Corvids are really smart

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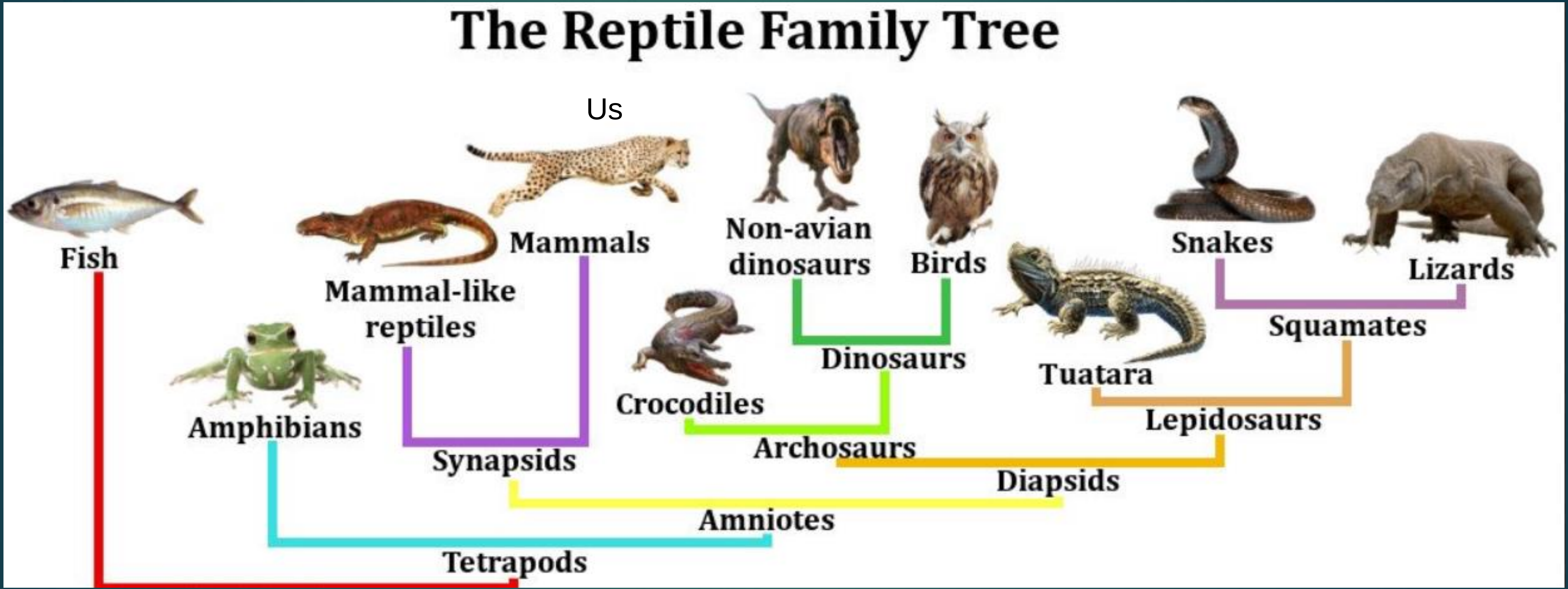
THANKS TO JOHN MARZLUFF,
KEVIN MCGOWAN

Charlie’s new interest in corvids

- I am not a regular bird watcher
- I count the geese at Stow Lake on our walks
- I keep an eye on 3 crows in our Glen Park neighborhood
- One night I got curious about how smart crows were
- This talk is result of my curiosity.
- It combines scientific studies and anecdotal information

Birds have been evolving for 320 M years:
Archaeopteryx: 150 Ma

Phylogeny: 320 Ma split between birds & humans



Birds

- Birds (Aves) are an extensively divergent animal group with highly specialized characteristics.
- Sustained powered flight is the most conspicuous feature of birds, and sociality.
- There are over 10,000 species of birds: highly successful adaptation during evolution.
- All modern birds are classified into Archosauromorpha, a group of amniotes (Tetrapods who lay eggs on land) that includes crocodiles and extinct dinosaurs
- The distinctive characteristics of avian brains are undoubtedly derived from ancestral bird-like dinosaurs
- Estimates: 200-400 billion birds = 55 per 1 person

Bird senses

- Vision: power at a distance, speed in resolving detail, broader spectrum of colors. Birds can see ultraviolet light.
- Can detect earth's magnetic field
- Sense of smell: Oil companies add sulfur smell to natural gas: find pipeline leaks as vultures circle above
- Hearing: detect wider range of sounds than humans
- Language: calls (used to transmit socially important info; danger, type of predator); birdsong (50% have it; related to breeding); claiming territory, warning off rivals, convincing girls to date; both innate and learned elements of birdsong; learned from father
- Nest building: innate and learned

Bird Capacities

- Migrations: 40% of 10 K bird species migrate between breeding and wintering areas. Arctic tern: 55,923 mi roundtrip. Some birds lose 50% of weight.
- Navigational maps: Capacity to find exact locations in migrations. Return to exact areas of birthing.
- In migrations, birds learn from older birds, use earth’s magnetic field, detect low-frequency sounds (made by the sea), and smell.
- 500 million are killed during every annual migrations.
- Spatial mapping: Hummingbirds keep track of which flowers in vast area they have already drained of nectar. Corvids and seed caching.

Intelligent animals

- Humans
- Bottlenose Dolphins
- Chimpanzees
- Orangutans
- Racoons
- Border Collies
- African Grey Parrots
- Crows/Ravens
- Pigs
- Rats
- Elephants

What constitutes intelligence:

Adaptable
Curiosity
Good attention
Good problem solving (fluid IQ)
Good knowledge (crystalized IQ)
Good working memory (temporary)
Good memory (permanent)
Generalists
Good self control
Passion and perseverance

Avian insults are insults of your intelligence

- Silly as a goose
- Dumb as a Dodo
- You are a birdbrain

But some birds exhibit innovate behaviors

- Ravens (*Corvus corax*) drop nuts on roads for passing cars to crack
- Barbados bullfinches (*Loxigilla barbadensis*) taking and pecking open sugar packets from restaurants.
- Rufous treepies (*Dendrocitta vagabunda*) stealing burning candles from a Hindu temple, only to extinguish the flames and eating the cotton-and-butter wick.

Avian TV dinner: Bullfinch stealing sugar packets

SWEET IDEA: A bullfinch (*Loxigilla barbadensis*) makes off with a sugar packet from a restaurant in Barbados.
LOUIS LEFEBVRE

Birds exhibit innovate behaviors

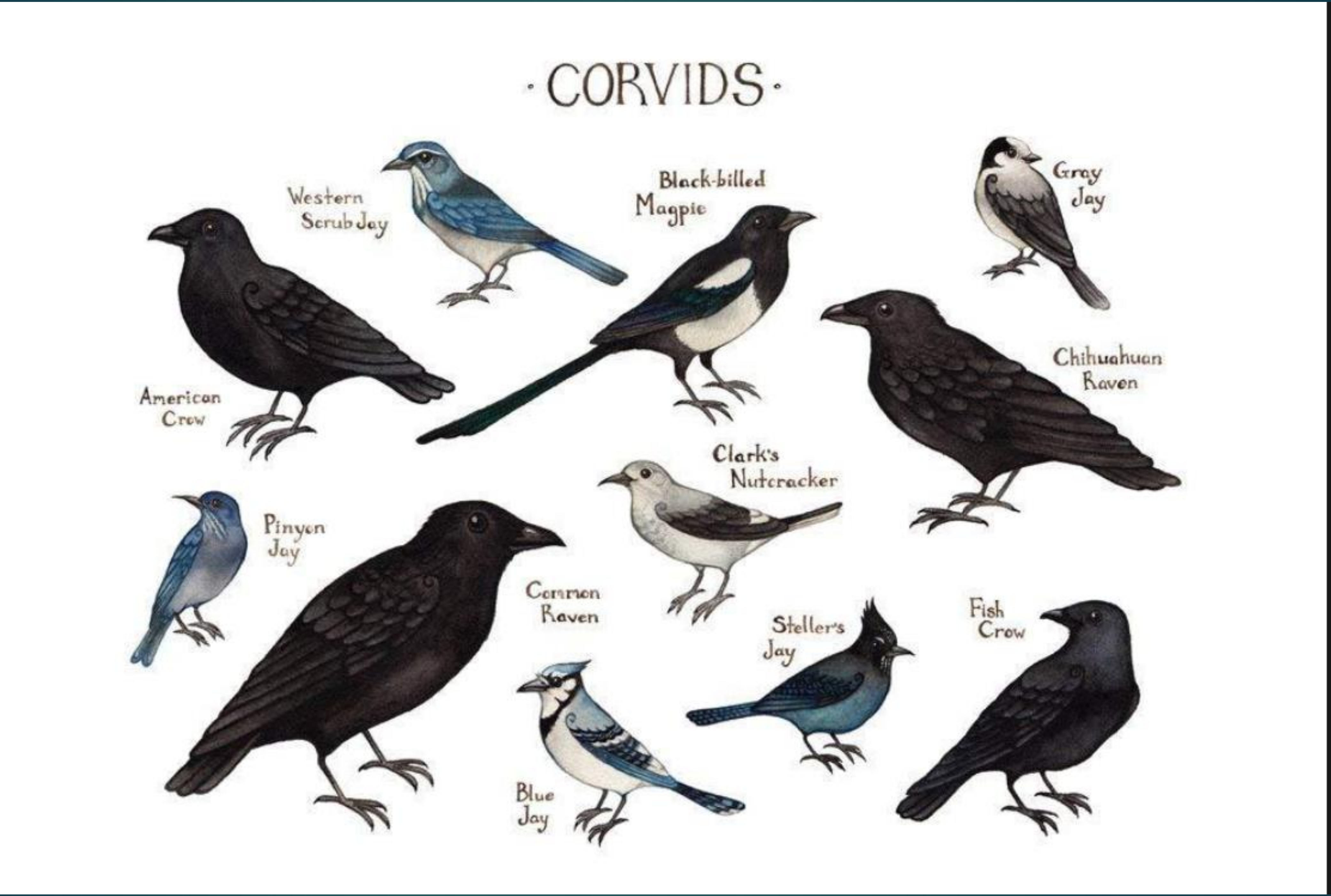
- Great cormorants (*Phalacrocorax carbo*) in New Zealand following ferries to catch fish disturbed by the boats' wake.
- Carib grackles (*Quiscalus lugubris*) stealing dry cat food left on porches and softening it by dipping the pellets in water puddles.
- Crows: will use urban landfills for food; known to learn zoo animal feeding schedules and garbage collection schedules

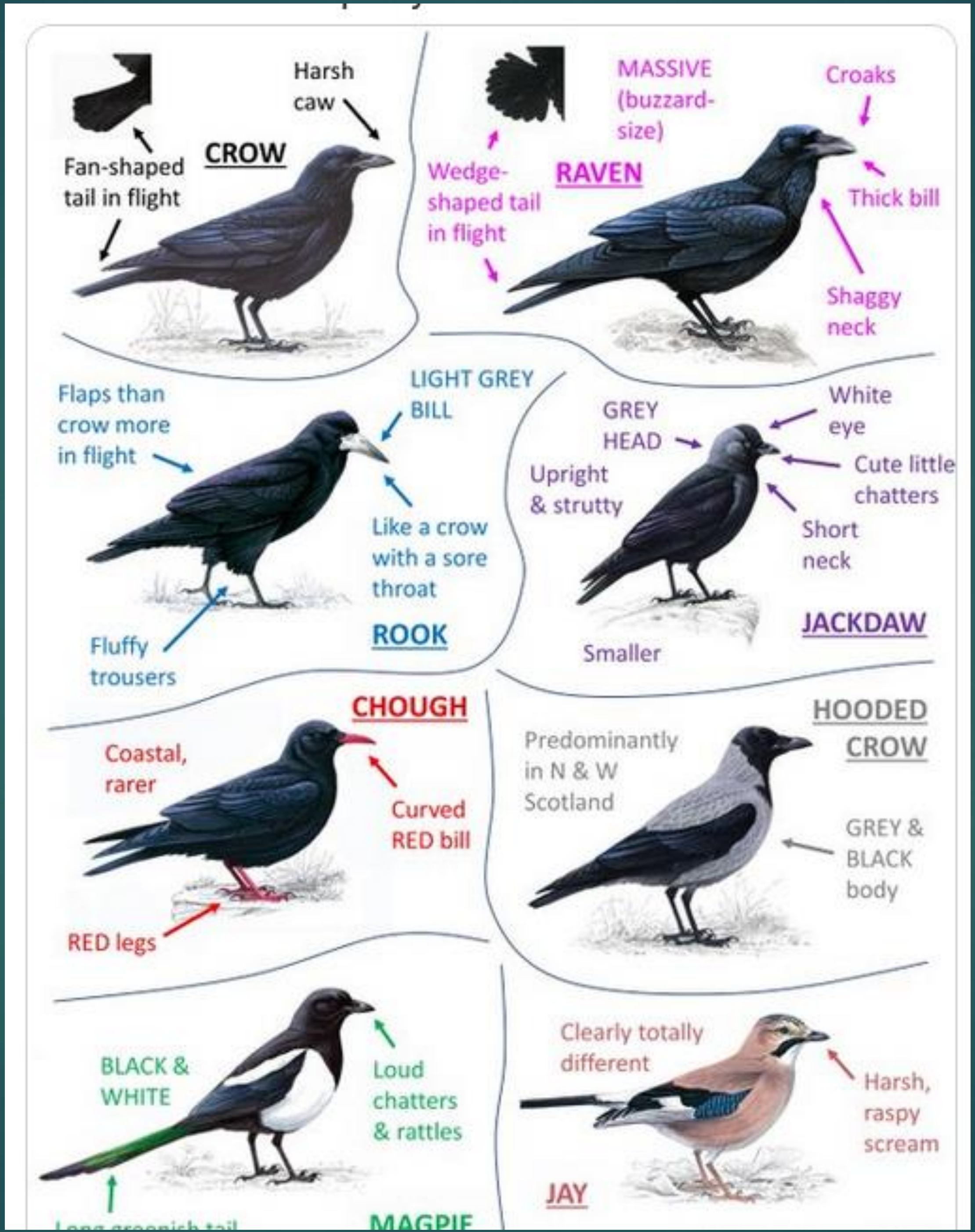
Scientists have been studying just how smart birds are

Birds of a Feather Quilt

A favorite of quilters

And of pumpkin carvers: Association with Halloween


· CORVIDS ·
Western
Scrub Jay
Black-billed
Magpie
Gray
Jay
American
Crow
Chihuahuan
Raven
Clark's
Nutcracker
Pinyon
Jay
Common
Raven
Steller's
Jay
Fish
Crow
Blue
Jay


CROW
Harsh caw
Fan-shaped tail in flight
RAVEN
MASSIVE (buzzard-size)
Croaks
Thick bill
Wedge-shaped tail in flight
Shaggy neck
ROOK
Flaps than crow more in flight
LIGHT GREY BILL
Like a crow with a sore throat
Fluffy trousers
JACKDAW
GREY HEAD
White eye
Cute little chatters
Upright & strutty
Short neck
Smaller
CHOUGH
Coastal, rarer
Curved RED bill
RED legs
HOODED CROW
Predominantly in N & W Scotland
GREY & BLACK body
BLACK & WHITE
Loud chatters & rattles
MAGPIE
JAY
Clearly totally different
Harsh, raspy scream

Corvids: Crows, Ravens, Magpies, Jays

127 species
worldwide;
4 species
In USA

Corvids originated in the Australo-Papuan region around 14 M years ago in rainforest habitats

California Scrub Jay

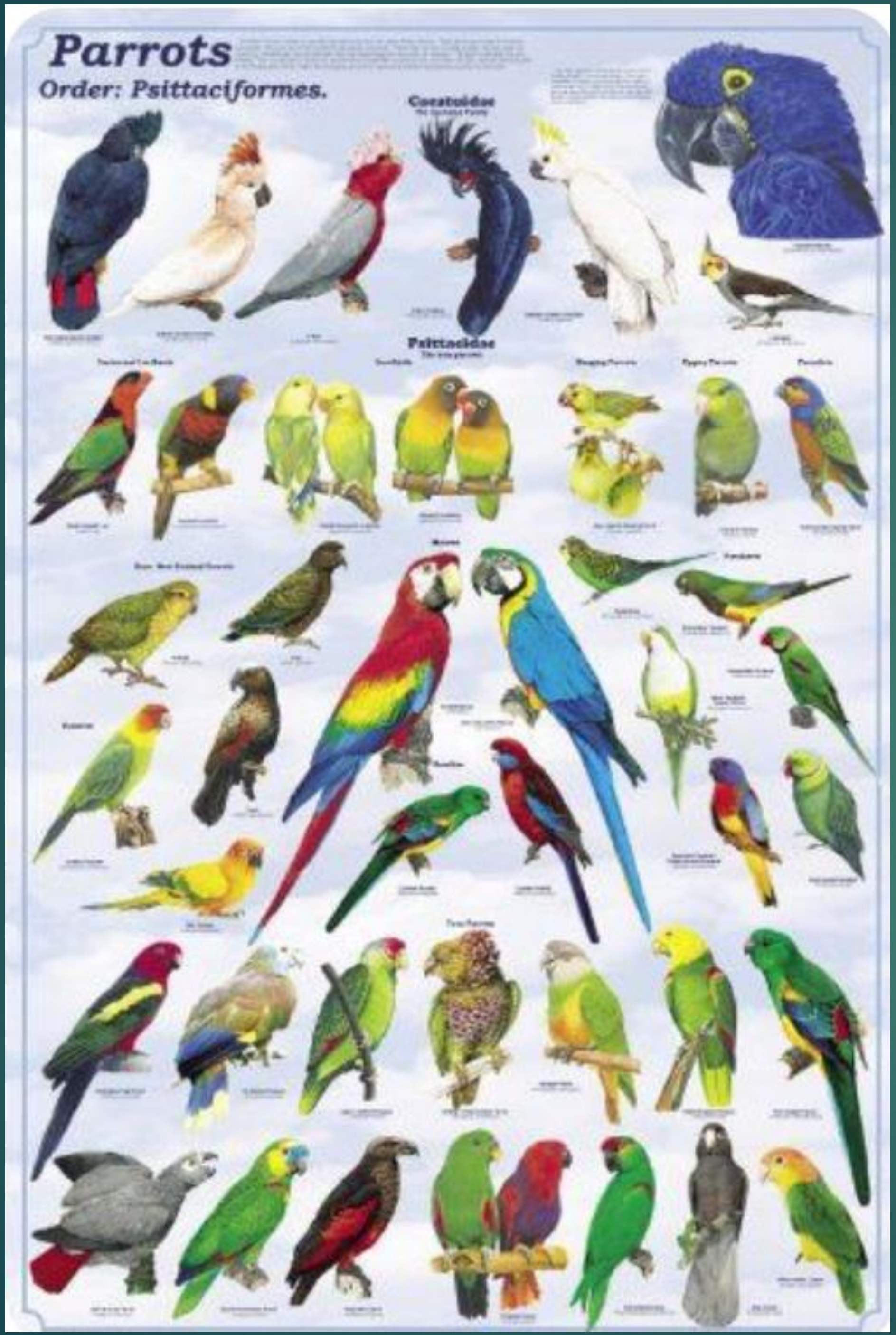
Common Green-Magpie in Thailand

Magpies

Magpies


LOOKOUT!
MAGPIE
SWOOPING ZONE
• Avoid this area if possible during Magpie season.
• Bicycle riders dismount.
• Protect your face, eyes and head.
NATIONAL PARKS & WILDLIFE SERVICE
N.S.W

402 species of Parrots



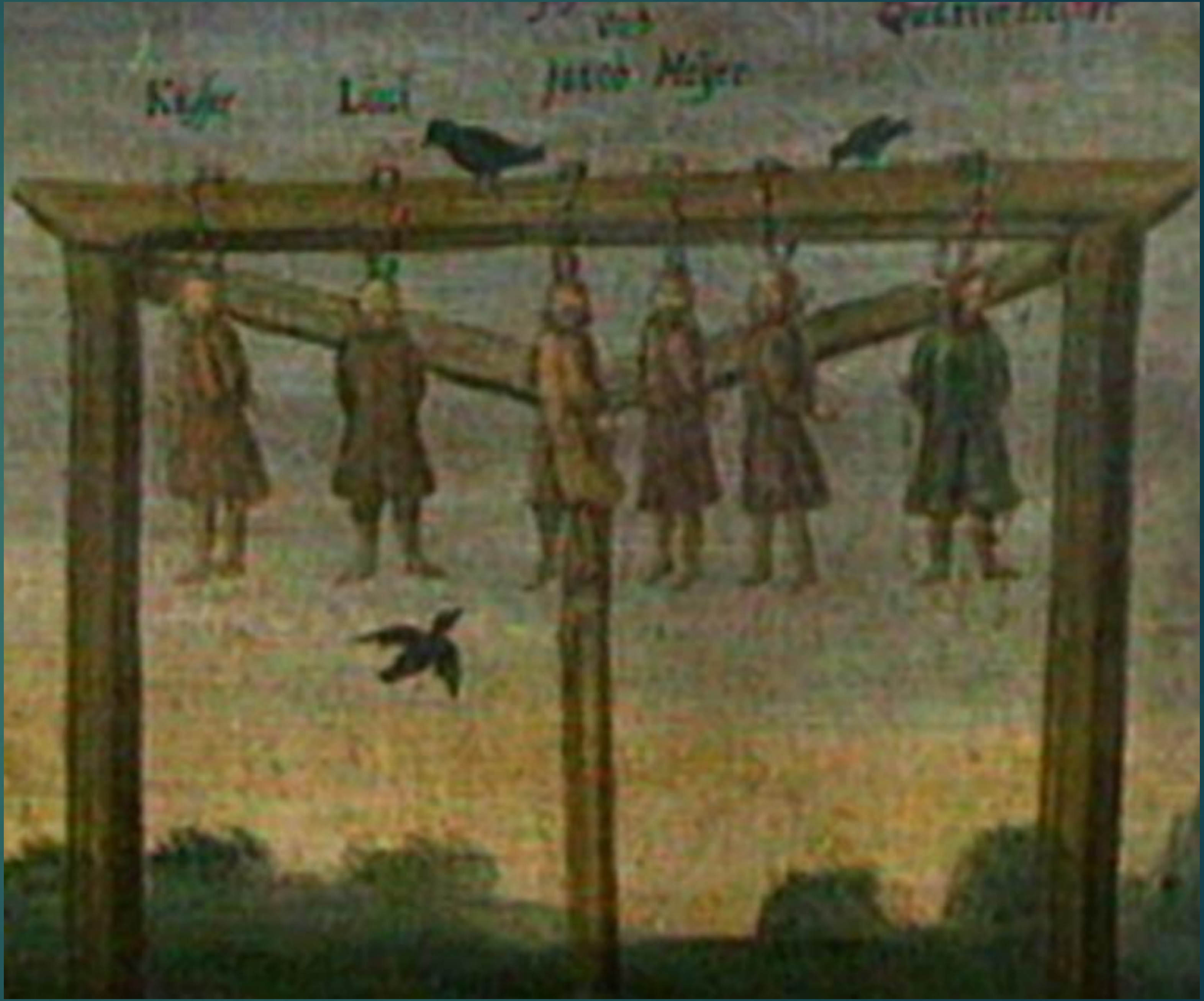
Murder of Crows

Crow as the Demon Bird

Long history of fear and loathing: negative views toward crows:

