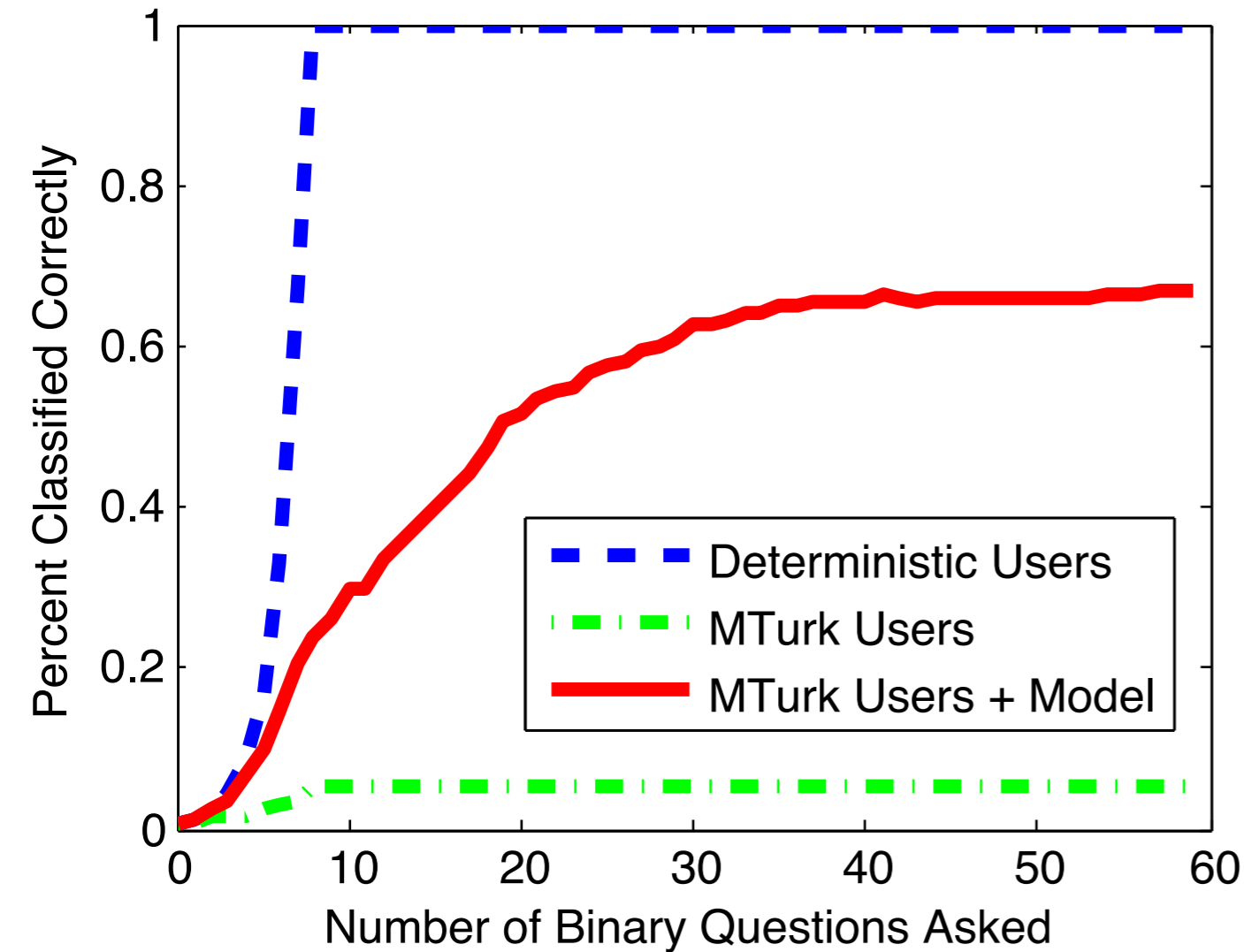
What is the color of the belly?