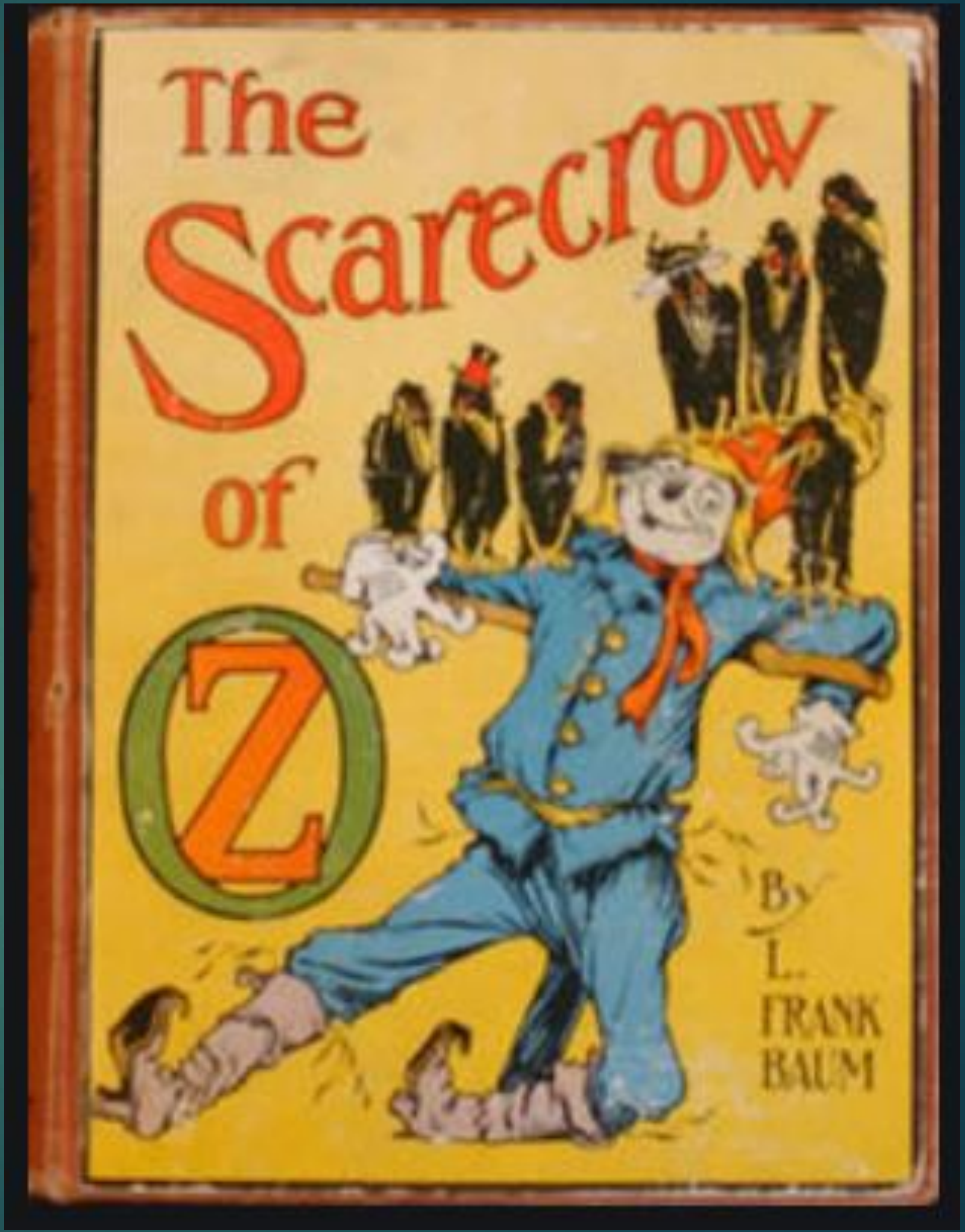
- Black color
- Cunning
- From Middle Ages, bird of death in league with Devil; associated with plague
- Harbinger of death
- Group = “murder” of crows; 31 million crows in US
- Omnivore. Eat carrion. Fight with predators over dead animals.
- Evil despoilers of corn crops. Attack livestock, viciously and ingeniously. Farmers usually hate them.
- Magpies prey on young songbirds (but snakes & chipmunks are real scourge of these birds),
- Brazen tormentors of the poor scarecrow in the *Wizard of Oz*.

Negative reputation



Historical imagery

Scarecrows in corn fields



Evil Crows

- Show up at gallows and battlefields; pluck out eyes of dead humans
- Koran: Allah sent a crow to show Cain how to bury body of his brother Abel
- Then Hitchcock's *The Birds* film confirmed their reputations
- "Eating crow" is humiliating

- But Norse God Odin liked his 2 ravens, Huginn (means "thought") and Muninn ("memory"): referencing their smartness

Crow history

- It doesn't help that a group of crows is called a "murder," that they are viewed by some as harbingers of death, or that the birds are clever enough to steal trinkets and food.
- In February 1533, the parliament of Henry VIII passed an act allowing the destruction of choughs, rooks and crows. Previously, the birds had been protected under the law because of the "janitorial services they performed on city streets".
- Recently: The rooks at the Puy du Fou theme park in the west of France have been taught to collect cigarette ends and other small bits of rubbish.
- Hired as garbage collectors. They then deposit the litter into a small box which will deliver some bird food as a reward for their hard work.

Charles Dickens consults his pet raven Grip. Now stuffed in PA Museum

Bird hangings after new law forbidding killing of English corvids

Crow hunting

A crow’s life

- There is usually only one breeding monogamous pair, but other individuals will help build the nest, feed sitting hens, and defend the territory.
- Crows are permanently territorial (but forage & roost off territory), with one family staking out an area of 20 acres or more.
- There are often several generations of crows in a territory, forming a clan. These birds’ complex societies include dozens of large interrelated families, with dominance hierarchies and ruling lineages.
- Chick survival rate: 50%
- In the morning and late afternoon, crows hunt their territory vigorously; at midday they feed more casually with plenty of breaks for socializing.

Crows: Omnivores

- The omnivorous crow will eat corn, road-killed opossum, baby mice, earthworms, seeds, beetles, slugs, sumac fruits, nestling birds, frogs, fish, grasshoppers, dead deer, or old French fries. Whatever is available is fine; they are not finicky.

- They like easily visible seeds, such as corn, a fact that has led farmers to slaughter them ruthlessly.

- Unlimited crow hunting is legal in practically any agricultural state. Dec 5 - April 7 in California. That's too bad, because although crows do eat some seed, they make up for it by eating significant numbers of caterpillars and other pests.

Swiss Alpine Choughs (~couff) like French fries

Crows know how to eat poisonous toads: catch, flip them on their backs, and eat organs thru abdomen; dogs don’t know how to do this

In Tasmania, forest ravens eat more than roadkill.

These innovative foragers quickly have learned to check the pouches of killed marsupials just in case a baby is inside.

Here a forest raven robs the pouch of a Tasmanian devil.

Family Life

- Crows are cooperative breeders; young crows often stay with family for many years (i.e. like millennials not leaving home); make themselves useful; feed and care for chicks; forage together; guard each other; have fun together
- Females start breeding at 2-4 yrs; Males, 4-6 yes
- Females die younger because of nest predation
- Females frequently replace breeding females who have died
- 7% of males are with their father & a stepmom; 10% of males had different father; 4% have sex with mom

Roosting

- For their roosts, crows choose tall, mature trees but not dense forest—they seem to prefer a commanding view of the area.
- But the biggest reason we notice crows at this time of year is their distinct *kaw-kaw* call.
- During spring and summer, crows have many calls, including clicks, whistles, coos and even a sort of sigh. But as fall approaches they begin to use the *kaw* almost exclusively. No one knows why; it may have something to do with socializing young birds for the roost.

Anne B. Clark, Binghamton University and Kevin McGowan, Cornell Lab of Ornithology

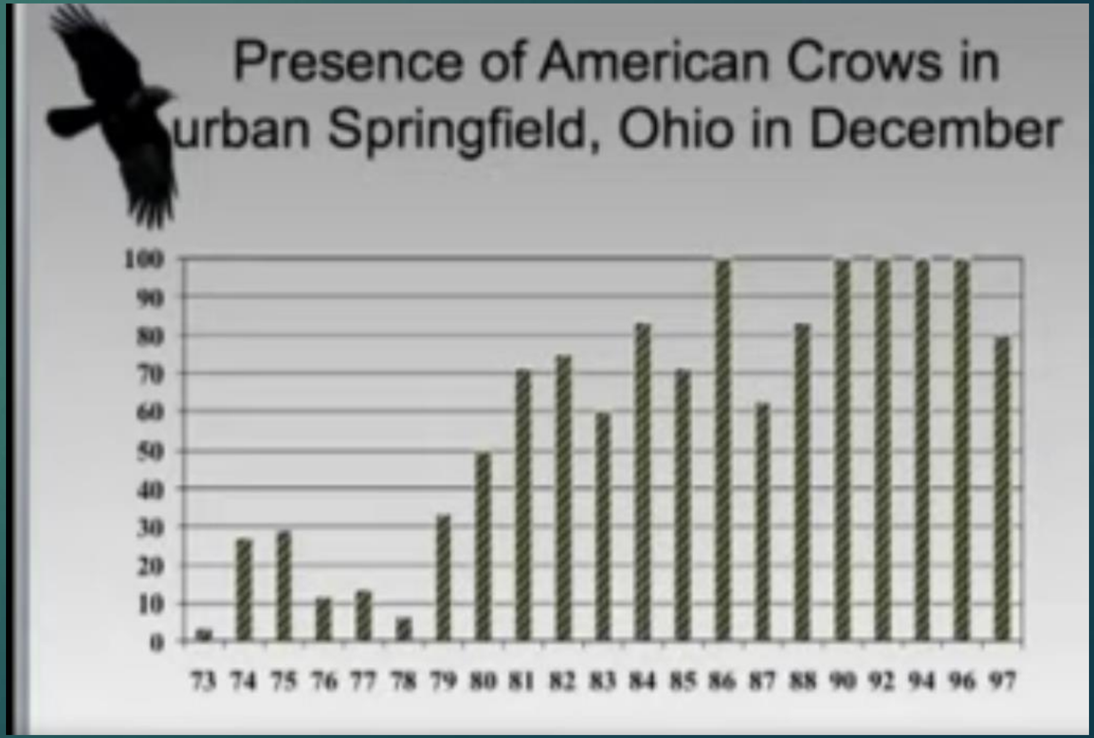
- Crows develop keen memories of people who touch their nests.
- “Crows are very observant birds," adds Kevin McGowan.
- One irony is that whereas "crows can recognize people as individuals, we still see crows as just crows."
- Crows have facial recognition, car recognition, know our routines; have memory for past; can predict our future behavior; plan ahead
- Know us as individuals and base like/dislike on our behavior toward them
- Capable of cultural transmission of information

Convergence: Generalists

- Both humans and corvids became “generalist species” that are not bound to a narrow ecosystem but survive nearly everywhere.
- High cognitive capacities were needed to quickly find solutions to novel problems and to outsmart competitors.
- Thus, the strong selection pressure in both vertebrate classes produced very sophisticated cognitive abilities.
- Corvids are “Feathered apes” in cognitive capability

Urbanization: crows are generalists

- Lots in urban settings
- Eat anything; like meat, but hard to get; fruits, nuts, seeds, insects
- Human food sources
- Cities are safer: No hunting in the city
- Few predators
- Lawns are great for earthworms
- Garbage cans



Crows are increasingly Urban

Possible reasons:

- A prohibition on the discharge of firearms within city/village limits.
- Cities are warmer than rural areas.
- Fewer Great Horned Owls (*Bubo virginianus*) in urban areas. Next to people with guns, Great Horned Owls pose the largest danger to an adult crow.
- Artificial light assist crows in watching for owls.

Nest made almost entirely of metal clothes hangers

Your neighborhood crows

- **The crows in your neighborhood** know your block better than you do. They know the garbage truck schedules and routes.
- They know which kids drop animal crackers and which ones throw rocks.
- They know the pet dogs, and they might even play with the friendly ones.
- If you feed them, they probably will not only recognize you, but also your car as well, and they might just leave you trinkets in return.

Your neighborhood crows

- These birds live their lives intertwined with ours, carefully observing us even as most of us barely take note of them.
- That’s how they survive, and they’re good at it: In recent decades the American Crow has taken over our suburbs, and even moved into the hearts of our big cities.
- As we’ve reshaped the landscape, we’ve created an ideal environment for an animal that is canny and perceptive enough to exploit our riches

Corvids are also very smart

- Ravens & Crows are avian dinosaurs that shared an ancestor with mammals around 320 million years ago.

- Corvids are some of the most intelligent animals in the world.

- Birds are smart. They use tools, engage in social learning, plan for the future, and do a variety of other things that were once thought to be exclusively the stuff of primates.

Michelle Starr, 30 AUG 2019

Human-crow interactions

- Bring presents to specific people
- Like to play: 1 crow used a twig as a fencing sword vs another crow
- Known to drop rocks on people
- Ravens opening beer cans by puncturing them with bill and drinking it
- Turning lights on in Alaska to warm their feet near lights
- Steal food: brought back the plastic packaging after stealing golfer’s sandwich
- As corn has been planted further north, corvids have also migrated north

Cause of bird fatalities

- Habitat destruction
- Window strikes: 97 to 976 million birds/year
- Feral cats: 500 M
- Raptors, esp. owls

Protected species

- *Are crows protected/Is it legal to kill or hunt crows?*
- As of 1972, crows are protected under the migratory bird act.
- This means that it is illegal to "take (gov speak for kill), possess, import, export, transport, sell, purchase, barter, or offer for sale…the parts, nests, or eggs…except under the terms of a valid permit issued pursuant to Federal regulations."
- But all US states allow hunting. States regulate hunting of crows.
- Can not keep a crow you find.

Who is the cleverest of them all?

Among the smartest birds

Corvids

Psittachines

Crow smarts

- A crow's brain is only about the size of a human thumb, so how smart could they be?
- Except for size, a crow's brain and a primate brain are neurally comparable.
- Professor John Marzluff at the University of Washington's Aviation Conservation Lab, in terms of intelligence, a crow is essentially a flying monkey.
- The corvids and psittacines (parrots, macaws, and cockatoos; 402 species) are often considered the most intelligent birds, and among the most intelligent animals in general.

Bird cognitive capacities

- New Caledonian crows make tools out of leaves or novel human-made materials, use them to retrieve food, & are thought to pass this knowledge on to other crows through social learning.
- Scrub Jays show episodic memory - the ability to recall events that take place at a specific time or place
- Owls have a highly sophisticated capacity for sound localization, used for nocturnal hunting, that is developed through learning
- Parrots, hummingbirds, and songbirds possess the rare skill of vocal learning
- Parrots can learn human words and use them to communicate reciprocally with humans
- African grey parrots can use human words in numerical and relational concepts

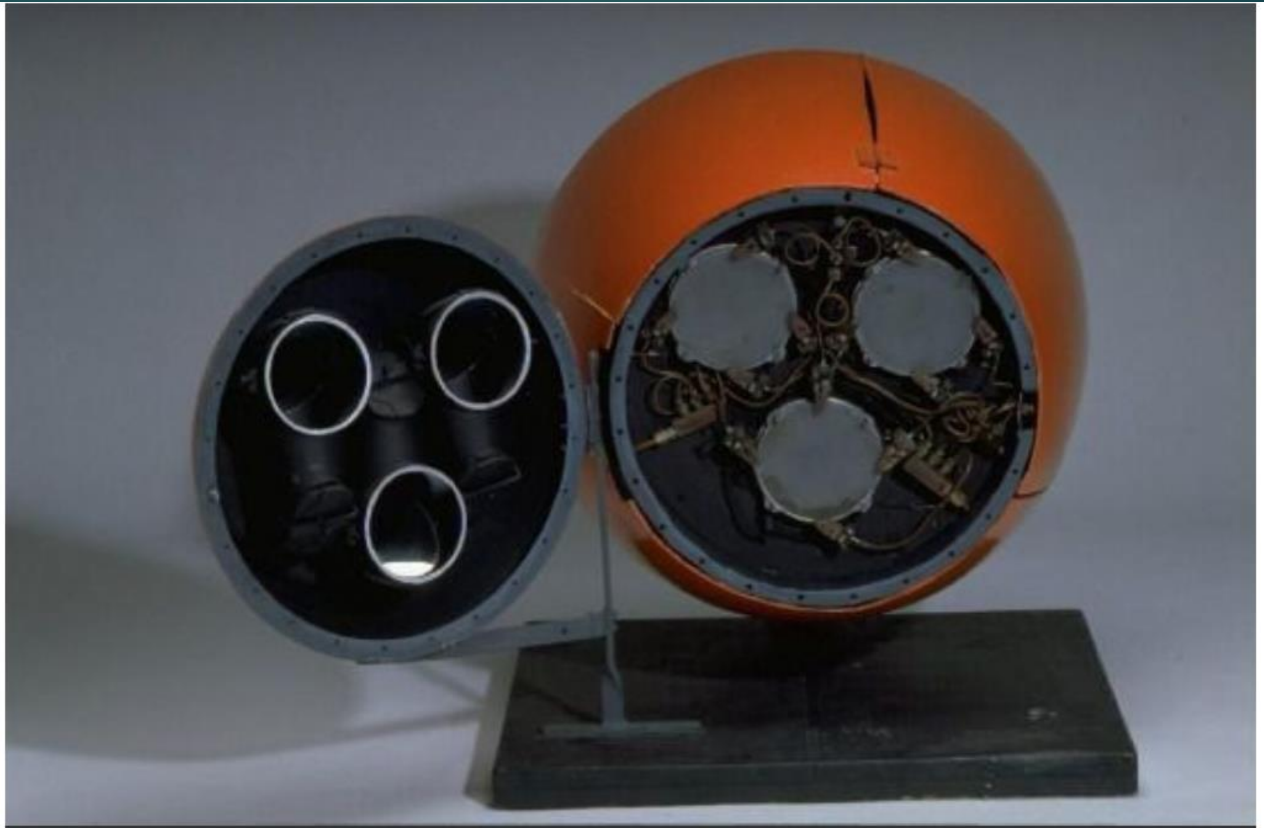
Jarvis et al. (2005):

Cognitive abilities in birds

- Pigeons can memorize up to 725 different visual patterns, learn to categorize objects as 'human-made' vs. 'natural', differentiate Monet vs Picasso paintings; Pigeons have impressive memories, with an uncanny ability to distinguish human faces and expressions, letters of the alphabet, landscape features
- Japanese tits, small East Asian songbirds, use their high-pitched *pi-pi* alarm calls to alert their fellows to predators, and have a kind of grammar, with syntactical rules for combining the *pi* notes with *dee-dee-dee* notes to summon the flock to drive off a predator.
- Green-rumped parrotlets in South America have calls that function as names. Parent parrotlets apparently assign the names to their chicks for life, much the way human parents give names to their children.

Pigeons' discrimination of paintings by Monet and Picasso

- Pigeons were trained to differentiate a set of paintings by Monet vs Picasso. On other paintings by them, pigeons had a differentiating accuracy rate of 90+%



Nose Cone from B.F. Skinner's Pigeon-Guided Missile, on display in

Project Pigeon by B. F. Skinner using operant conditioning, 1943: three small electronic screens and three tiny pigeon cockpits of glider bombs. Onto the screens was projected an image of the ground in front of the rocket. As the pigeons pecked, cables harnessed to each one’s head would mechanically steer the missile until it finally reached its mark. Project was canceled but 7 years later pigeons could still hit the mark.

Black Kites at bushfire in Queensland, Australia

Figure 1. Black Kites at bushfire in Queensland. Photo by Dick Eussen.

Intentional Fire-Spreading by "Firehawk" Raptors in Northern Australia

- Perhaps the most amazing use of a tool for catching prey comes from Australia. In stories and traditional ceremonies, Aboriginal Australians in the northern part of the country have long referred to birds carrying fire. Recently, ornithologists documented birds of prey use smoldering branches to spread fires and scare prey from safe cover.
- Observations of intentional firespreading by the fire-foraging raptors. Black Kites, Whistling Kites, and Brown Falcons are known to hunt small prey at the edges of brush fires. Black Kites and sometimes Brown Falcons will pick up a firebrand or a stick not much bigger than your finger and carry it away to an unburnt area of grass and drop it in there to start a new fire .
- Observers report both solo and cooperative attempts, often successful, to spread wildfires intentionally via single-occasion or repeated transport of burning sticks in talons or beaks. This behavior, often represented in sacred Aboriginal ceremonies, is widely known to local people in the Northern Territory, Aboriginals have historically used the same technique to sustain biodiversity.

Mark Bonta, et al., 2017

Feathered apes

Have favorite coffee:
In Juneau, Alaska, urban ravens known to drink coffee out of stolen cups

A raven in Alaska sips the dregs of a cup of *Raven's Brew* coffee.

Sociality and evolution of larger brain

- Social brain hypothesis: cognitive demands of sociality have driven the evolution of substantially enlarged brains in primates.
- American crows have complex social lives that might shape their evolution: They mate for life; have extended families; communicate in complex vocalizations; and travel, forage, and roost in large social groups. Social hierarchies and social deception capacity.
- If similar social pressures drove both avian and primate intelligence, it would be a stunning example of convergent evolution.
- If there is a food fight, once a bird brings a minimum of nine allies, the territorial pair backs down from a large mammal carcass
- In mammals, it is the mother-infant bond, but in birds it is the partner relationship, the pair-bond. It is a bond that develops through learning.

Avian Brains

- Birds have large brains relative to body size compared to other vertebrates, such as reptiles, and birds also exhibit complex behaviors and sophisticated cognitive abilities.
- The increased volume of avian brains is largely due to the enlarged cerebellum and midbrain, which correlate with exceptional motor control abilities and visual perception.
- In addition, modern birds have a large cerebrum (telencephalon) or pallium, which includes nidopallium (cortex), hippocampus, amygdala, & olfactory bulb.

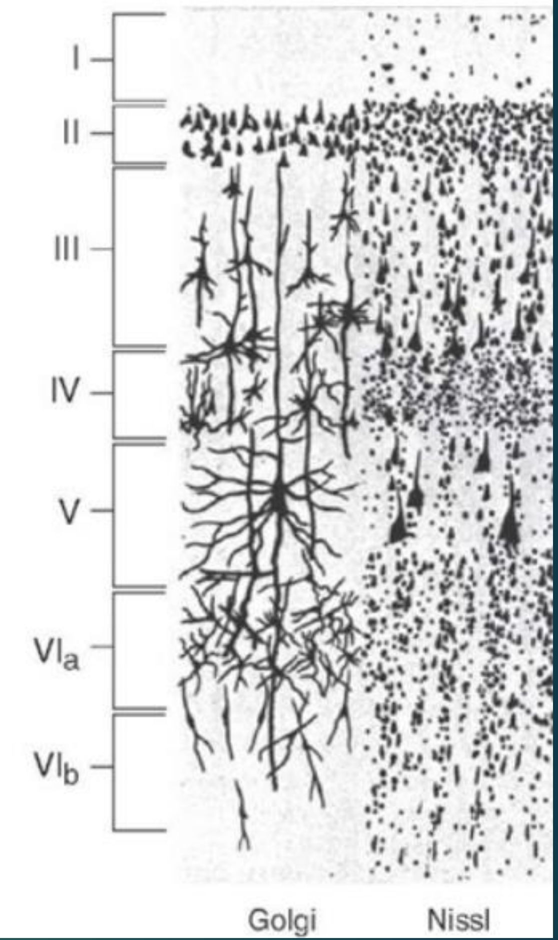
“Birdbrain”

- The term “birdbrain” used to be derogatory.

- For centuries, “bird cognition” was an oxymoron and term “bird-brained” was shorthand for stupid.

- Part of the cause for derision is that the pallium of the bird brain lacks the obvious layering that earned the mammalian pallium its “cerebral cortex” label.

- Because their neurons are smaller, the pallium of songbirds and parrots actually comprises many more information-processing neuronal units than the equivalent-sized mammalian cortices



The debate

- On one side are researchers who consider bird’s stereotypical and instinctual behaviors as evidence of mental inflexibility.
- On the other are those who suspect that animals have more complex thought processes, but who struggle to prove it.
- 2004: an international team of neurobiologists and ornithologists reported that the brains of birds have structures, including an advanced forebrain, that are analogous with those of mammals.
- Comparative cognition researchers had demonstrated that some birds—especially parrots, crows, and jays— behaved in ways that suggest sophisticated cognitive skills

Instinctually, birds imprint on parent at birth;
but who they imprint to is learned

Flocking: Cause still unknown, but every bird copied its direction only from its closest 6 or 7 neighbors

History of Parrot cognition studies: Who’s a clever bird?

- Birds were historically considered as inflexible, stereotyped automata governed by genetically determined behavioral routines, when it was assumed that complex cognitive abilities required a large, primate-like brain as well as a mammalian neocortex
- Parrots are renowned for their intelligence and ability to imitate human speech ever since they have been kept as pets.
- They often parallel primates if not great apes in cognitive ability.
- The ability of parrots to imitate speech was recorded as early as 500 BC when the Greek physician Ctesias, travelled to India; parrots there spoke both Indian and Greek.
- Roman philosopher Pliny who noted in his Natural History Records that his ring-necked parakeet could say ‘Hail Ceasar’ and was particularly ‘merry in vino’ .

Alice M.I. Auersperg & Auguste von Bayern, 2019

Parrots & corvids can count

- Birds can Count: Research in the 1920-1930s Otto Köhler: numerical assessment - established the respective species' limit at differentiating quantities.
- The upper numeric limit they found for pigeons was 5, for jackdaws and parakeets 6, for magpies, ravens and amazon parrots 7 and for an African grey parrot 8.
- Acceptance of the pallium as a cortex-equivalent region in birds was only achieved in the early 2000s.
- The number of pallial neurons is also almost twice as densely packed per square inch as that of mammals with similar brain sizes and that in parrots and corvids, the neuron numbers essentially resemble those of higher primates

Alex, the very smart Grey Parrot

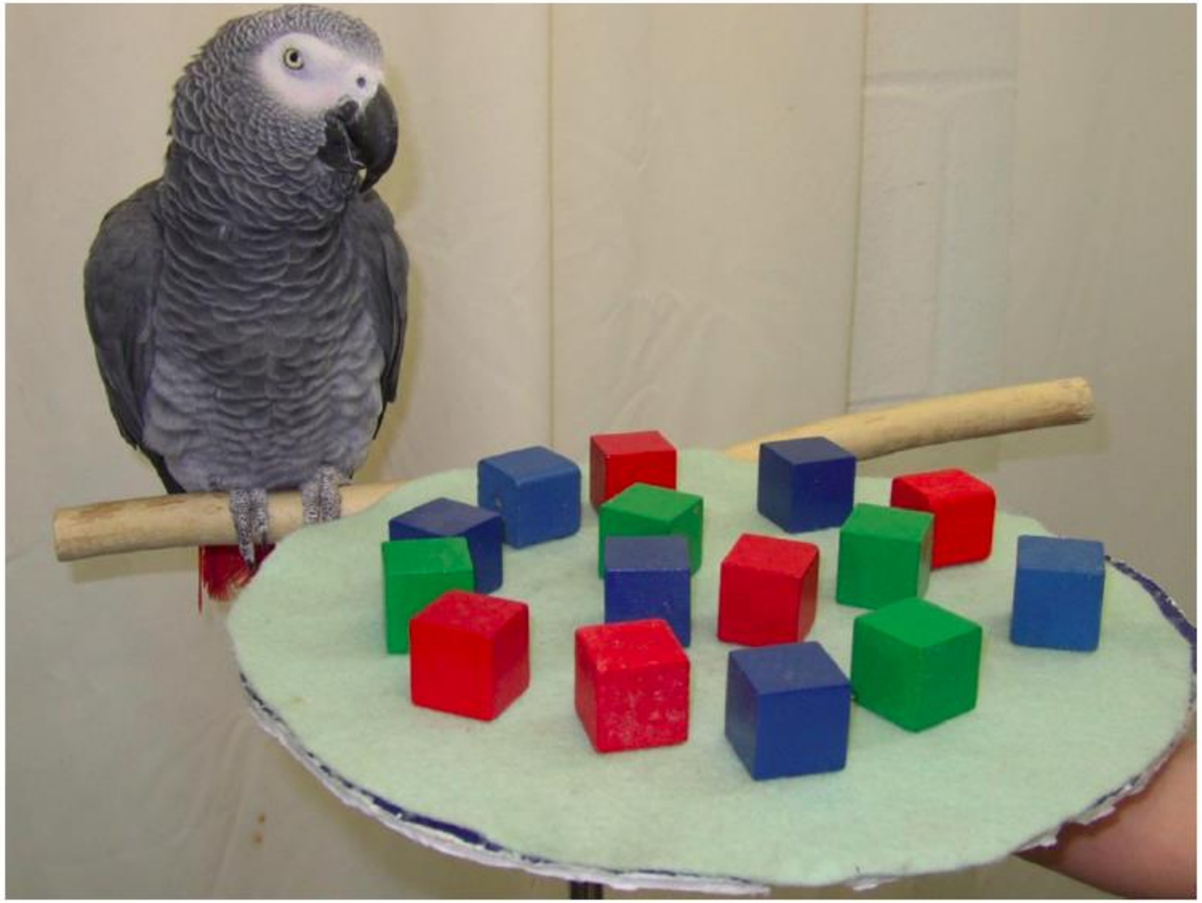


Figure 1. Alex the African grey parrot confronted with a tray of blocks while being asked to count specific colours. Photograph by Irene Pepperberg.

Irene Pepperberg

- Worked for years with a single grey parrot, Alex
- Acquired a large vocabulary and used it in a sophisticated way, which is often described as similar to that of a two-year-old child. Alex could understand labels to describe objects, colors, shapes, and materials. He could differentiate meaning and syntax.
- Working with a single animal always incurs the risk of Clever Hans effects, Pepperberg's work has strengthened the argument that humans do not hold the monopoly on the complex use of abstract communication.
- He had the problem-solving skills of a 5-year-old.

Alex: Conceptual abilities

- Skills:
  - vocally label more than 100 objects of different colors and shapes and which were made from different materials.
  - categorizing various objects, actions
  - numerical quantities up to eight
  - understanding of concepts of relative size
  - discerning of when an object was absent
  - ability to detect similarities and differences in an object’s individual attributes
  - simple addition by applying a zerolike concept in numerical tasks
  - could form abstract concepts such as "same vs. different“
  - could also request or refuse these objects ("I want X")
  - was used as a "teacher" for other younger grey parrots in Irene Pepperberg's lab. Alex would observe and listen to the training on many occasions, verbally correcting the younger learning parrot or calling out a correct answer before the learner could give a response.

Alex, the gray parrot

- By the time of his death in 2007 at age 31, Alex had mastered roughly a 100 English sounds for colors, objects, numbers, and shapes. He could clearly pronounce “green,” “yellow,” “wool,” “wood,” “walnut,” and “banana,” and used these sounds to communicate with people.
- Knew the names of 50 objects. He could also answer questions about properties of objects.
- He understood “same” and “different,” ‘bigger’ versus ‘smaller’, could count to eight, and grasped the abstract concept of zero, or “none,” as he called it. Could add and subtract numbers and was learning Arabic numbers as well the alphabet.
- Alex used his talent to talk back, telling Pepperberg to “calm down” when she was in a bad mood, and asking to “go back” when he yearned for his home during an illness that kept him at the vet’s.
- And he always wished her a good night, as he did just before he died. “You be good. See you tomorrow. I love you.”

Parrot cognition

- Kea, the New Zealand Mountain parrot, have some appreciation for connectivity, attend to social information during problem solving, can cooperate and even use objects as tools to gain access to an out-of-reach food rewards.

- Wild birds use specific vocalizations as an emotional contagion eliciting play behavior;

- Captive crows can do Aesop’s fable paradigm

Corvid characteristics

- Highly intelligent
- Extended parenting
- Highly social
- Ecological generalists
- Large brain for body size
- Long life: 20-30 years
- Great memory and learning: learn from own experience and from watching others: accumulate knowledge; learn from mistakes and from the innovations of others

Corvid cognition

- Corvids:
  - food caching behavior,
  - pilfering food caches of other birds
  - sophisticated cognitive skills such as the ability to follow invisible displacement,
  - planning,
  - episodic-like memory,
  - theory of mind-like cognitive abilities such as perspective taking and knowledge attribution.
- Earned corvids the nickname ‘feathered apes’

Smart birds: but small brain

- Structurally, their brains look very distinct. Plus there's the whole size thing.
- If you look at a bird's head, it's clear that there's not a whole lot of space for mental hardware in it. So how do the birds manage with smaller brains?

- Birds pack neurons into their brains at densities well above densities in mammals' brains, putting some relatively compact bird brains into the same league as those of primates when it comes to total cell counts.

John Marzluff: “Birdbrain” is a compliment

- John Marzluff, University of Washington wildlife biologist, who has studied corvids and their behavior for more than 35 years. Worked under behavioral ecologist Bernd Heinrich.
- Corvids: deceive each other, hold “funerals” around their dead, and learn from one another—even banding together to mob humans who have somehow wronged one of their own.
- Marzluff calls them flying monkeys.

Crows Rival Monkeys in Cognitive Capacity

- Despite their small brain size, all corvids have relatively big brains for their size.

- Seed storer like a Pinyon Jay or a nutcracker has a huge hippocampus – memory central

- Crows and ravens are more like primates in problem solving

- They have exceptionally large forebrains, the domain of analytical problem solving, higher-level sensory processing, and flexible behavior.

Corvid cognition

- Gavin Hunt discovered in 1996 that New Caledonian crows (*Corvus moneduloides*)
  - could use and make a variety of tools in the wild and
  - set off an effort to also study the physical problem-solving abilities of corvids.

- In the late 1990s studies of the New Zealand kea (*Nestor notabilis*).
  - the world's only mountain parrot
  - known for their playful drive to explore their physical environment and its apparent lack of neophobia

Cooperation

Crows are friendly and helpful

Intelligence

- Measures of human intelligence:
  - solving complex problems,
  - making tools,
  - using analogies and symbols
  - reasoning about what others are thinking.
  - recognizing oneself in a mirror

- The greatest intellectual rival to the brainy apes may be a noisy scavenger with a sharp beak, bright eyes and a brain about the size of a walnut: the crow and its corvid relatives.

Correlates of avian intelligence

- There is a positive association between brain size and more “complex” natural histories:
  - frugivorous, carnivorous or omnivorous feeding (depending on the taxon),
  - larger social groups,
  - monoparental care,
  - more elaborate nests,
  - more play
- Correlates of avian memory:
  - correlation between amount of food-storing and relative size of the hippocampus in corvids
- Correlates of relative size of avian brain size and size of forebrain:
  - feeding innovations in birds, esp. corvids
  - tool use

Corvids and Parrots

- Birds in the crow family (corvids), and parrots (psittacines) have been shown to
  - live socially,
  - have long developmental periods,
  - possess large forebrains,
  - Implying the possibility for greater cognitive abilities.

Bird Behaviors

- Problem Solving: Some birds have the capacity to reason and make causal, logical inferences.
- Using Tools: Some can use objects—found or fashioned—to solve problems.
- Studying: some species are able to learn through observing other birds' behavior.
- Vocal Learning: Some species learn vocalizations that can then be used in social interactions.
- Socializing: Some species engage in complex social relationships within groups.
- Remembering: Some birds are even able to recall episodic, personal, experiences from the past.
- Playing: Some birds engage in play fighting or other forms of social play

Avian cognitive capabilities

- Corvids and parrots appear to be cognitively superior to other birds, rivalling great apes in many cognitive domains. They
  - manufacture and use tools
  - solve problems insightfully
  - comprehend basic principles of physics for objects
  - adapt new food sources, i.e. insects on car grills
  - can count
  - understand object permanency, water displacement
  - make inferences about causal mechanisms
  - understand analogies
  - exercise self control for future rewards
  - plan for future needs

Avian Cognitive Abilities

- Have facial recognition: can recognize friends and enemies
- have working memory, episodic and permanent memory
- learn by observation and imitation
- have capacity for vocal learning
- parrots can learn words and use them to communicate with humans.
- can innovate, show behavioral flexibility
- barter for goods
- show curiosity

Avian Cognitive Abilities

- play
- take risks
- use their own experience to anticipate future behavior of other birds or even humans
- use different nutcracking techniques
- show empathy, cooperate
- can deceive and steal
- use gestures to communicate
- have theory of mind?
- self awareness; recognize themselves in a mirror??

Herons use fish bait

- Spotted green herons (*Butorides virescens*) using bread thrown to ducks to lure fish
- Also use picnic leftovers, or even small leaves as bait to attract fish for their hunting.

Heron uses bread thrown to ducks as fish bait

African honeyguides: Jekyll and Hyde

- African honeyguides are small birds named for their habit of leading people to bee hives.
- Natural born killers: they are brood parasites who kill original chicks in nests.
- The birds will call and fly backwards to get the people to follow them.
- After the people open the hive and retrieve the honey, the birds feed on the leftover honey wax and larvae.

Nutcracking techniques

- Crows have adapted to life in a human-dominated world. They watch what we do and learn from us.
- Carrion crows (*Corvus corone orientalis*) in urban Japan and American crows (*C. brachyrhynchos*) in the United States have innovated a technique to crack hard-shelled nuts by dropping them onto crosswalks and letting them be run over and cracked by cars.
- They will even watch traffic lights, only retrieving the nut when the crosswalk sign is lit. This in itself probably makes the crow smarter than most pedestrians.
- Over 20 years younger crows have learned it from parents and practice has increased. Japanese drivers now helpfully aim for the walnuts.

Nutcracker: drop technique

Nutcracker: Street lights

Use urban rails as nutcrackers

- Norway: city rail system has rails that are depressed into the street. As I was waiting for the bus each day I would regularly see crows come to drop shells into the rail depressions - then promptly leave, only to return a couple of minutes later - always right as the next rail-car was scheduled to pass (about 10 minutes between) and sit and wait.
- When the rail car passed it of course cracked the shells, and the crows would then go retrieve their prize and fly off.
- I made it a point to predict the next rail-car based on the crows waiting, and it was rarely more than a minute off.

Egyptian Vultures and ostrich eggs

- Sometimes a hard object is too large to be carried aloft.
- The Egyptian Vulture faces this problem with ostrich eggs. And the ostrich shells are too thick for the vultures to break with their bills.
- They compensate by “throwing” stones at them.
- The vultures pick up the largest stones that can be held in their bills, raise their bills skyward, and forcefully throw them at the eggs.

Emerging human-crow interactions

- Crows know to drop clams on rocks from right height to break them open.
- Blue tits in the 1920s that learned which color of milk caps on delivered milk had the most cream (whole milk) and pierced those caps to drink the cream.
- Crows have been known to memorize restaurant schedules and garbage days, to take advantage of prime scavenging times.

Opening locked items

Burrowing Owls & dung beetles

- Burrowing Owls gather animal dung from nearby fields and place it around their burrows.
- The "bait" attracts dung beetles, which can reach 2 centimeters in length and are a major prey item of the owls.
- In one study, biologists compared dung beetle remnants in regurgitated pellets of owls that had dung placed around their burrows with pellets from burrows without dung.
- Owls with dung near their burrows consumed 10 times more beetles than the others.

Marshmallow test – delayed gratification at age 4: Wait 5 minutes & get two; ability to wait = 200 points more on SAT

Parrots and Crows can exercise self control

- Crows can experience anticipation, and exercise self-control if the end result is a greater reward.

- 2014 “Marshmallow” study: devised a test based on the Stanford marshmallow experiment. Determined bird’s favorite snack.

- Next, they were given a snack and the option to trade their snack - if they were willing to wait. They could either receive a better-quality snack – meat - in exchange for a grape, or a higher quantity of the same snack.

- They preferred to wait until a better snack was on offer, but not for more of same. In some cases, they waited up to 10 minutes for a better snack.

- The fact that they waited for better quality, not quantity, showed that they were waiting because they wanted to - not because they were actually hungry.

Self-control for the future reward

- Working memory: limited capacity that can hold and process information temporarily (i.e. like computer RAM); crucial for problem solving and planning; highly correlated with IQ

- Self-control behavior involves working memory to internally compare between the current and future rewards and to choose a better one.

- The NCL, a crucial region of avian pallium (cortex) for working memory, has been revealed to be involved in self-control behavior at the level of single neuron activity

Ravens can plan for the future

- When trained in the use of tools, ravens recognise that a tool as valuable and can set it aside against a future need.
- Study: trained ravens to stick a tool into a tube sticking out of a box to release a treat.
- Then they took the tool and box away, returning an hour later to offer the raven a choice of objects - one of which was the tool they had used.

Ravens can plan for the future

- After another 15 minutes following the raven's selection, the box was returned

- 80 % of the time, the raven chose the correct tool.

- After a 17-hour interval in returning the box, ravens had a 90 % success rate.

Waiting ravens: barter for items they want

- Study: ravens were trained to return a token to a human in exchange for a high-quality food reward.

- After 60 minutes, offered a choice of objects: the token or a low-quality snack.

- Chose the token 73 % of the time.

- After 15 minutes, the bartering experimenter would come back, and the raven exchanged the token for the higher quality snack.

Ravens waiting

- This study suggests that ravens make decisions for futures outside their current sensory contexts, and that they are domain-general planners (learning in 1 context transfers to different context) on par with apes.
- Ravens are able to plan for different kinds of future events.
- The birds opt to choose a tool, such as a stone, over an immediately available small reward. With these implements, they can obtain a larger reward the next day by either bartering or using the tool to directly obtain some benefit.

Goffin's cockatoo (*Cacatua goffiniana*).