Pine Grosbeak

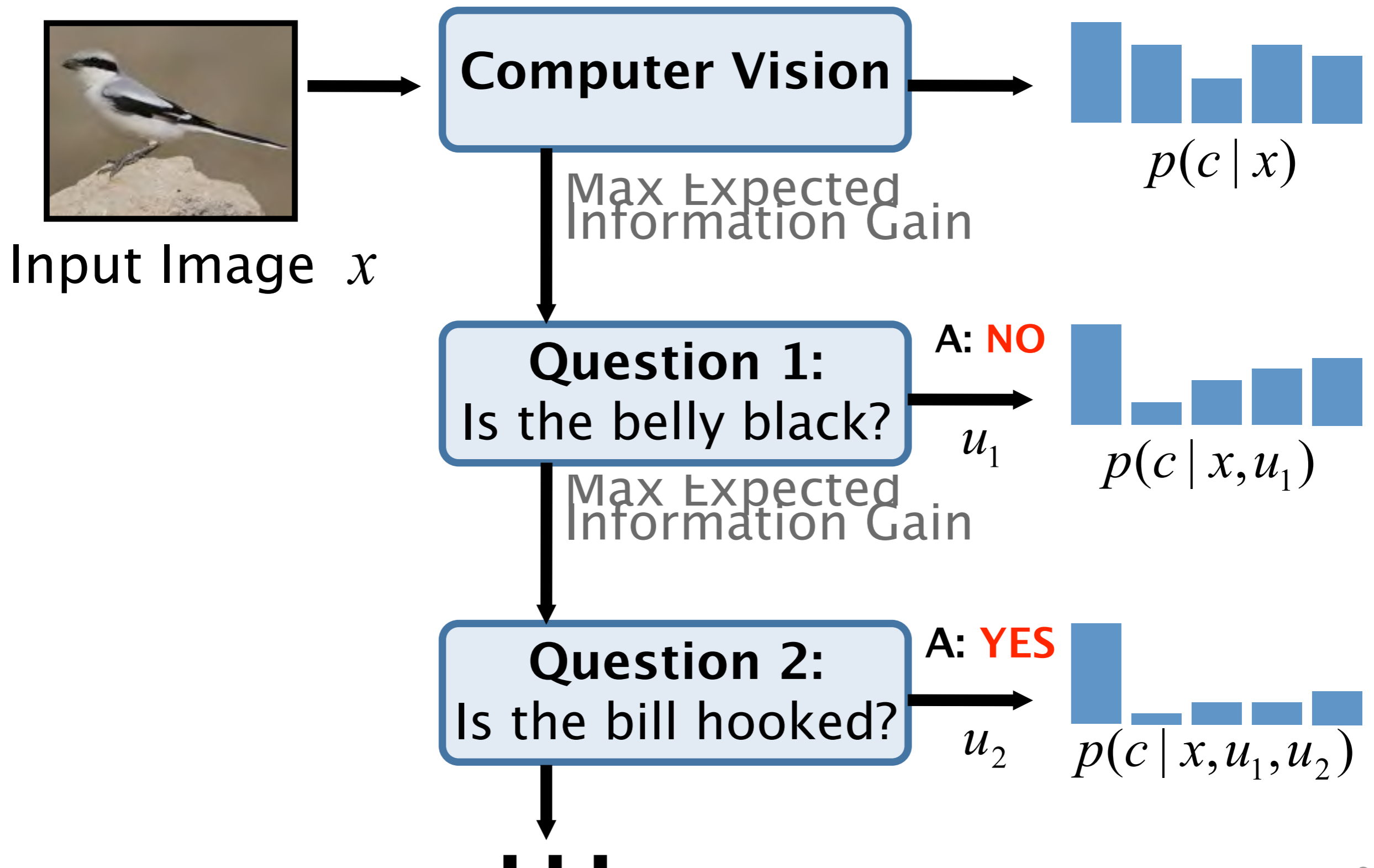


w/o Computer Vision

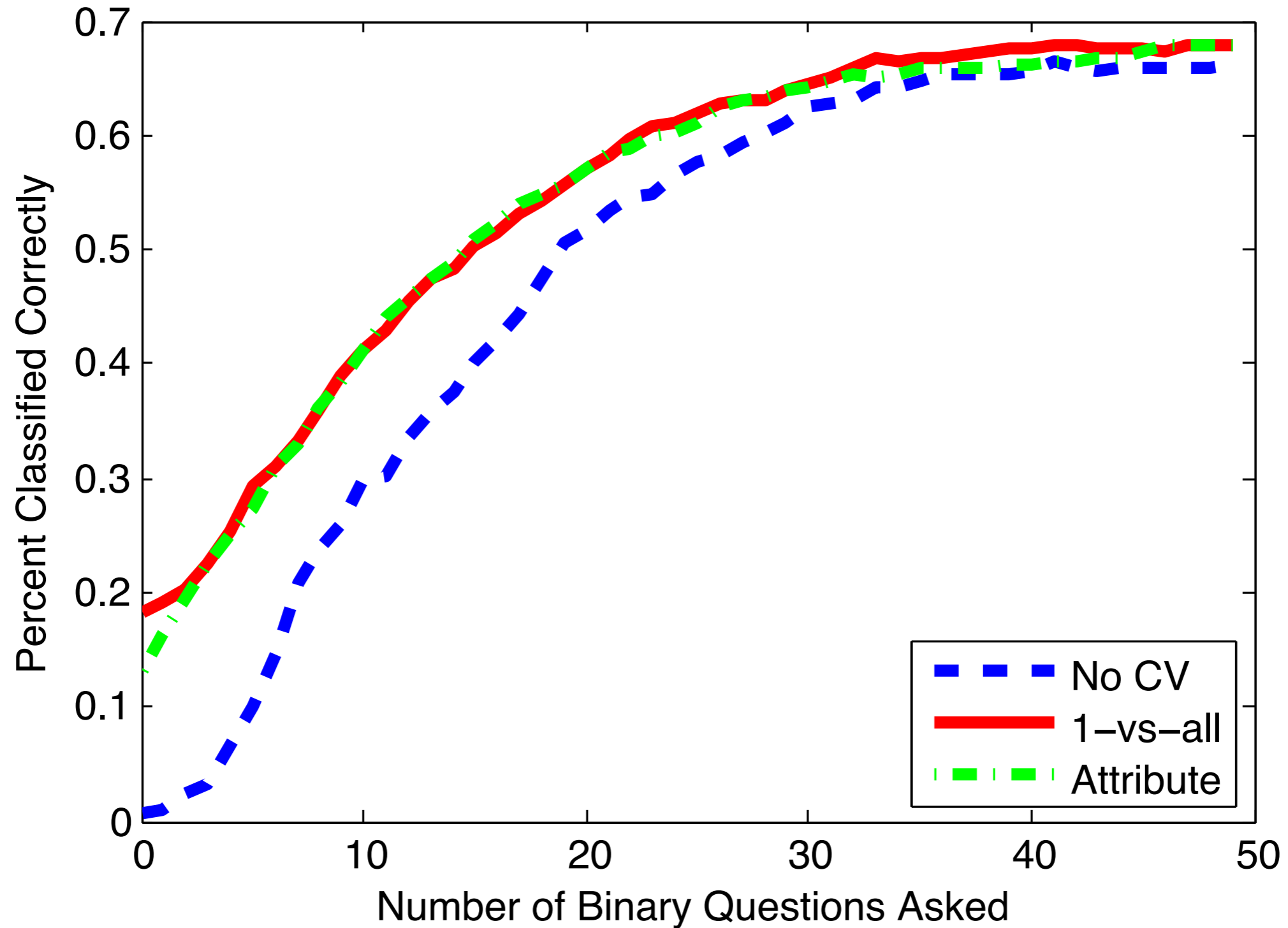


- User Responses are Stochastic

Basic Algorithm

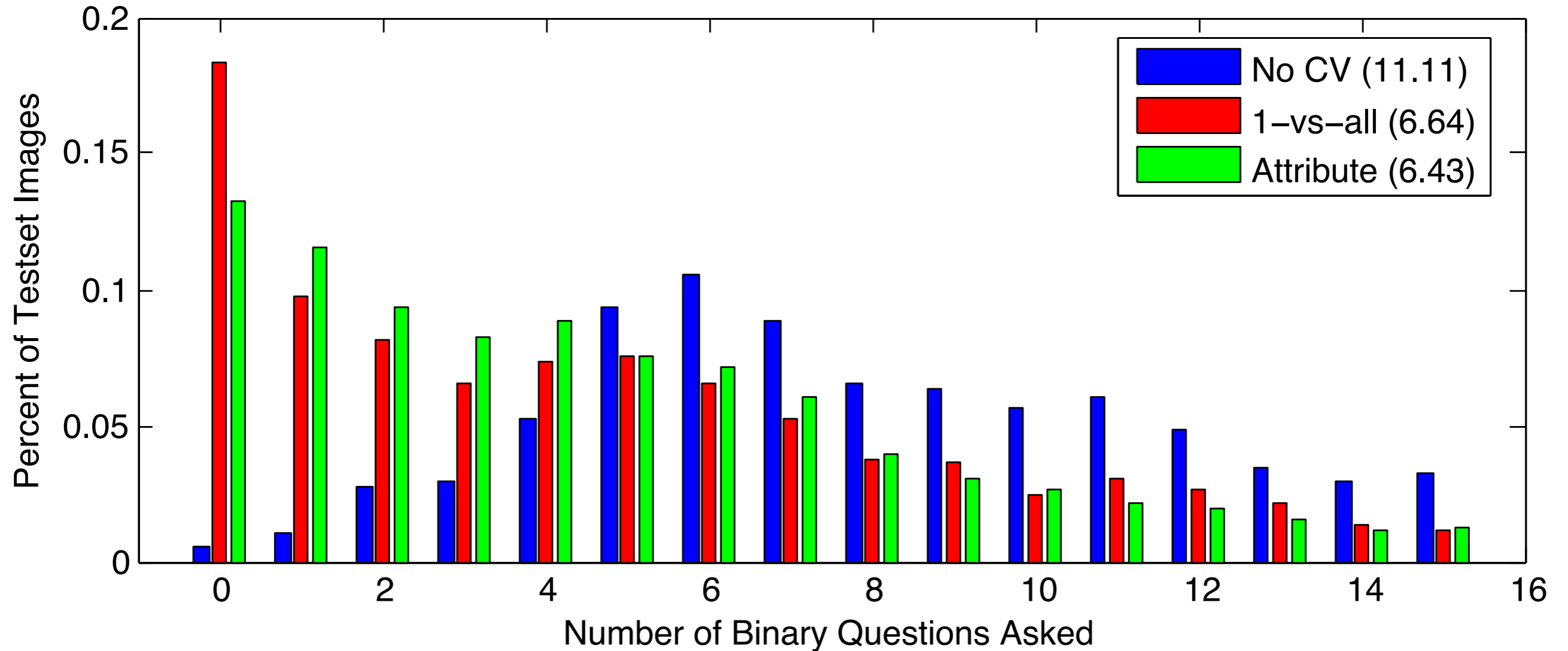


w/ Computer Vision