A notoriously curiosity driven investigative Indonesian Island parrot

Goffin's cockatoo

- Object manipulation: These cockatoos could spontaneously innovate both, the use and manufacture of tools and that they could socially transmit it to other birds.
- Spontaneously create rakes (shape splinters of wood and small sticks) that they then use to extend his reach and retrieve otherwise unavailable food items located upon the other side of his aviary mesh
- Ability to solve complex multi-step mechanical problems: spontaneously worked out how to open a five-part locking mechanism in sequence to retrieve a food item.
- Not just a learned sequence of actions: able to very quickly adapt their behavior and again open the lock when the mechanism sections were modified or re-ordered

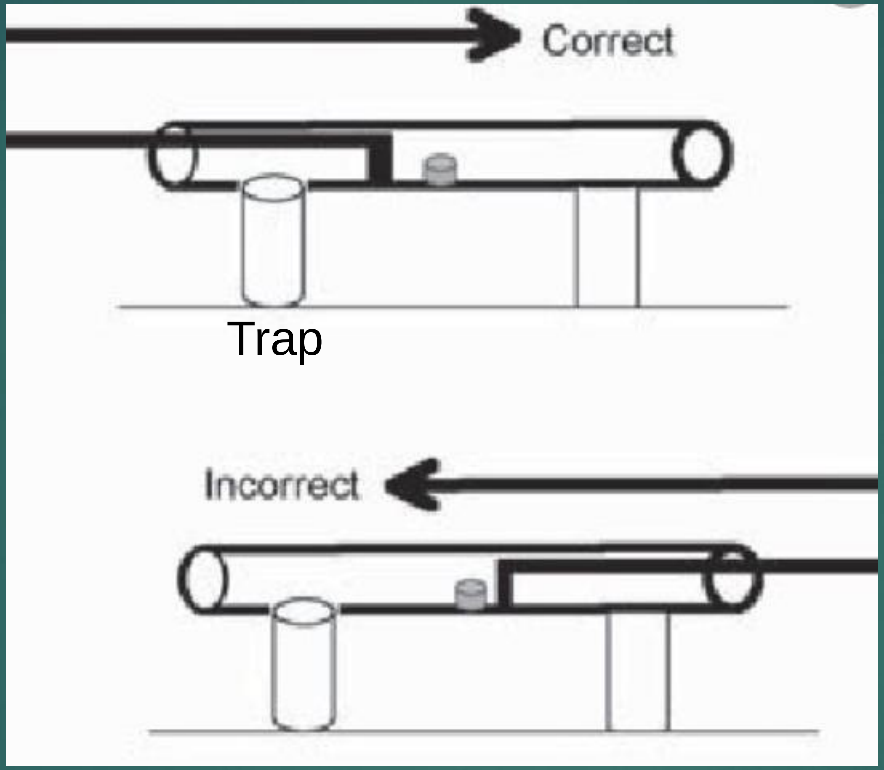
A food treat in clear box, with just a small hole for access; ramp so the food, when knocked off its perch, rolls out.
The cockatoo could see the treat, but not reach it without aid. A piece of cardboard was placed in front of the box.
Cockatoos fashioned a long, thin piece of cardboard that they could fit through the hole to knock the food loose. When the food was moved closer or farther away in the box, the birds would adjust the length of their cardboard stick accordingly.

Goffin cockatoo

- Goffin cockatoo's tool using abilities: Despite the birds not being specialized tool users in the wild, their tool-related capacities imply domain general problem-solving abilities

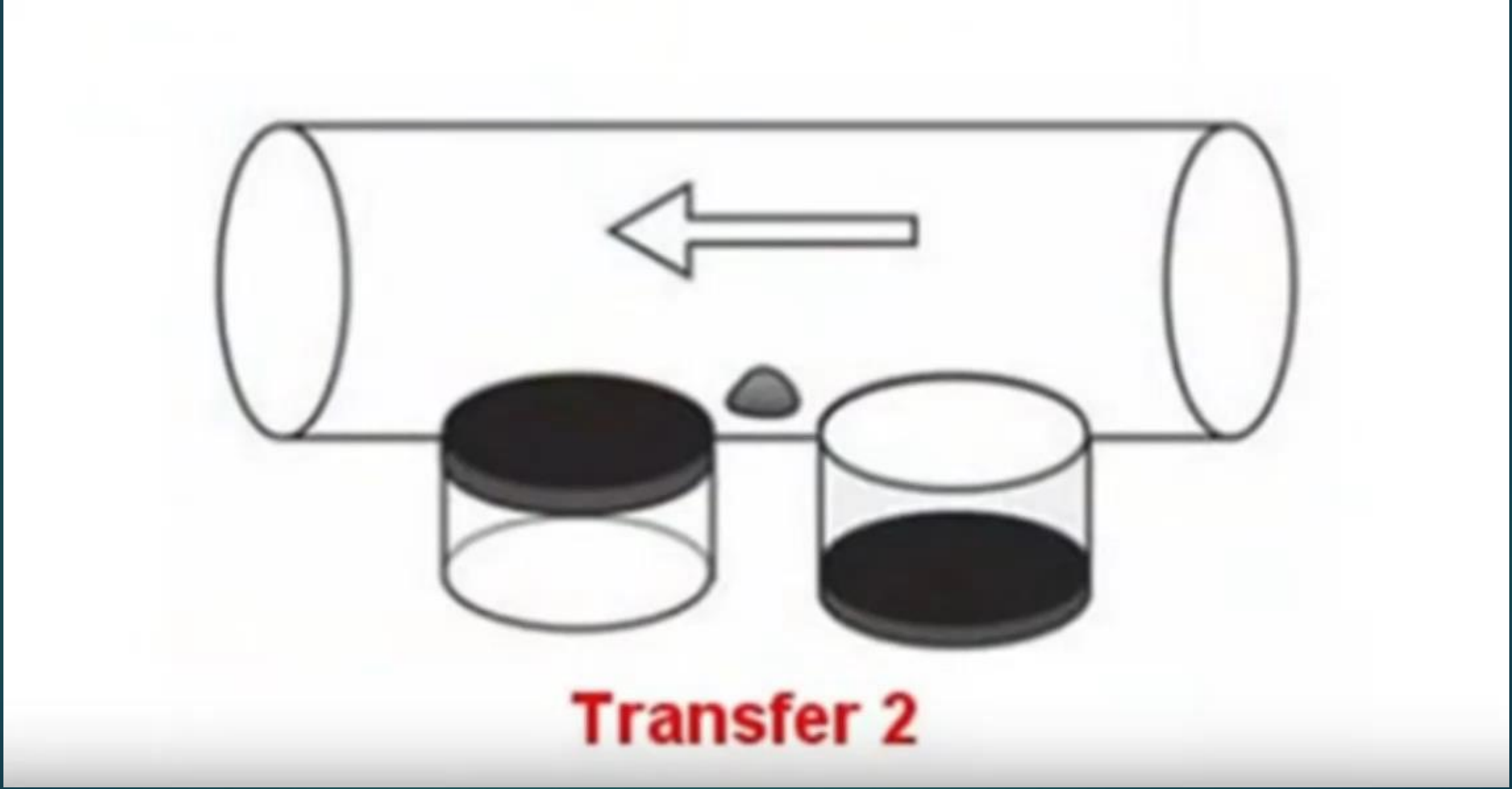
- Marshmallow test: they could resist the temptation to eat the nut for periods of time for up to 80 seconds once aware that a cashew was also on offer.

Trap tube Test: Decide which direction to push food out in transparent tube; open tube on left is a trap

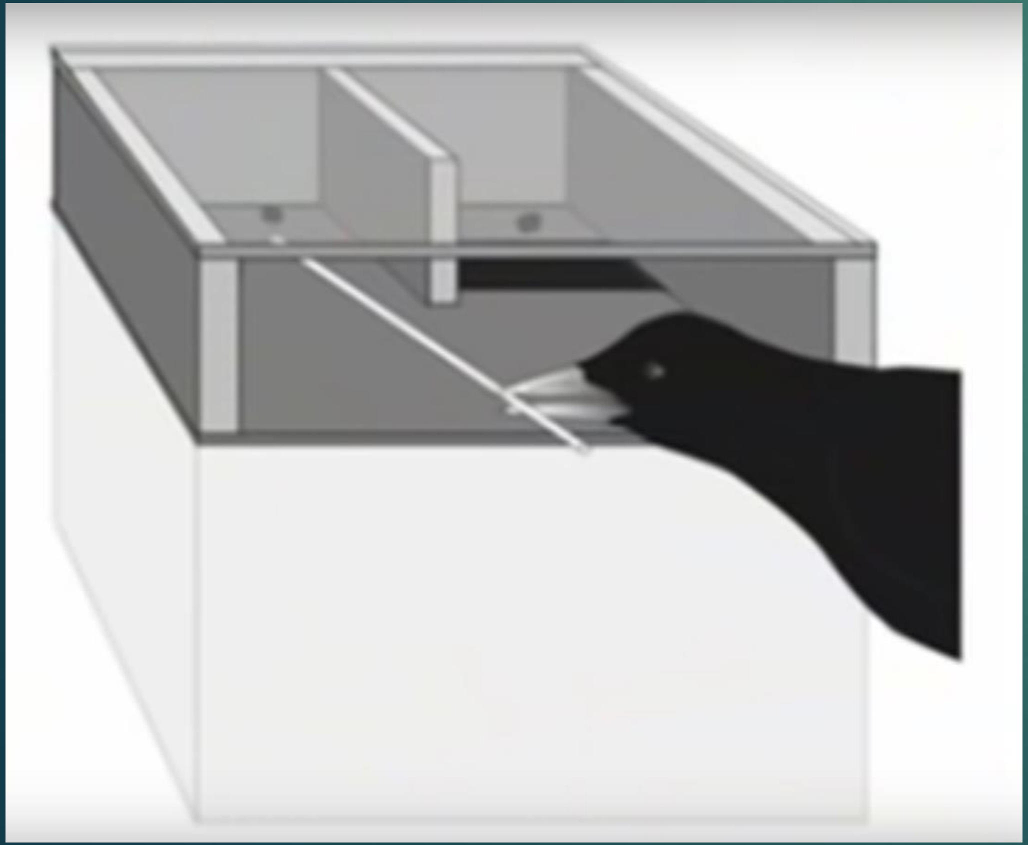


Parrot compatible version of the trap tube task. The latter is a task that has been used as a benchmark paradigm to investigate causal reasoning in animals; dogs (with pulls on end) and chimps can do it correctly

Tube with 2 bottom tubes: 1 a trap, other covered



Switch to trap table with hole on one side; transferred their klg from trap tube and avoided hole; 28 gorillas, chimps, bonobos, orangs learned tube, but never comprehended table (had causal, but not analog, comprehension)



*** Avian Neuroanatomy

Neurons and Cognition

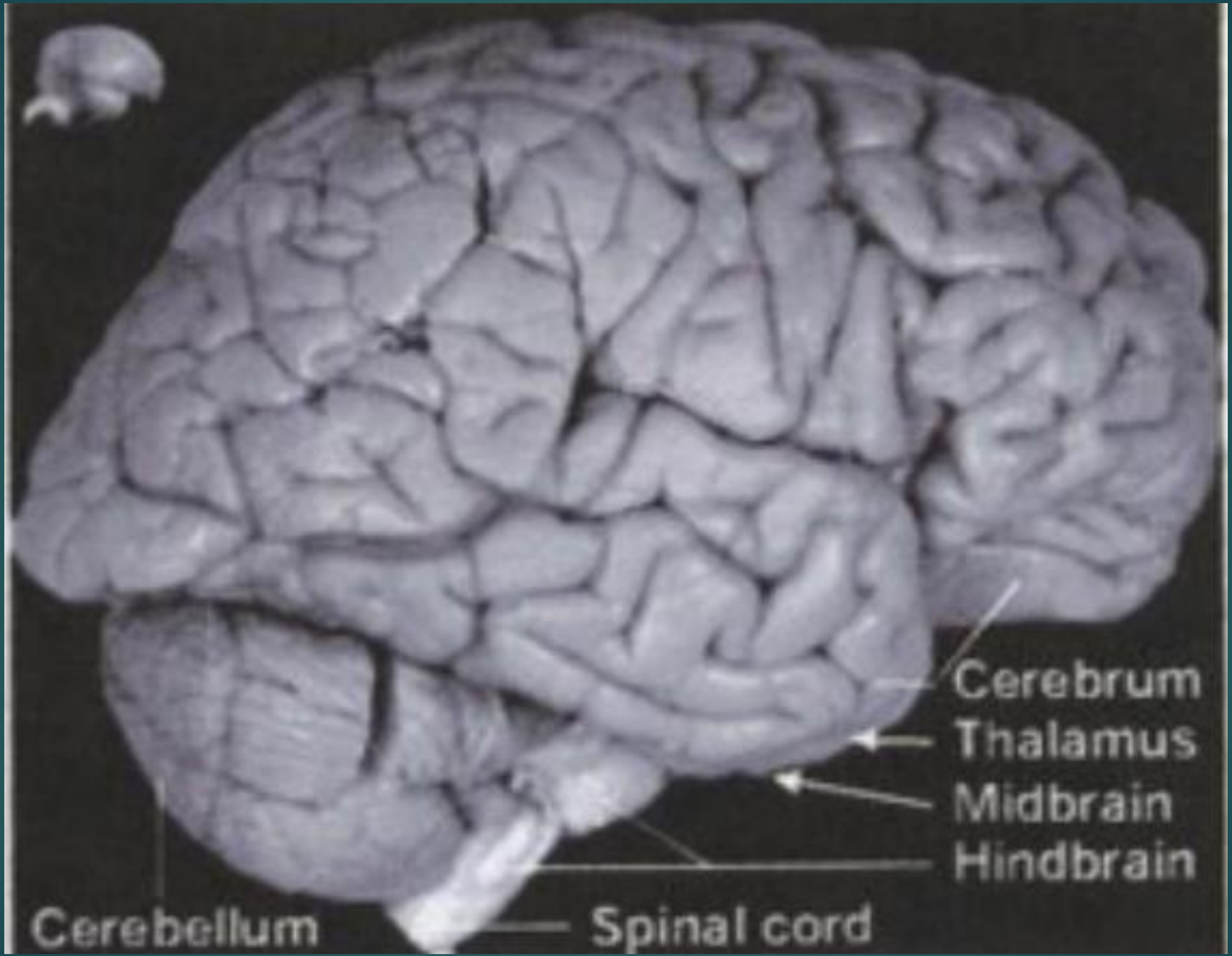
- Birds and mammals cognitively thrived by increasing neuron numbers.

- Mammals did so by expanding brain size and birds by amplifying neuron density.

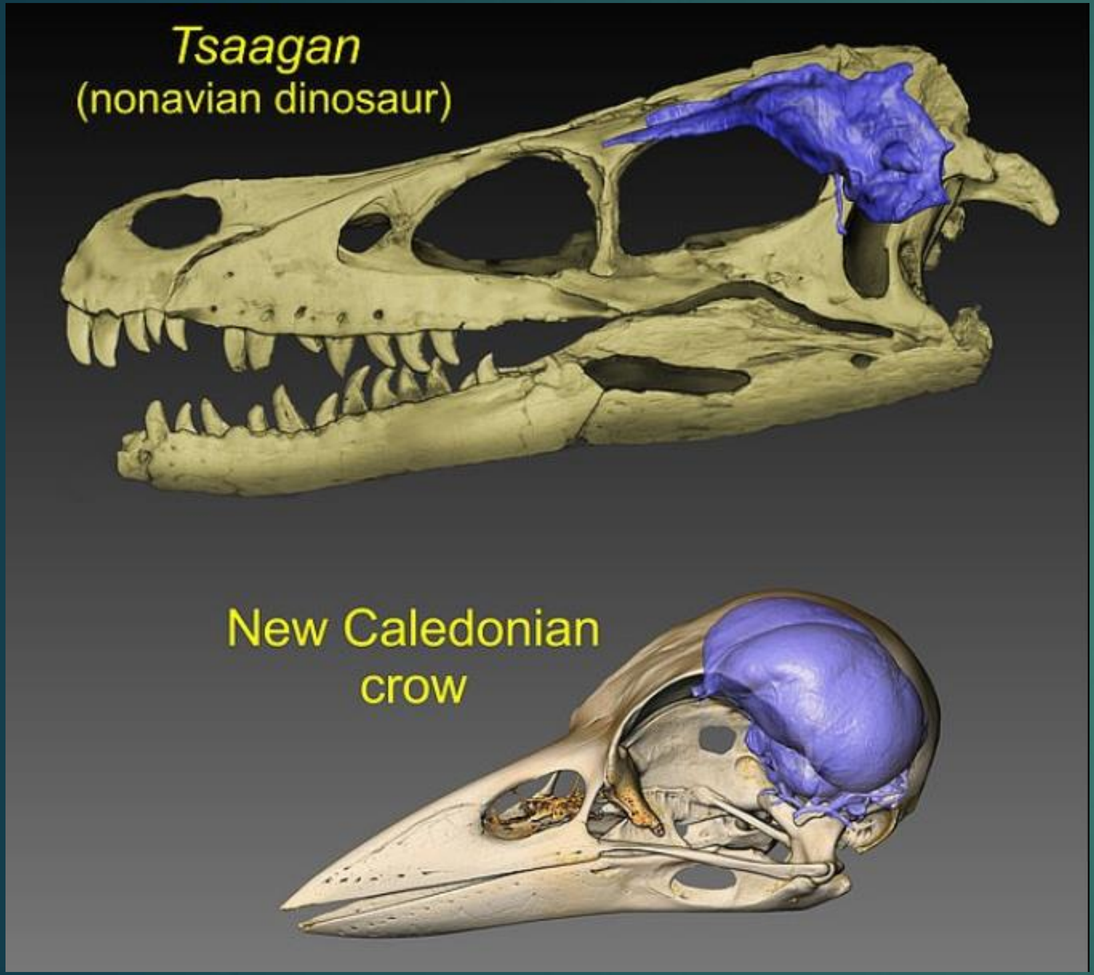
- They both developed substantially similar networks of pallial connections and evolved “prefrontal” areas with identical physiological, neurochemical and functional features.

- The same can be said for cognition itself.. Birds and mammals evolved similar neural mechanisms and ways of thinking—taking different paths that ended in the same place.

Bird brain


Cerebrum
Thalamus
Midbrain
Hindbrain
Cerebellum
Spinal cord

Study of brain-body evolution in birds & dinosaurs



D. Ksepka, et al., 2020

- Comparison of 2,000 modern birds, fossil birds, and theropod dinosaurs post 66 Ma
- Prior to the mass extinction at the end of the Cretaceous Period, birds and non-avian dinosaurs had similar relative brain sizes. After the extinction, the brain-body scaling relationship shifted dramatically
- Multiple avian clades achieved higher relative brain sizes because of a reduction in body size.
- Parrots and corvids achieved the largest brains observed in birds.
- Parrots primarily reduced their body size, whereas corvids increased body and brain size simultaneously

2% of body weight

- Birds need to be light for flight, but a raven’s brain accounts for almost 2% of its body mass, a value similar to humans.
- Relative to body size, corvid brains are large

History of Bird Neuroanatomy Theories

- Neuroanatomical lab of Ludwig Edinger of Goethe University Frankfurt in Germany at the end of the 19th century

- Birds were dismissed as “birdbrains” even before Edinger misinterpreted their neural anatomy, around 1900. He thought birds lacked a neocortex.

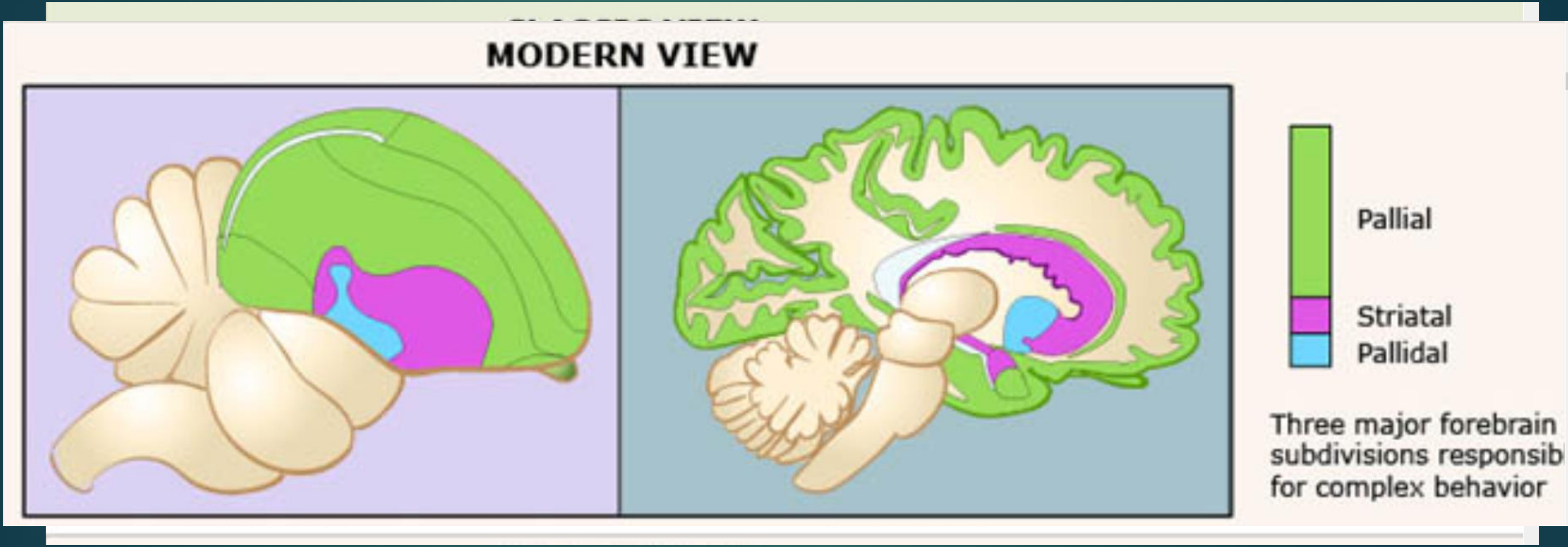
- Scientists then argued that birds had hyper-developed basal ganglia, motor control areas, with tiny mammalian-like telencephalon/cortical structures.

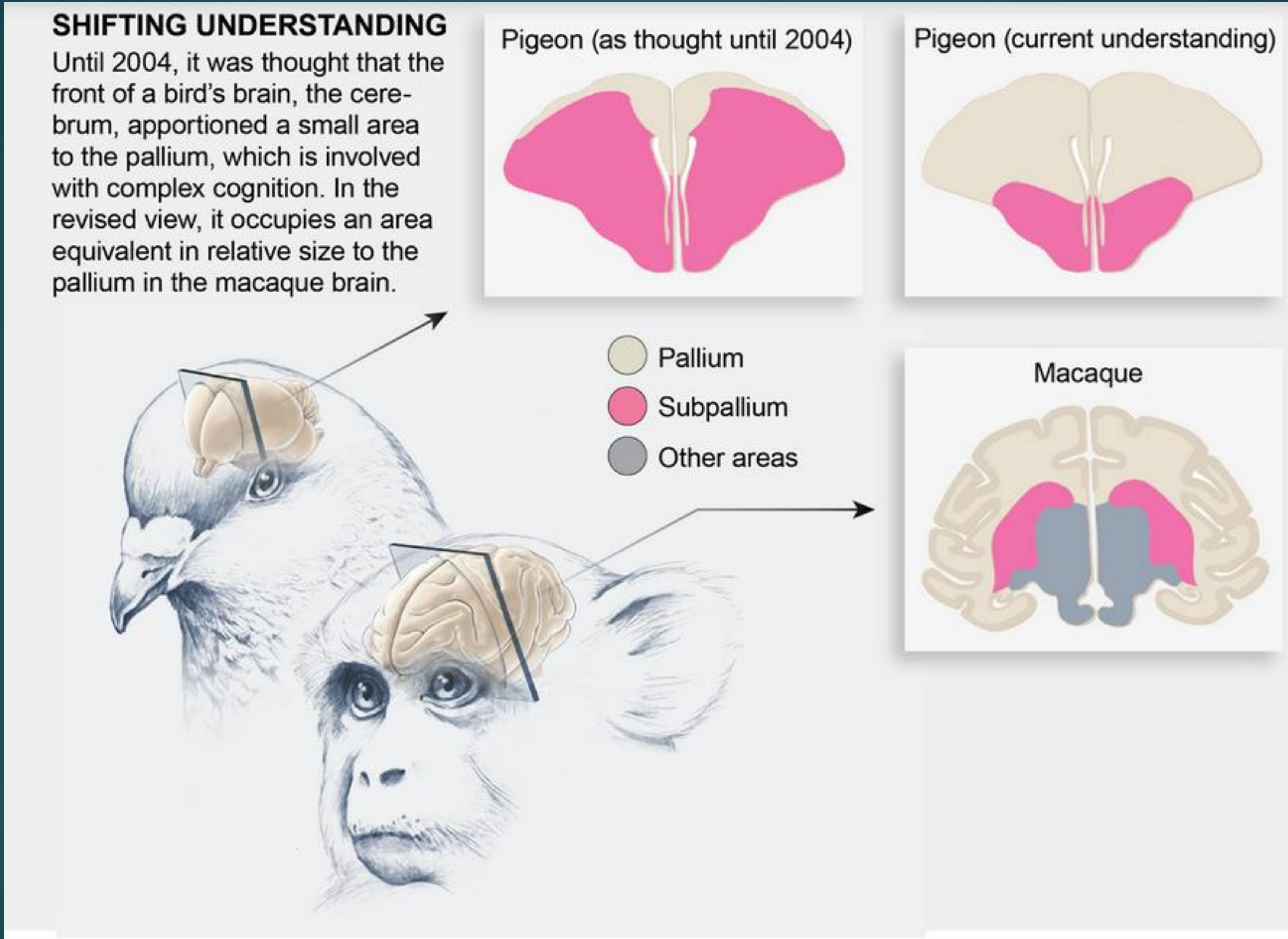
History of Bird Neuroanatomy Theories

- An international team of researchers reexamined the long-standing Edinger model of avian neural anatomy.

- In 2005 they issued their reevaluation, revealing that birds' brains do possess neural structures, called the pallium, that resemble the mammalian neocortex and other areas associated with sophisticated thinking.

Cortex vs not

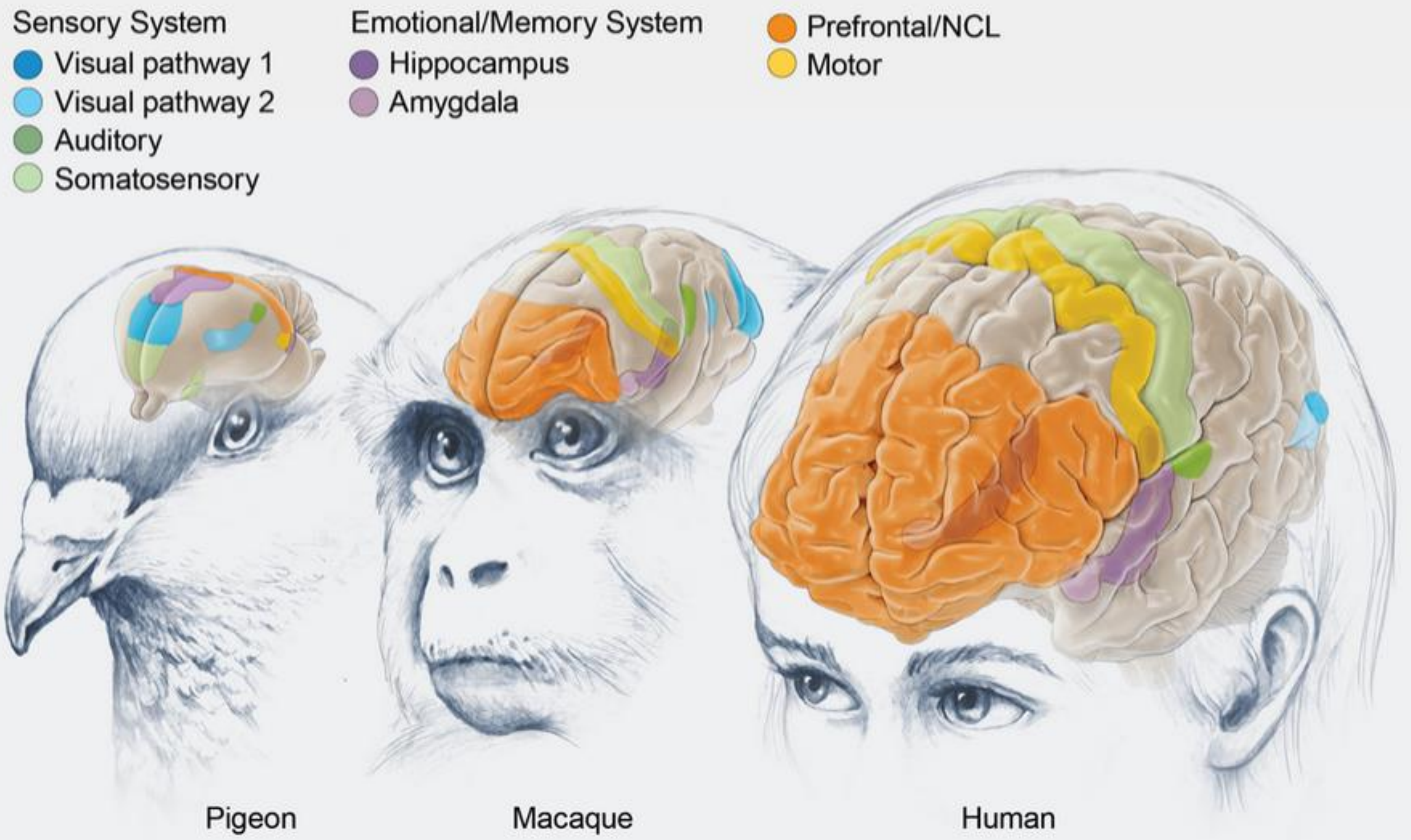


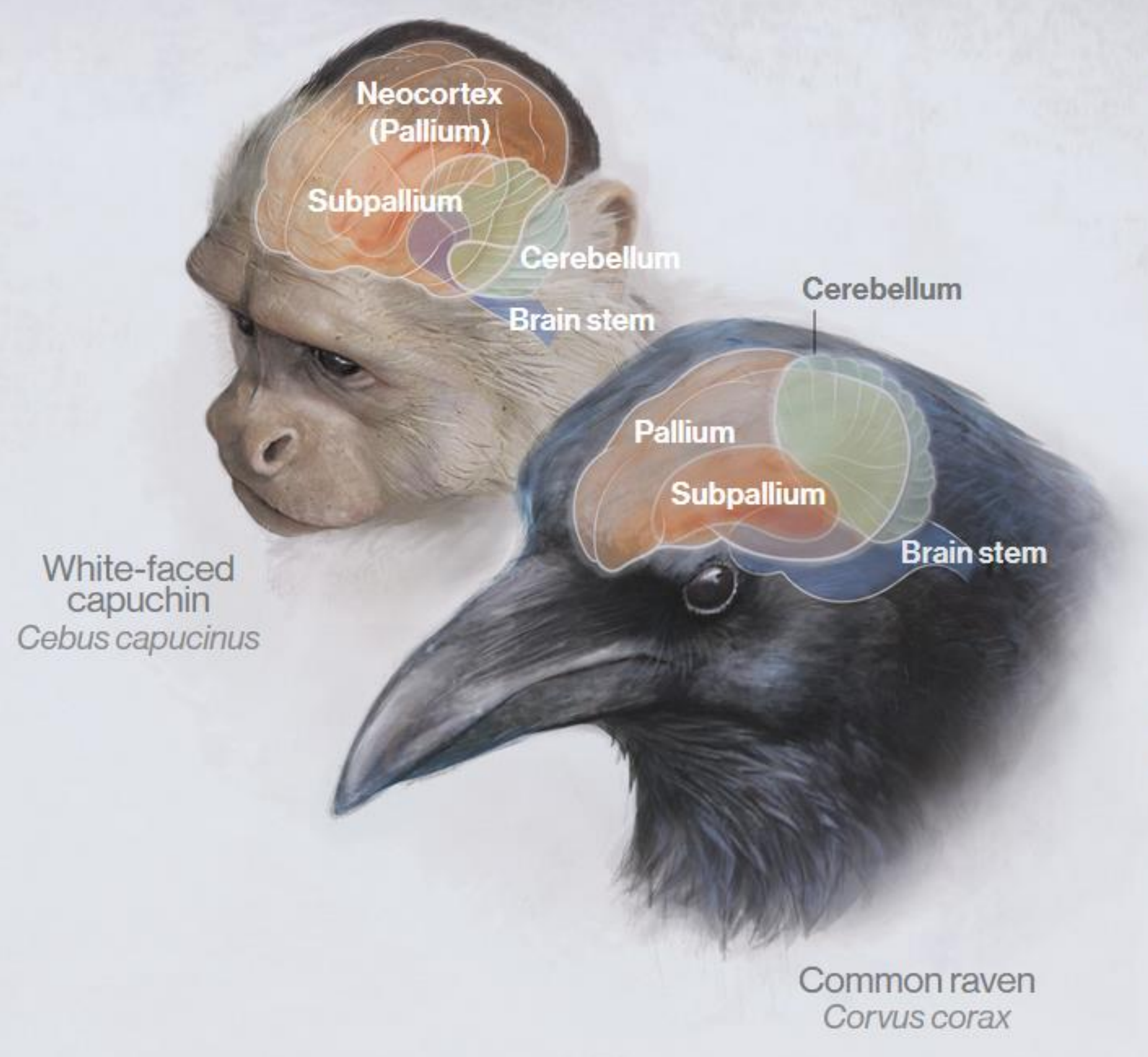


Credit: Mesa Schumacher

SIMILAR FUNCTIONS, DIFFERENT PLACEMENTS

Birds' brains are equipped with sensory and cognitive processing centers roughly equivalent to those in primates. But their placement can differ. The nidopallium caudolaterale (NCL) at the back of the brain, for instance, serves as an integrating hub for all of the animals' sensory, limbic and motor systems—similar to the prefrontal cortex in primates.





Intellectual heavyweights

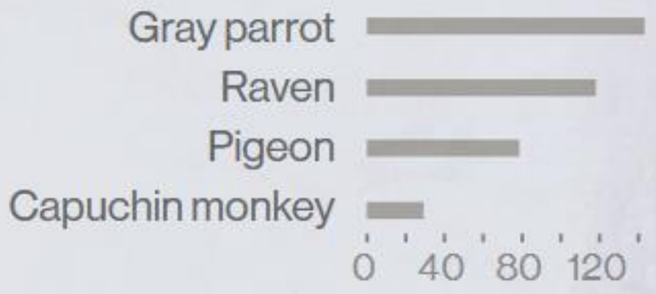
The forebrain's pallium and subpallium regions—responsible for higher-order function—evolved differently in birds and mammals. Birds' brains are smaller but more densely packed with neurons, the cells responsible for cognition.

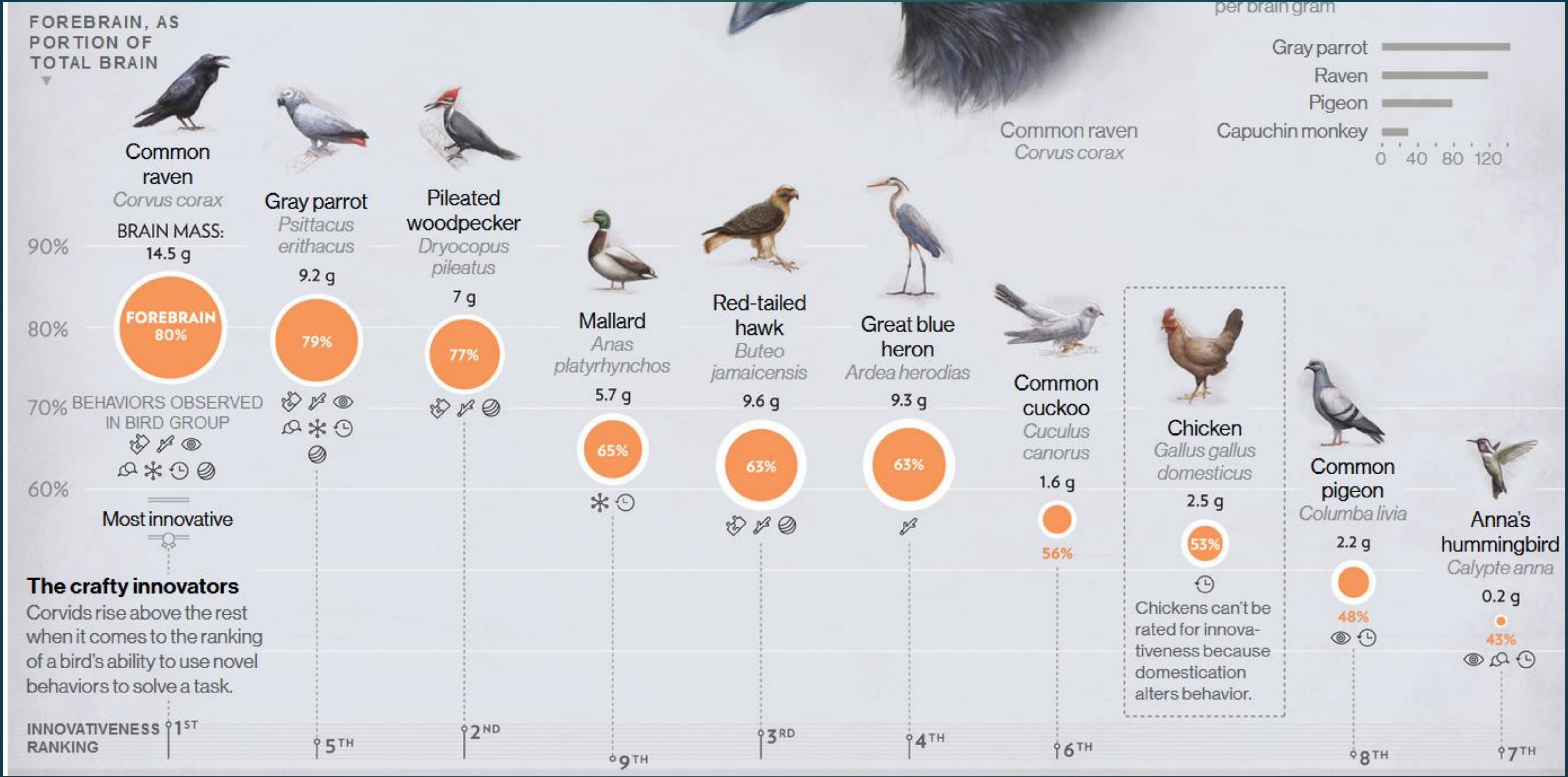
FUNCTIONS

- Higher-order thinking; cognition
- Cognition and spatial orientation; control of voluntary movements
- Cardiac and respiratory processes

NEURON DENSITY

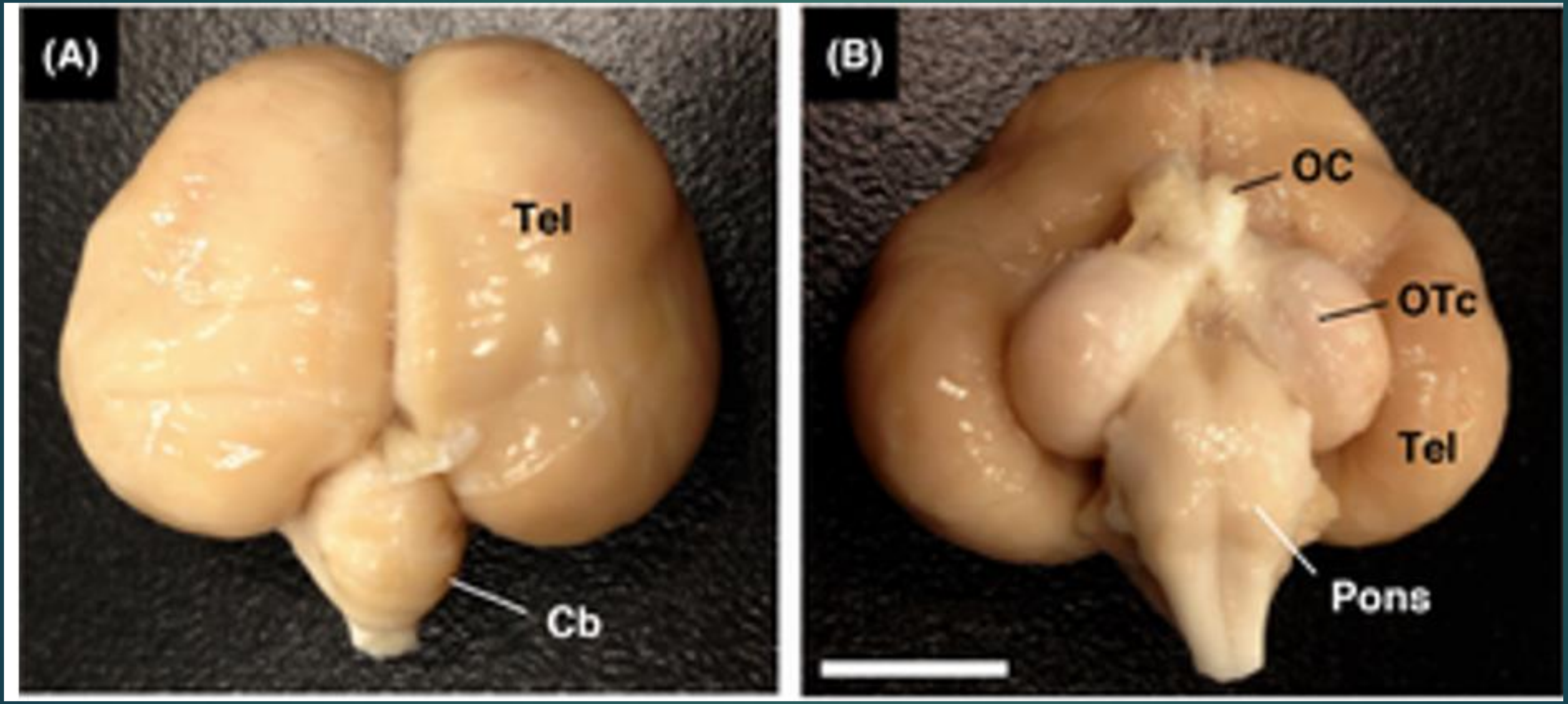
Pallium neurons (in millions) per brain gram





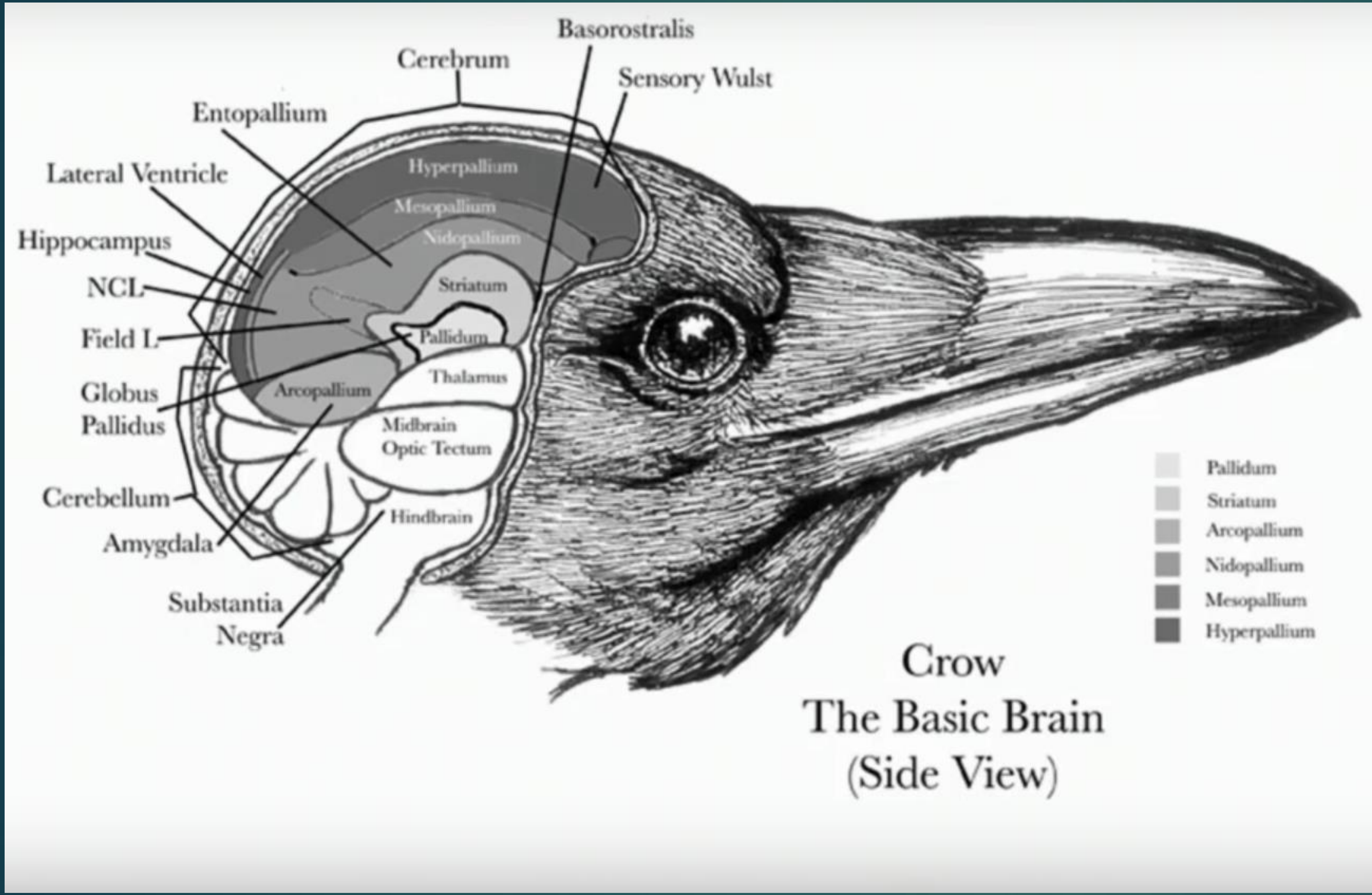
FOREBRAIN, AS PORTION OF TOTAL BRAIN
per brain gram
Gray parrot
Raven
Pigeon
Capuchin monkey
0 40 80 120
Common raven
Corvus corax
90%
80%
70%
60%
Common raven
Corvus corax
BRAIN MASS:
14.5 g
FOREBRAIN 80%
BEHAVIORS OBSERVED IN BIRD GROUP
Most innovative
Gray parrot
Psittacus erithacus
9.2 g
79%
Pileated woodpecker
Dryocopus pileatus
7 g
77%
Mallard
Anas platyrhynchos
5.7 g
65%
Red-tailed hawk
Buteo jamaicensis
9.6 g
63%
Great blue heron
Ardea herodias
9.3 g
63%
Common cuckoo
Cuculus canorus
1.6 g
56%
Chicken
Gallus gallus domesticus
2.5 g
53%
Chickens can't be rated for innovativeness because domestication alters behavior.
Common pigeon
Columba livia
2.2 g
48%
Anna's hummingbird
Calypte anna
0.2 g
43%
The crafty innovators
Corvids rise above the rest when it comes to the ranking of a bird's ability to use novel behaviors to solve a task.
INNOVATIVENESS RANKING
1ST
5TH
2ND
9TH
3RD
4TH
6TH
8TH
7TH

The top and bottom views of a jungle crow brain (*Corvus macrorhynchos*). Enlarged telencephalon covers the rest of the brain.