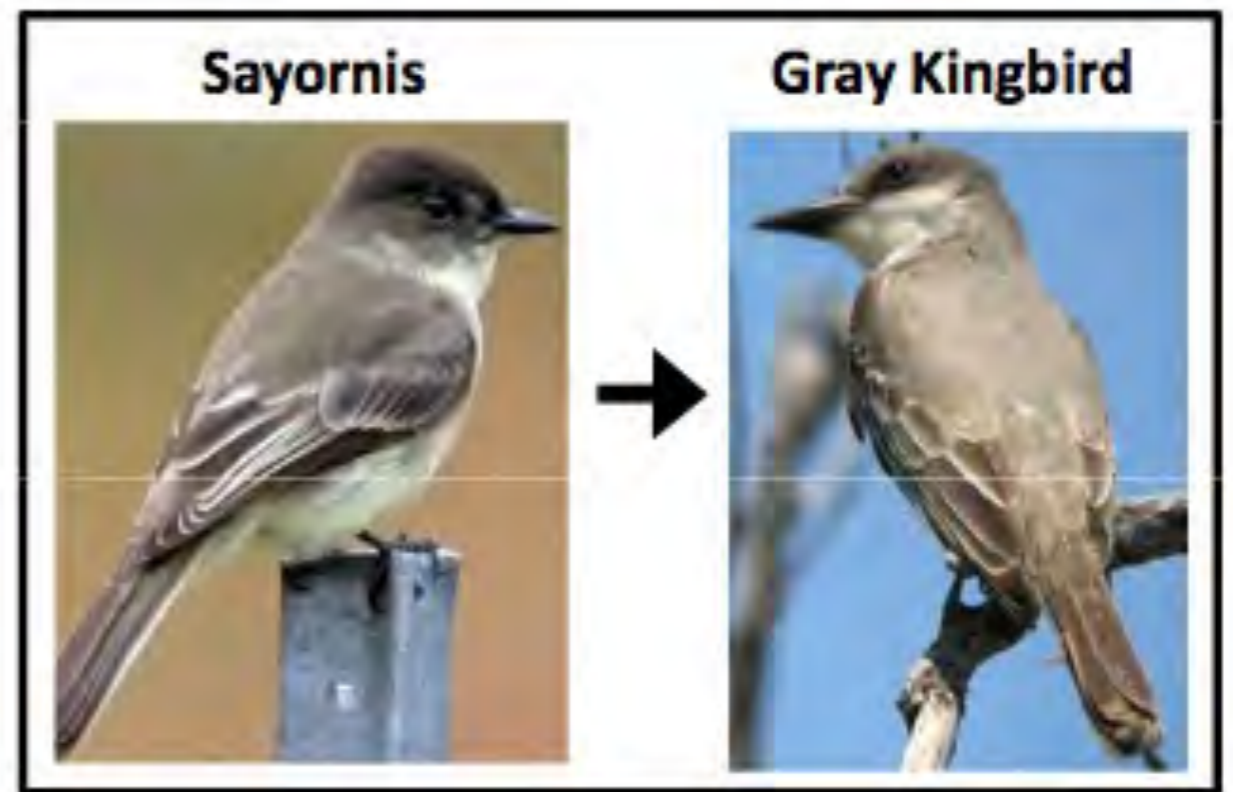
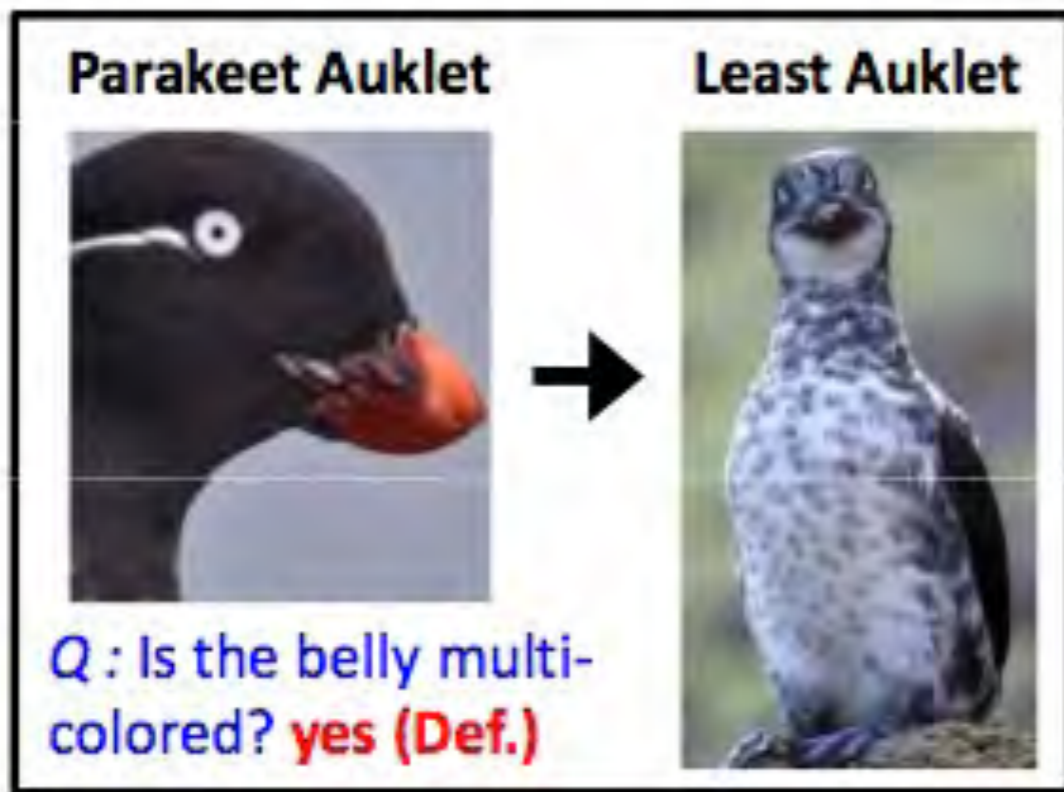


- Computer Vision Reduces Manual Labor

w/ Computer Vision (cont'd)



- User Responses Drive Up Performance



- Recognition is not Always Successful

Indigo Bunting



Blue Grosbeak



Field guides

- Humans & machines complementary
- Try with better user input

Conclusions

- Visipedia
- Obtaining knowledge from experts
- Humans annotating images
- Automating field guides

Collaborators

Caltech

- Pietro Perona
- Peter Welinder
- Takeshi Mita

UCSD

- Serge Belongie
- Steve Branson
- Catherine Wah
- Boris Babenko
- Florian Schroff

Papers, data etc:

<http://vision.caltech.edu/visipedia>