OTc = Tectum = Visual processor

Bird brain



Grey area: large forebrain with its subdivisions

Birds have hippocampus and amygdalas

Less hemispherically connected

Share same neurotransmitters (i.e. dopamine, etc.) as humans

Tadashi Nomura & Ei-Ichi Izawa, 2017

Telencephalon = bird cortex

- Bird brain architecture is different, but some organizational principles are the same. Birds and humans are surprisingly similar in many studied capacities.
- A bird's telencephalon/pallium is equivalent to a cortex derived from similar types of stem cells during fetal life. A similar type of cell becomes the mammal's cortex and birds' dorsal ventricular ridge (DVR). The DVR is important in the songbird vocal learning.
- The human prefrontal cortex (PFC) is particularly important for advanced thinking. In mammals, understanding other's minds, decision-making, reward learning, emotional and social learning and insight need PFC regions.
- Very recently, bird genetic studies show that a region called nidopallium caudolaterale (NCL) is involved in all of these cognitive functions. It has dopamine 1 and 2 neurons connected with striatum.

Convergent evolution: Apple vs PC Computers

- That such distantly related animals with such different brains could evolve such similar abilities is surprising, but when two different species face similar evolutionary pressures, natural selection can lead to similar traits.

- This is convergent evolution, and it's the same process by which birds and bats both evolved wings.

- The ancestor of today's corvids must have found itself in an ecological niche where intelligence boosted the odds of survival, so corvid brains evolved with cognitive abilities similar to those of primates.

Apple vs PC computers

- Convergent evolution may have led to similar wiring despite the differences in physical structure between bird and mammalian brains.

- The network of connections between areas of the brain looks very similar in corvids and primates, and one recently published paper compared bird and primate brains to Apple and PC computers.

Brain architecture: layers

- Mammalian brains have evolved with what is called a laminar structure, in which brain cells are organized in six layers that make up the cerebral cortex, or forebrain.

- In birds' brains, cells form clusters called nuclei instead of layers. “Mammals’ brains are layered like a club sandwich, while birds’ brains are more like a pizza. All the pieces are there, but they’re not stacked.”

- More recently other researchers discovered that the wiring that underlies long-term memory and decision-making is very similar in avian and mammalian brains.

Organization of Pallium

- Since 2013 study known that the neural circuits formed by the pallial neurons are functionally organized in a similar manner in birds as they are in mammals - - in a layer and column-like connectivity,

- The pigeon pallium was shown to be functionally organized and internally connected just like a mammalian cortex, with sensory areas, effector areas, richly interconnected hubs, and highly associative areas in the hippocampus and nidopallium caudolaterale.

- The nidopallium caudolaterale is the equivalent of the prefrontal cortex

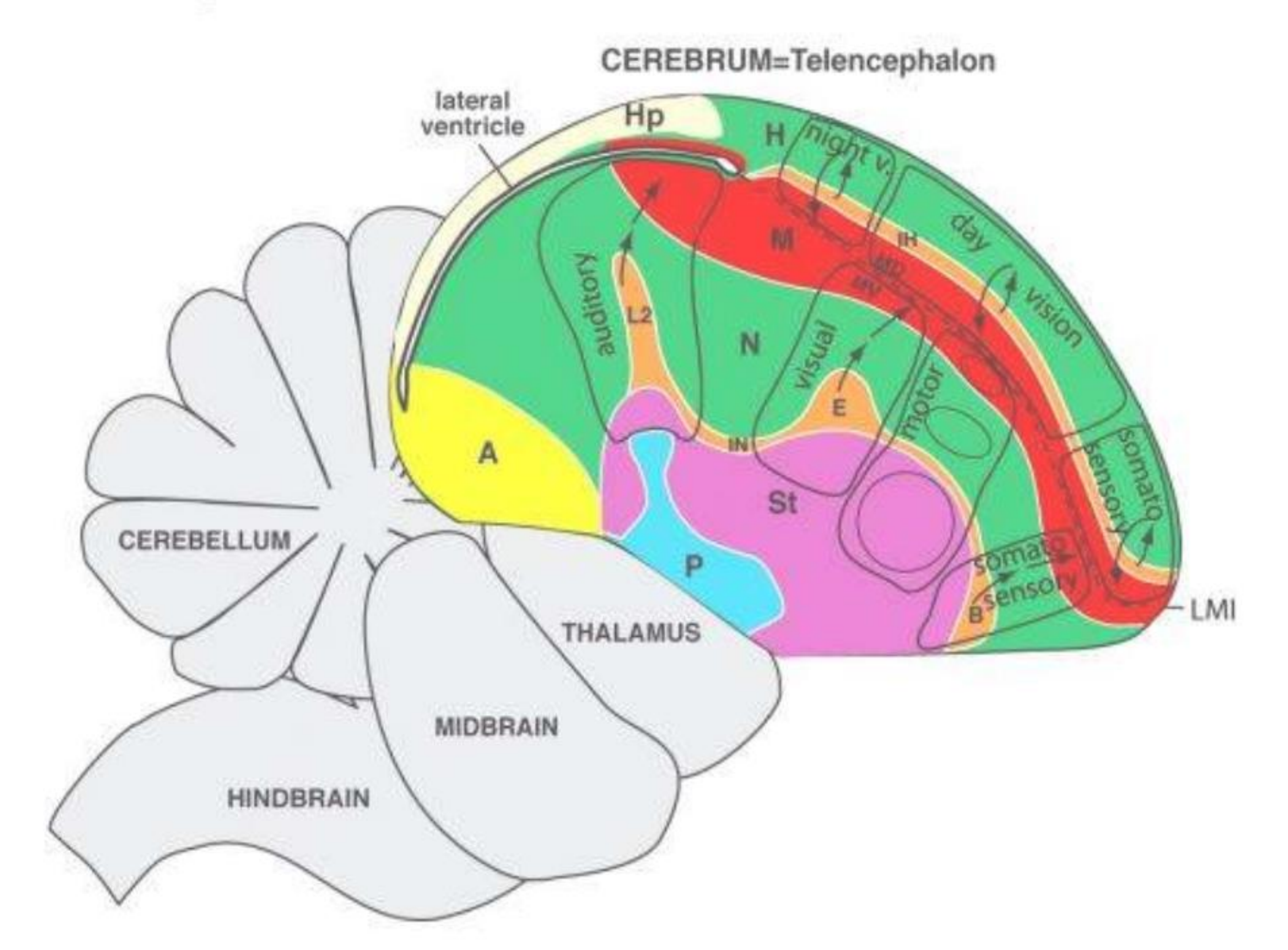
Avian and mammalian cortex: layers & cortex

- Mammalian cortex: cortical layers running parallel to the cortical surface, as well as columns that run orthogonal to layers and thus create a radial organization

- Stacho *et al. 2020* show that the pallia of pigeons and owls, like that of mice, monkeys, and humans, is criss-crossed by fibers that run in orthogonal planes.

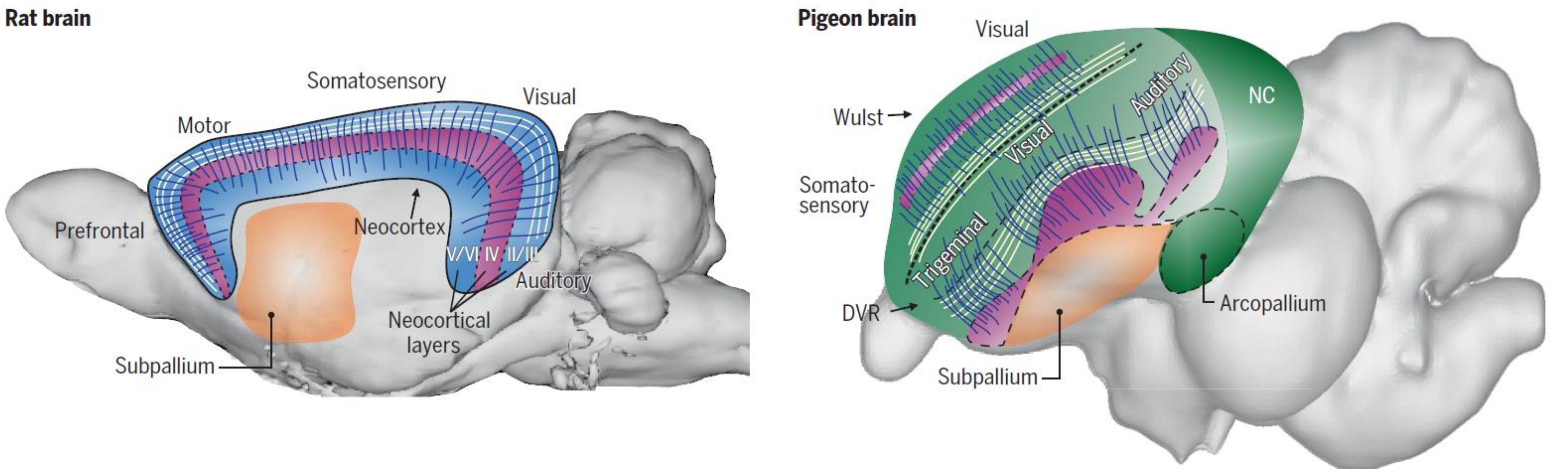
- Both mammals and birds show an orthogonal fiber architecture constituted by radially and tangentially oriented fibers. Tangential fibers associate distant palliai territories.

A 2013 revised map of the bird brain shows cortical areas organized in columns, as in mammals and humans



Jarvis, et al., 2013

Cortex-like columnar layering in the avian forebrain



29, 2021

Fiber architectures of mammalian and avian forebrains. Schematic drawings of a rat brain (left) and a pigeon brain (right) depict their overall pallial organization. The mammalian dorsal pallium harbors the six-layered neocortex with a granular input layer IV (purple) and supra- and infragranular layers II/III and V/VI, respectively (blue). The avian pallium comprises the Wulst and the DVR, which both, at first glance, display a nuclear organization. Their primary sensory input zones are shown in purple, comparable to layer IV. According to this study, both mammals and birds show an orthogonal fiber architecture constituted by radially (dark blue) and tangentially (white) oriented fibers. Tangential fibers associate distant pallial territories. Whereas this pattern dominates the whole mammalian neocortex, in birds, only the sensory DVR and the Wulst (light green) display such an architecture, and the associative and motor areas (dark green), as in the caudal DVR, are devoid of this cortex-like fiber architecture. NC, caudal nidopallium.

Behavioral flexibility

- In theory, any brain that has a large number of neurons connected into associative circuitry … could be expected to add flexibility and complexity to behavior

- A 2014 study showed that New Caledonian crows, rooks, and European jays can solve an Aesop’s Fable challenge, dropping stones into a water-filled tube to bring a floating bit of food within reach, something kids generally can’t do until ages 5-7.

- These birds were the first nonhuman animals to solve the task.

- In wild most are right-handed, indicating importance of the brain’s left hemisphere in solving non-spatial problems

Bird handedness

- Parrots tend to be "left-handed.“ Parrots, like humans, choose to use one side of their body more than the other, with more of them left handed -- or, more precisely, left footed than anything else.

- Study of 320 Australian parrots: 47 % were left-handed, 33 percent right-handed, and the remainder ambidextrous.

- If parrot looks with its left eye, then uses its left foot = *handedness*. That’s when one hand — or foot — is used consistently over the other for doing complex tasks. Sulphur-crested Cockatoos are almost *all* left-handed ... that is... left-footed.
- Parakeets have a left/right preference when veer while flying

Avian pallium/cortex

- The pallium receives copies of all that goes on elsewhere in avian brain. These pallial neurons create new associations that endow animal behavior with flexibility and complexity.

- The more neurons there are in the pallium as a whole, regardless of body size, the more cognitive capacity is exhibited by the animal.

- Humans are at top: Despite having only half the mass of an elephant cortex, the human cortex still has three times more neurons, averaging 16 billion.

- Corvids and parrots have 1-3 billion neurons in their pallia, higher than most monkeys.

Birds have small brains, but higher neuron density

- The notion that higher encephalization (relative brain size deviation from brain–body allometry; humans at 8, have highest) endows species with improved cognitive abilities has recently been challenged

- New data suggests that intelligence instead depends on the absolute number of cerebral neurons and their connections

- Absolute rather than relative brain size is the best predictor of cognitive capacity.

Birds have small brains, but higher neuron density

- Avian brains contain many more pallial neurons than equivalently sized mammalian brains.

- Corvids and parrots have probably twice as many neurons in their brains as primate brains of the same size. And about four times as many neurons as mammal brains of the same size

- Conclusion: birds generally have higher neuronal densities than mammals, and further that parrots and songbirds have acquired an expanded pallium with increased neuronal densities and higher cognitive abilities.

Neuron densities

- Suzana Herculano-Houzel lab: 2016 Suzana Herculano-Houzel Study: samples from 28 different species

- The cellular composition of the brains of brains of songbirds and parrots contain very large numbers of neurons, at neuronal densities considerably exceeding those found in mammals.

- Because these “extra” neurons are predominantly located in the forebrain, large parrots and corvids have the same or greater forebrain neuron counts as monkeys with much larger brains.

- Despite a lack of layered neocortex, large areas of the avian forebrain are homologous to mammalian cortex, conform to the same organizational principles, and play similar roles in higher cognitive functions, including executive control

Seweryn Olkowicz et al., 2015

Avian Neuron densities

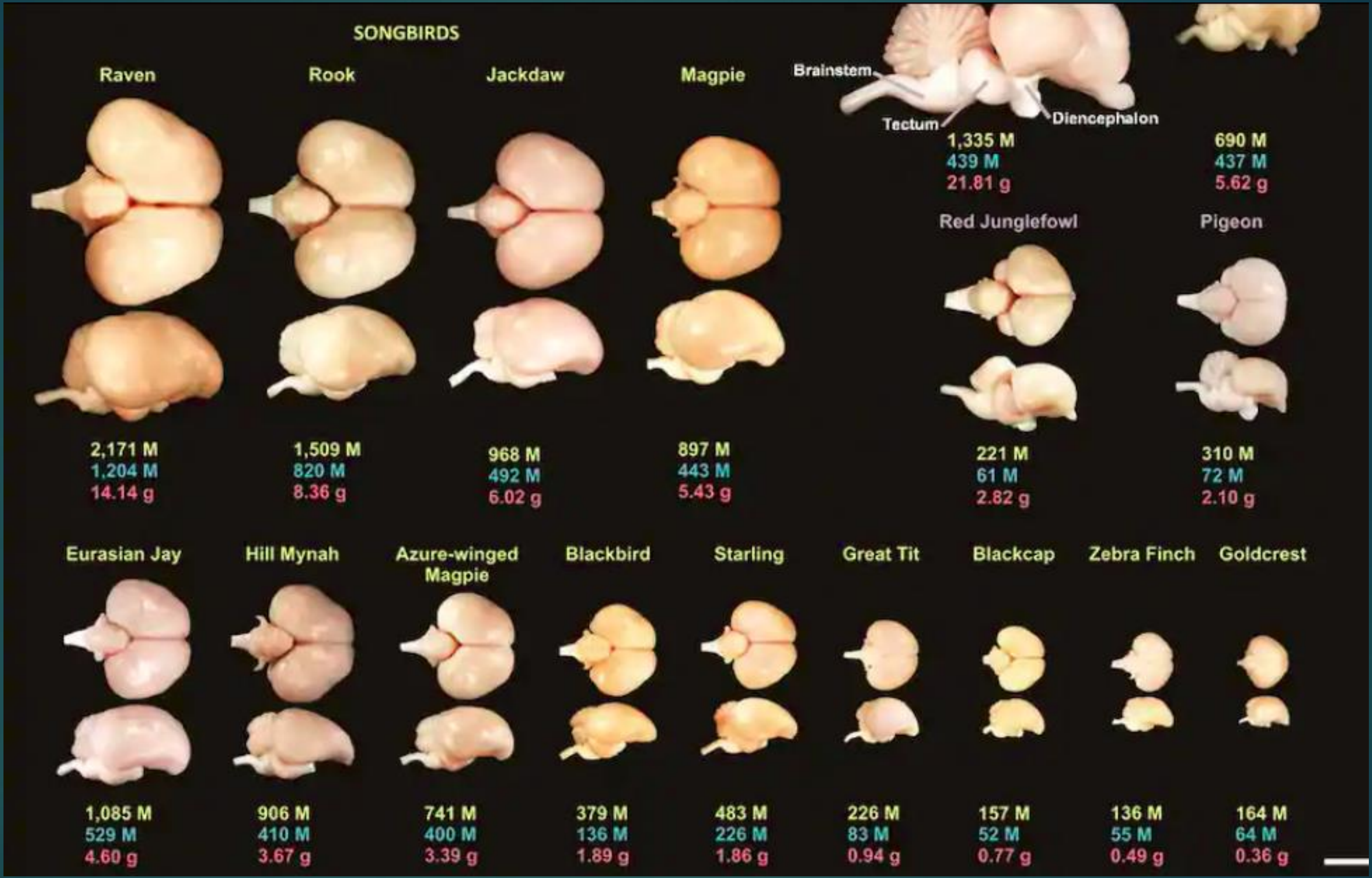
- Using the isotropic fractionator: brains of parrots and songbirds contain:
  - on average twice as many neurons as primate brains of the same mass,
  - avian brains have higher neuron packing densities than mammalian brains.
  - corvids and parrots have much higher proportions of brain neurons located in the pallium compared with primates or other mammals and birds; substantially contribute to the neural basis of avian intelligence.
  - Avian brains thus have the potential to provide much higher "cognitive power" per unit mass than do mammalian brains

Parrots & neuron

Parrots: Total number of neurons (in millions) in their brains in yellow, the number of neurons (in millions) in their forebrains (pallium) in blue and their brain mass (in grams) in red

Corvids:
1-2 Billion
Neurons

55% in
forebrain



Avian neuron density

- The goldcrest has ~64 million pallial neurons, almost five times more than the mouse pallium.
- The raven or the kea have ~1.2 billion pallial neurons, more than in the pallium of a capuchin monkey
- The blue-and-yellow macaw has ~1.9 billion pallial neurons, more than in the pallium of a rhesus monkey.

Neuron density in cortex

Cat	250 M
Magpie	443 M
Racoon	450 M
Capuchin Monkey	650 M
Crow	820 M
Grey Parrot	850 M
Dog	885 M
Raven	1.2 B (2.2 B total)
Kea	1.3 B
Rhesus	1.7 B
Macaw	1.3 B (3.1 B total)
Chimp	7 B
Dolphin	12 B
Human	16 B (of 87 B total)

Bird vs Mammal Cortical Neuron Density Comparison

64 M neurons

1.2 B neurons

70 M neurons

Capuchin monkey

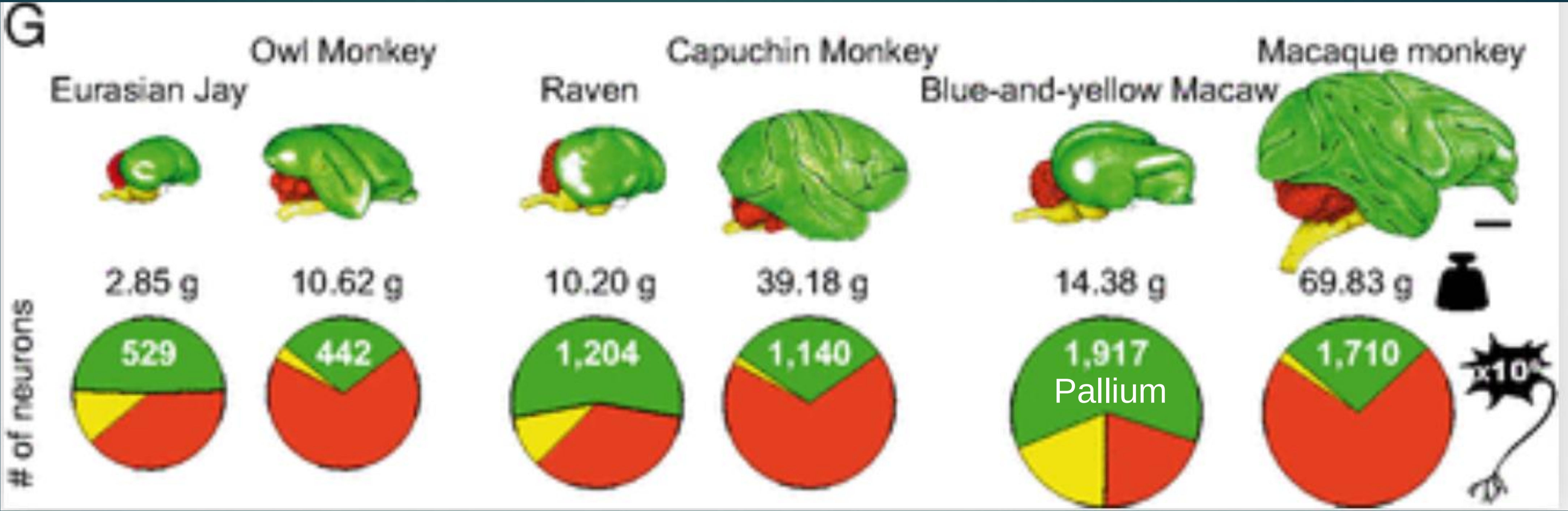
1.1 B neurons

Macaw

3.1 B neurons

Rhesus monkey

1.7 B neurons



- Numbers under each brain represent mass of the pallium (in grams) and total numbers of pallial/cortical neurons (in millions).
- Circular graphs show proportions of neurons contained in the pallium (green), cerebellum (red), and rest of the brain (yellow).
- Brains of these highly intelligent birds harbor absolute numbers of neurons that are comparable, or larger than those of primates with larger brains.

Faster neuronal connectivity

- How do birds compensate for small brain? A greater concentration of neurons results in the distances between avian neurons being shorter.
- In tasks in which information is repeatedly sent back and forth among groups of neurons in the densely packed cerebrum, a time gain may result as signals take less time to travel from one point to the next.
- Pigeons can react faster than humans when working on a particular cognitive task.
- The density of neurons in the bird pallium compensates for some of the smaller neuron numbers by affording faster conduction speeds.

Neuroanatomy Conclusions: Neuron Density & Connectivity

- Finding of greater than primate-like numbers of neurons in the pallium of parrots and songbirds suggests that the large absolute numbers of neurons in these two clades provide a means of increasing computational capacity, supporting their advanced behavioral and cognitive complexity, despite their physically smaller brains.

- Moreover, a short distance between neurons, the corollary of the extremely high packing densities of their telencephalic neurons, likely results in a high speed of information processing, which may further enhance cognitive abilities of these birds.

- Thus, the nuclear architecture of the avian brain appears to exhibit more efficient packing of neurons and their interconnections than the layered architecture of the mammalian neocortex.

** Corvid Fun

Crows like to play

- Play is relatively uncommon in birds, seen in only 1% of the approximately 10,000 species
- Corvids are playful.
- Engage in non survival behavior. Are they too smart and get bored?
- Tail Pulling
- Swinging
- Crow skateboarding

Play

- Corvid play challenges historical idea of evolutionary utilitarianism: only behavior that favors survival will spread in an animal population; corvids engage in activities with no apparent link to survival.

- Kea: most extravagantly playful of all birds. Voraciously novelty-seeking, often motivated more by play than food. Spend time tossing and catching objects, tussling with one another.

- Ravens: repeatedly slid down snowbanks and roofs for fun; executing rollovers in flight without necessity

Play

- Play activities--by definition--are any that serve no immediate biological function (survival and reproduction).
- The corvids, according to expert testimony, are irrepressibly playful. In fact, they show the most complex play known in birds.
- Ravens play toss with themselves in the air, dropping and catching again a small twig.
- They lie on their backs and juggle objects (in one recorded case, a rubber ball) between beak and feet.
- They jostle each other sociably in a version of "king of the mountain" with no real territorial stakes.

Play

- Crows are equally frivolous.
- They play a brand of rugby, wherein one crow picks up a white pebble or a bit of shell and flies from tree to tree, taking a friendly bashing from its buddies until it drops the token.
- And they have a comedy-acrobatic routine: allowing themselves to tip backward dizzily from a wire perch, holding a loose grip so as to hang upside down, spreading out both wings, then daringly letting go with one foot; finally switching feet to let go with the other.
- Such shameless hot-dogging is usually performed for a small audience of other crows.

Delinquency? Like to steal cigarettes in India: always trying out their environment; pet crows known to take them out of pockets of owner

Juvenile delinquent

Fearless: crow vs eagle

Only bird known to do this: eagle will climb until crow has no oxygen

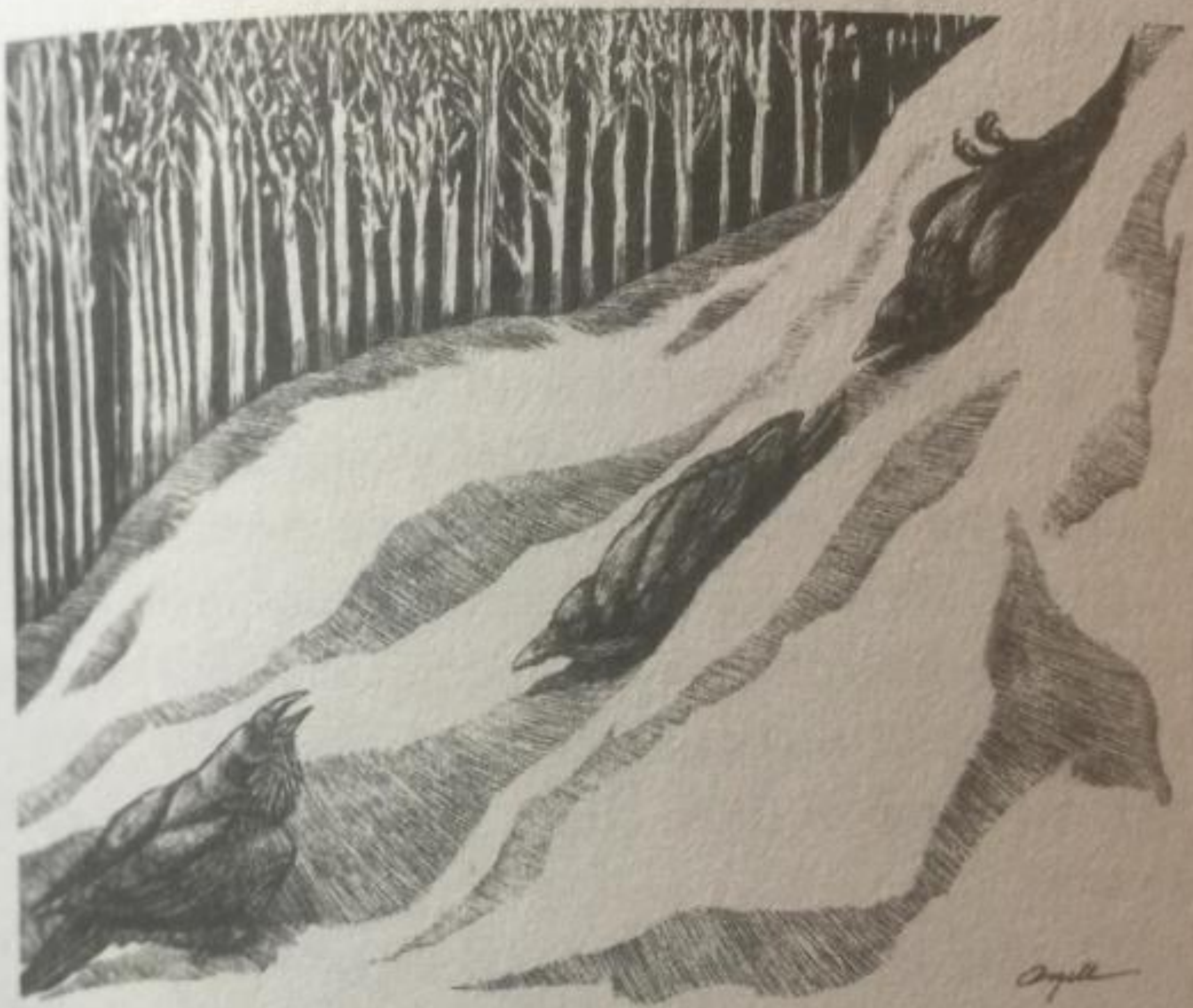
Or a vulture will do

Swinging

Story about ravens from John Marzluff's book, "Gifts of the Crow

- Wind surfing on updrafts in Colorado's Rocky Mountain National Park: "On this windy October day in 1999, a group of eight ravens took their practice to a more sophisticated level and surfed the gale, gripping quarter-inch thin, concave arcs of tree bark in their feet. Pairs of birds spread their wings and launched into the air. Without flapping, the birds used their legs to angle their inch-and-a-half-wide by six-inch-long bark surfboards into the wind so that they soared, then dived, slipped this way and then that. Each bird hung all eight of its toes off its board and maneuvered it perpendicular to its body, like a snowboarder slows a too-rapid descent. The surfers rose to fifty feet above the overlook, rarely higher. Oblivious of the human onlookers below, one pair surfed while the others rallied and chased, trying to steal the boards and take their turns at the fun." Lasted for an hour.

Fun: Using bark to surfboard on the wind updrafts of the Rocky Mountain National Park



Ravens often slide in snow.

Young ravens often play tug-o-war.

Omar, a pet crow, lured the family cat into games with a shoelace.

Captive raven playing with ball


Crowboarding: Russian roof-surfin' bird caugh...
Watch later
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Play (k)

Bird bait

Picking on a wiener…

Another tail…

All kinds of tails…

Smart or foolish?

Enough…

Just one more…

Don’t even think about it

Nest material from any source…

Somebody is going to eat crow tonight.

Let me help you with your shoe lace

Anting and the problem of self-stimulation
K. E. L. Simmons, 1966

- Anting behavior has been claimed for mammals but the evidence suggests that, in its characteristic forms, it is confined to birds and, in particular, to passerine birds. True anting consists of highly stereotyped movements whereby a bird rubs itself with mouthfuls of squashed ants. Crows wallow amid busy ant colonies and let themselves become acrawl. They revel in formication. Autoerotic stimulation?
- Active or passive anting has been recorded from 21 passerine species in 10 families in the wild, and in captive birds in a further 27 species of 3 families.
- Bactericidal and Fungicidal Activity of Ant Chemicals on Feather Parasites: self medication hypothesis that birds apply ants to control feather parasites was not supported.

Social eye gaze: object permanency – 3-4 yo child; pay close attention to what others are looking at or pointing at

*** Problem Solving Ability

Bird Ability tests used in experiments

- String test (2 strings, 1 with food): problem solving (PS): pass = crows, parrot, chimps, us; fail = dog
- Clear Box with multiple accesses with food inside: PS; pass = crows, parrot
- Aesop's water tubes (drop objects, water raises food): tool use, PS; pass = crows, jays, 5-7 yo kids
- Spoiled Food Test: memory, understand passage of time: pass = jay
- Family Ties Test: social IQ, visual recognition; pass = jay; not as friendly to non-relatives
- Facial Recognition Test: visual processing, LTM, rapid learning; 1 negative experience leads to permanent grudge

String Pulling

- Roman historian Pliny the elder: wrote of practice of training captive goldfinches to pull up a tiny bucket on a chain in order to get their water and food

String Pull test

- “String-pull" test. Bird’s favorite food, i.e. a peanut, is dangling on a string. He'll have to pull the string up to get the peanut.
- Bird had not been trained to do this. In fact, he's never seen this puzzle before, and it isn't a skill a corvid or parrot normally needs.
- New Caledonian crows, ravens, African gray parrots, and keas can do string pull test.
- The birds all use the same stepwise method: They pull up the string with their beak, then step on that segment with their feet, freeing their beak to pull up more string, and so on, until they reach the treat.
- Once he's figured it out, he can repeat it without trial and error.
- Even if the rewards and strings swapped around, they learn to pull the right one most of the time.

New Zealand Kea: String pull

Two String pull

Ice fishing version of string pull

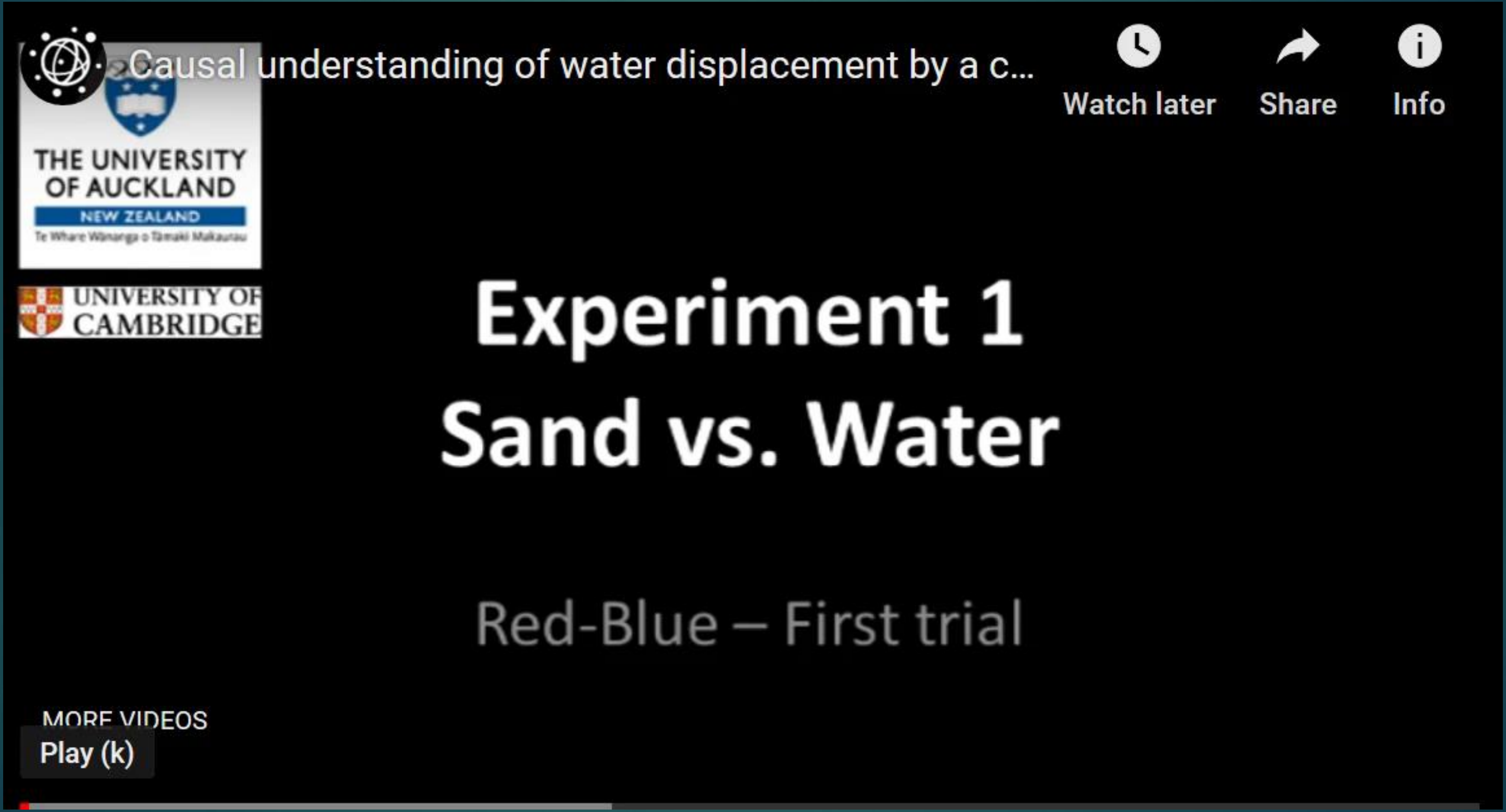
- There's the one about the hooded crow, a species whose range includes Finland: "In this land Hoodies show great initiative during winter when men fish through holes in the ice.
- Fishermen leave baited lines in the water to catch fish and on their return they have found a Hoodie pulling in the line with its bill, and walking away from the hole, then putting down the line and walking back on it to stop it sliding, and pulling it again until [the crow] catches the fish on the end of the line.

Crows understand water displacement

- In Aesop's fable of "The Crow and the Pitcher", a thirsty crow drops stones into a water pitcher to raise the water level to take a drink
- New Caledonian crows can not only tell the difference between water and sand - they also understand water displacement.
- The test involved tubes containing water and a treat floating on top out of reach. The crows filled the tubes with enough rocks or other heavy items to bring the food within reach.

Aesop's fable

- They also were presented with different scenarios, such as tubes with different water levels. The crows showed an absolute preference for the tube that would get them the food with the least amount of work.
- Human children gain this understanding of volume displacement around the ages of five to seven.


Causal understanding of water displacement by a c...
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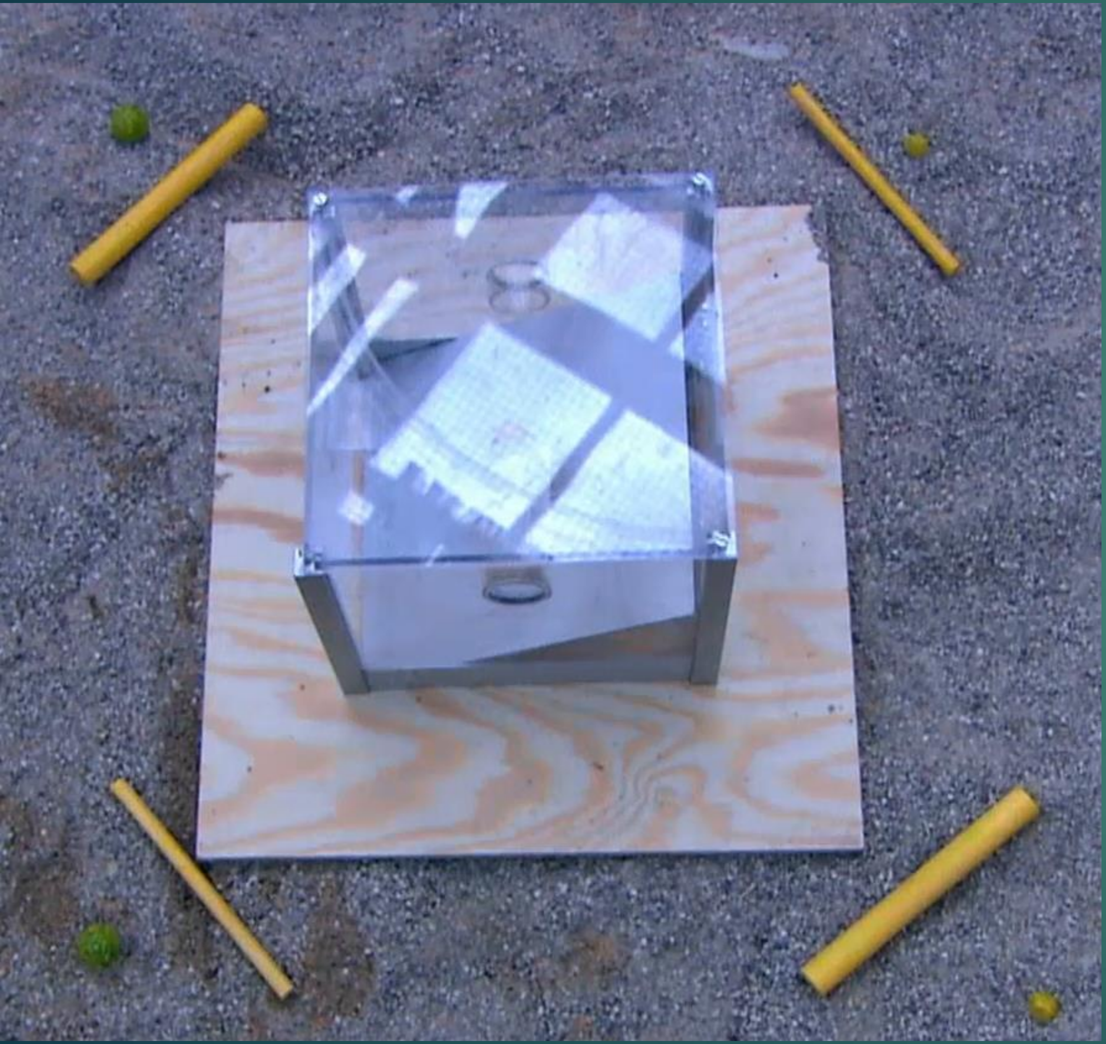
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
UNIVERSITY OF CAMBRIDGE
Experiment 1
Sand vs. Water
Red-Blue – First trial
MORE VIDEOS
Play (k)

Aesop series

Aesop’s crow

Multiaccess box with peanut at center: 4 solutions



1 – if peanut attached to string; pull it out

2 - use a stick to poke peanut out

3 - roll a ball into the peanut

4- open a door on side and pull peanut out

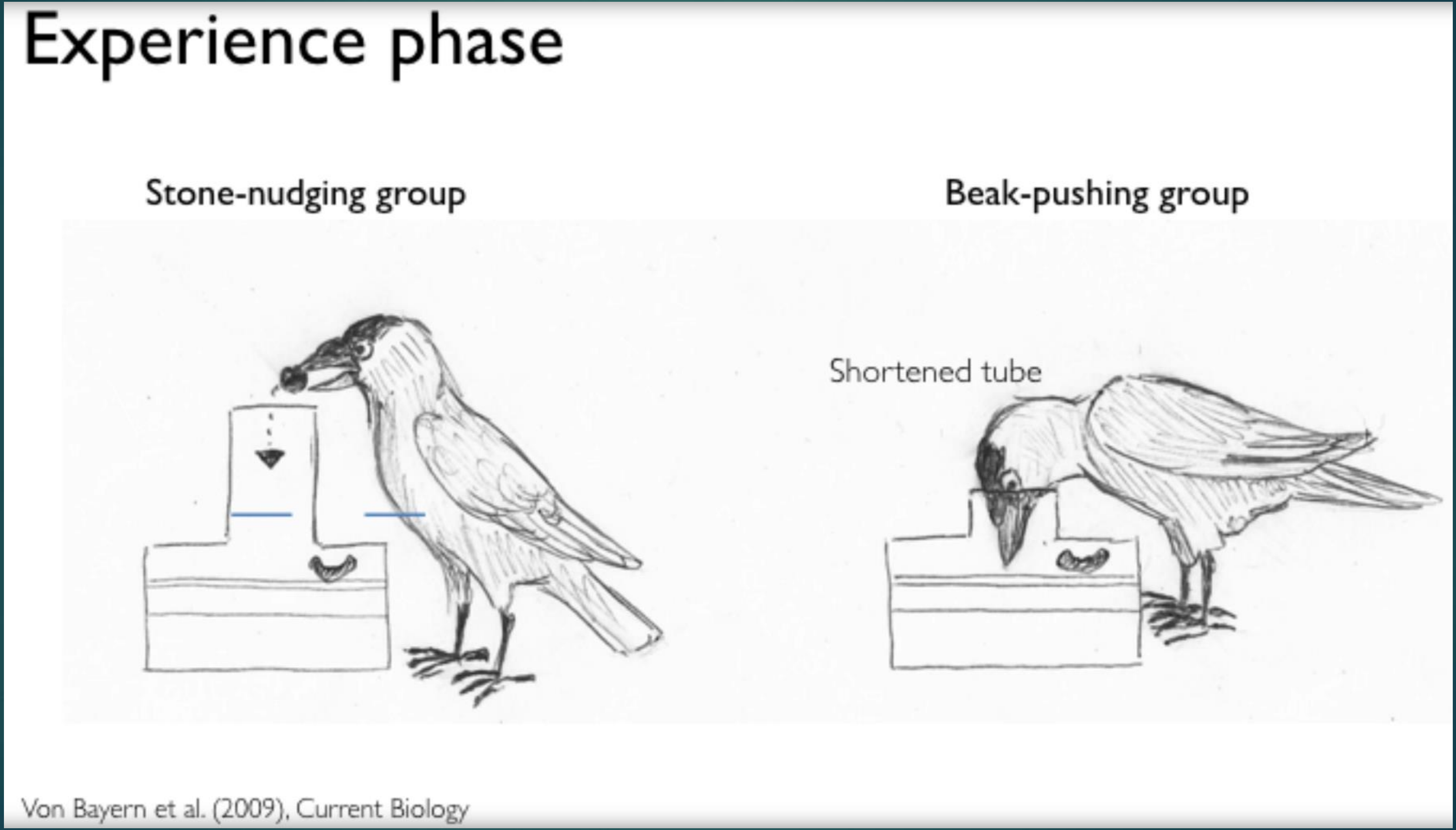
Kea do not use tools in wild

Ability to use flexible thinking

New Caledonian Crow & Kea parrot: both used all 4 solutions

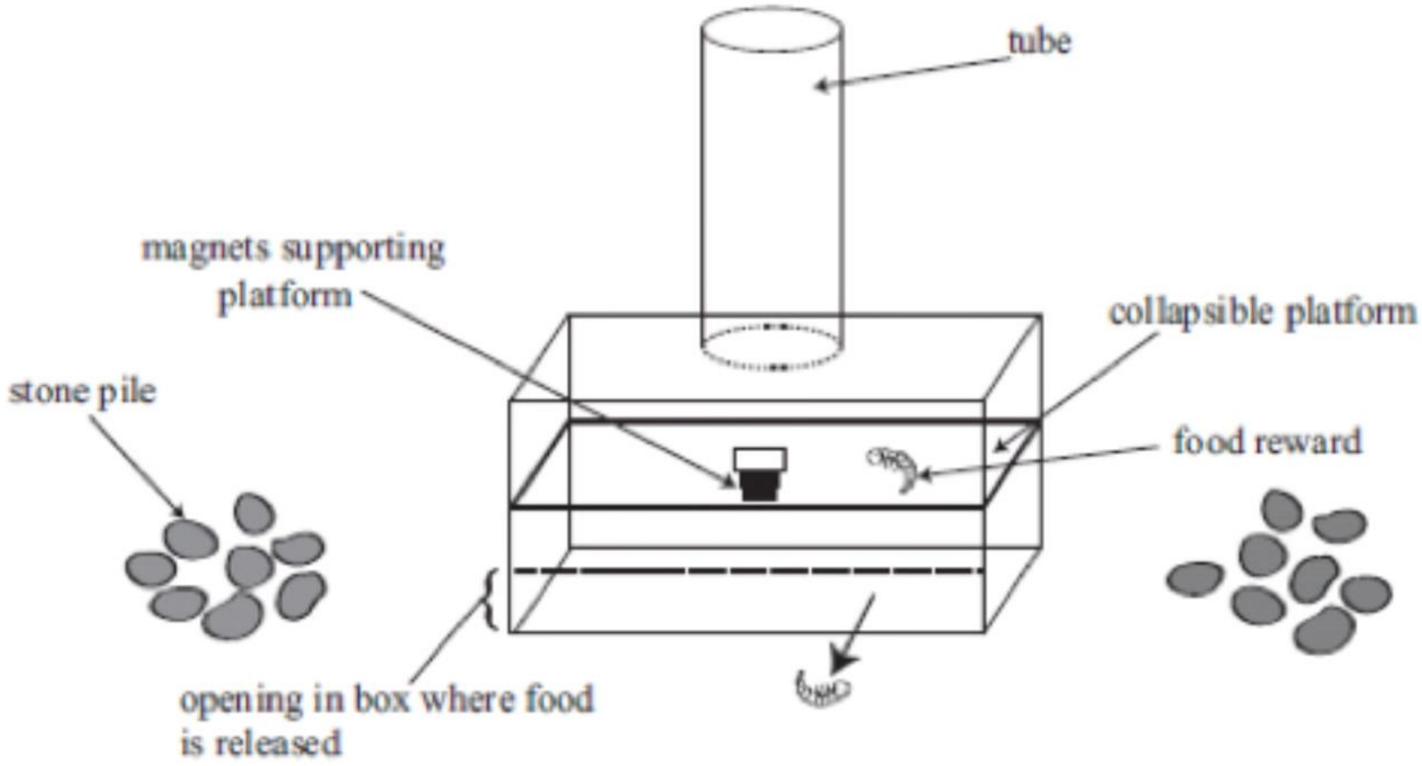
- Both first pulled peanut out using the string

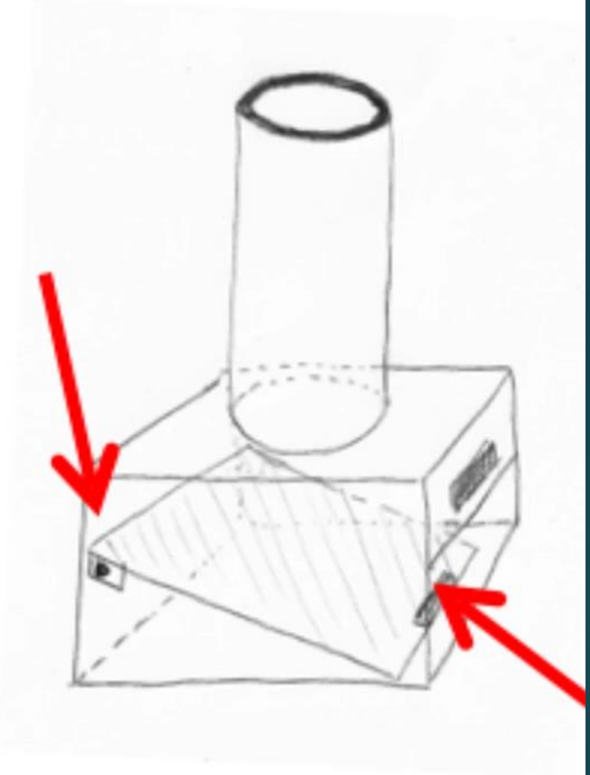
Causal reasoning: Crows do not use stones in wild; need to push trap door at bottom to get food treat



Causal reasoning

Von Bayern et al. (2009),Current Biology





Apparatus and experimental setup

Muppet the cockatoo: Problem solving

- Multistep problem: She placed a puzzle box containing a cashew nut on the platform. Muppet, a cockatoo, could glimpse the nut through a window in the box's door, but the door couldn't be opened until five sequential locks were removed:
  - remove a pin,
  - Unscrew a nut on a screw,
  - then remove a bolt;
  - turn a wheel 90 degrees;
  - shift a bar latch.
- Each lock jammed access to the next lock, so they had to be opened in a specific sequence.
- Other birds who watched the first attempt did all steps immediately and never forgot them for years.

A pin, a screw, a bolt, a wheel, and a bar in correct sequence

Multiple steps

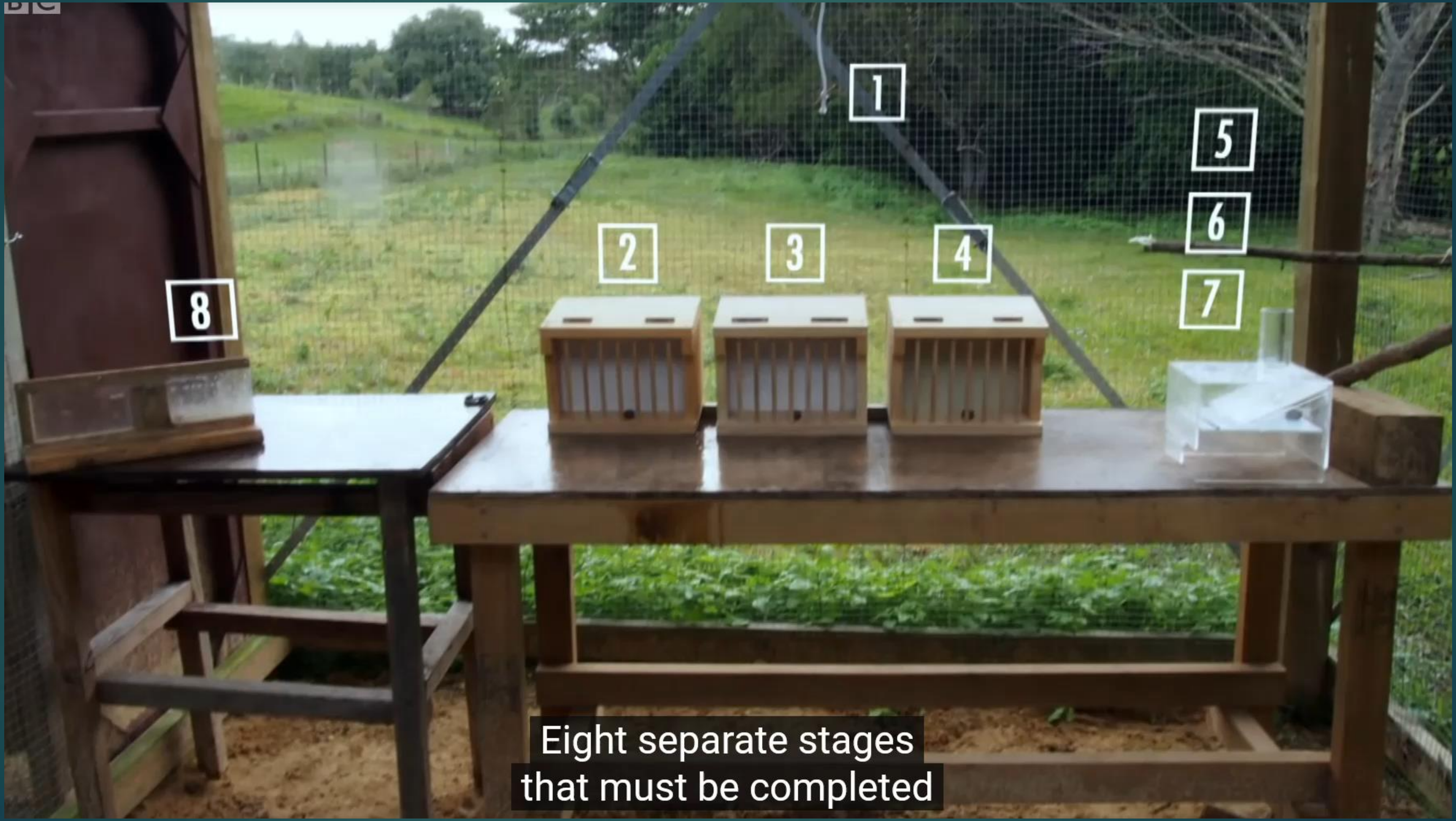
Crows can solve complex, multi-step puzzles

- In 2014, a New Caledonian crow named "007" by researchers from the University of Auckland in New Zealand solved an eight-step puzzle to get to some food.

- Wild crow, nicknamed 007, is apparently a genius. The puzzle involved eight individual steps that had to be solved in a very specific order to release the food reward.

- He was familiar with the individual tools, but had not had to combine their use before.

8 steps to get food



New Caledonian Crow (NCC) tool use

- The NCC's *tool kit* includes:
  - straight stick tools,
  - hooked stick tools
  - complex shapes of barbed leaf,
  - grass-stem probing for lizards and
  - candle-nut dropping onto rocks are described.

- Different populations of NCC have differing tool kits

NCC: 4 modes of tool use

- NCC show four modes of tool use in nature and four in captivity.

- *Drop objects*. Wild NCC drop candlenuts (*Aleurites moluccana*) from notched branches onto rocks below, in order to crack them open. Such standardized (aimed?) release from a specific launching site seems to be unique to NCC

- *Pry, apply leverage*. Crows in captivity bend segments of wire to make a hooked tool, by using the lip of a glass cylinder as a fulcrum.

NCC tool use

- *Insert and probe*. Wild crows insert elongated segments of various kinds of vegetation (leaf, petiole, stem, twig) into cavities or crevices, in order to extract prey items (e.g. long-horned beetle larvae) contained therein.

- *Use to Reach*. Captive crows use probes to retrieve objects from behind barriers or to investigate novel, artificial objects, but this has not been seen in nature.

- *Jab*. NCC use grass-stems to dislodge lizards from crevices.

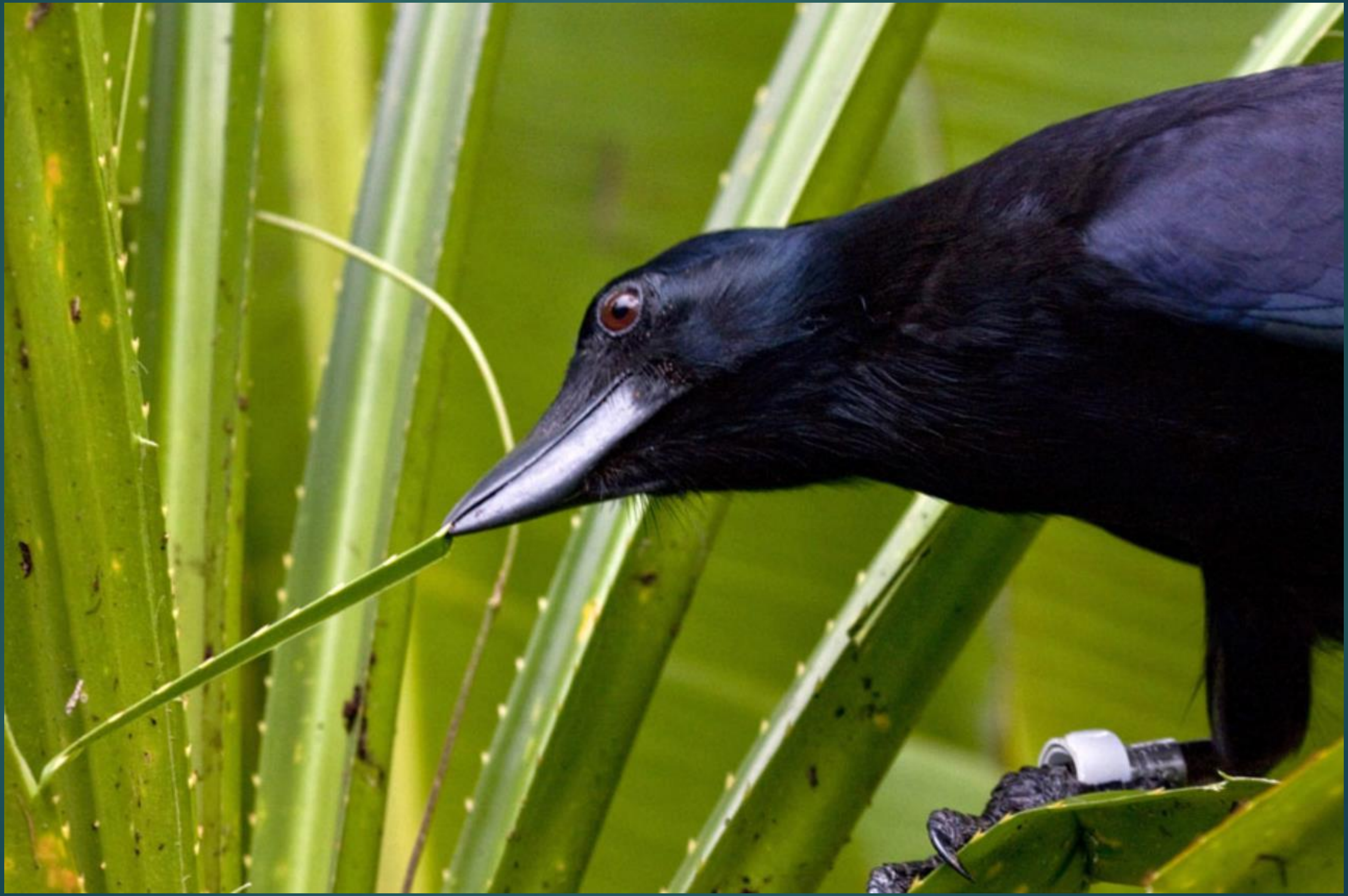
New Caledonian tool use

Grub target of tool use: long-horned beetle larvae. Latter grab stick with pincers.

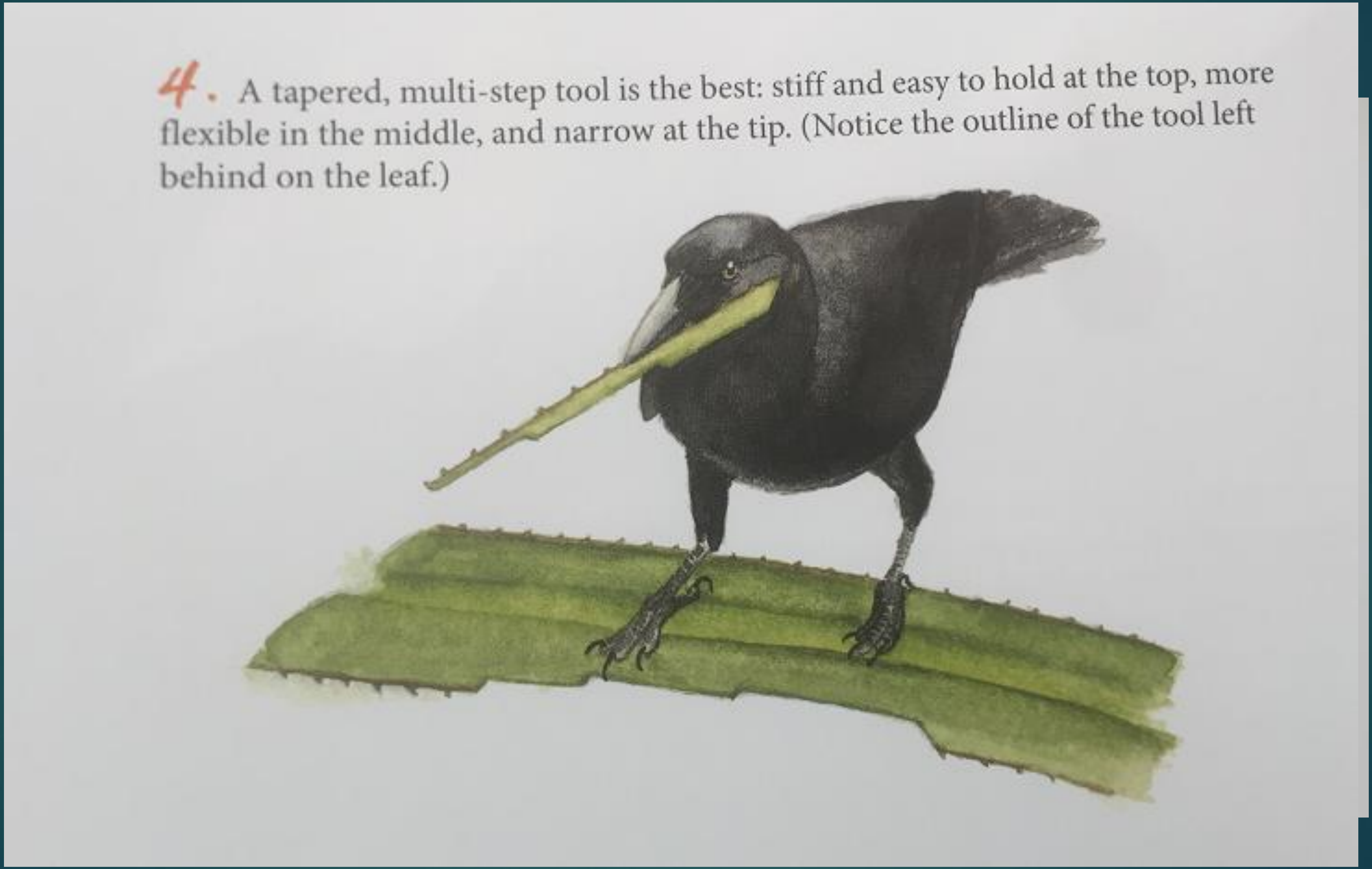
New Caledonian Crow using stick to pull out grub

Pandanus plant on New Caledonia

Tearing off 3 tier tool from Pandanus plant



3 step tool: *Pandanus* leaves



4. A tapered, multi-step tool is the best: stiff and easy to hold at the top, more flexible in the middle, and narrow at the tip. (Notice the outline of the tool left behind on the leaf.)

Crow: straight and hooked wire; food in handled bucket in tube

Cognitive buffer hypothesis

- Cognitive buffer hypothesis, introduced in the early 1990s, posits that animals capable of coming up with new behaviors are better able to respond to environmental change.
- Bird species that have larger brains and are thus more capable of innovating new foraging techniques have an above-average chance of finding a way to survive if normal habitat is disrupted

Louis Lefebvre: Bird Innovation and extinction

- Study: bird species trying a new food or using a novel foraging technique -- database covered more than 10,000 bird species and documented more than 3,800 behavioral innovations.
- Test whether birds' propensity for innovation correlated with their risk of extinction
- Species that had demonstrated at least one behavioral innovation were generally at a lower risk of extinction than species that had never been observed to innovate at all. Moreover, species with three or more documented innovations were more likely to have increasing populations than species with just one or two new behaviors.
- Birds' capacity to innovate is more important for extinction risk than individual innovative behaviors.

Brains, Innovations and Evolution in Birds and Primates

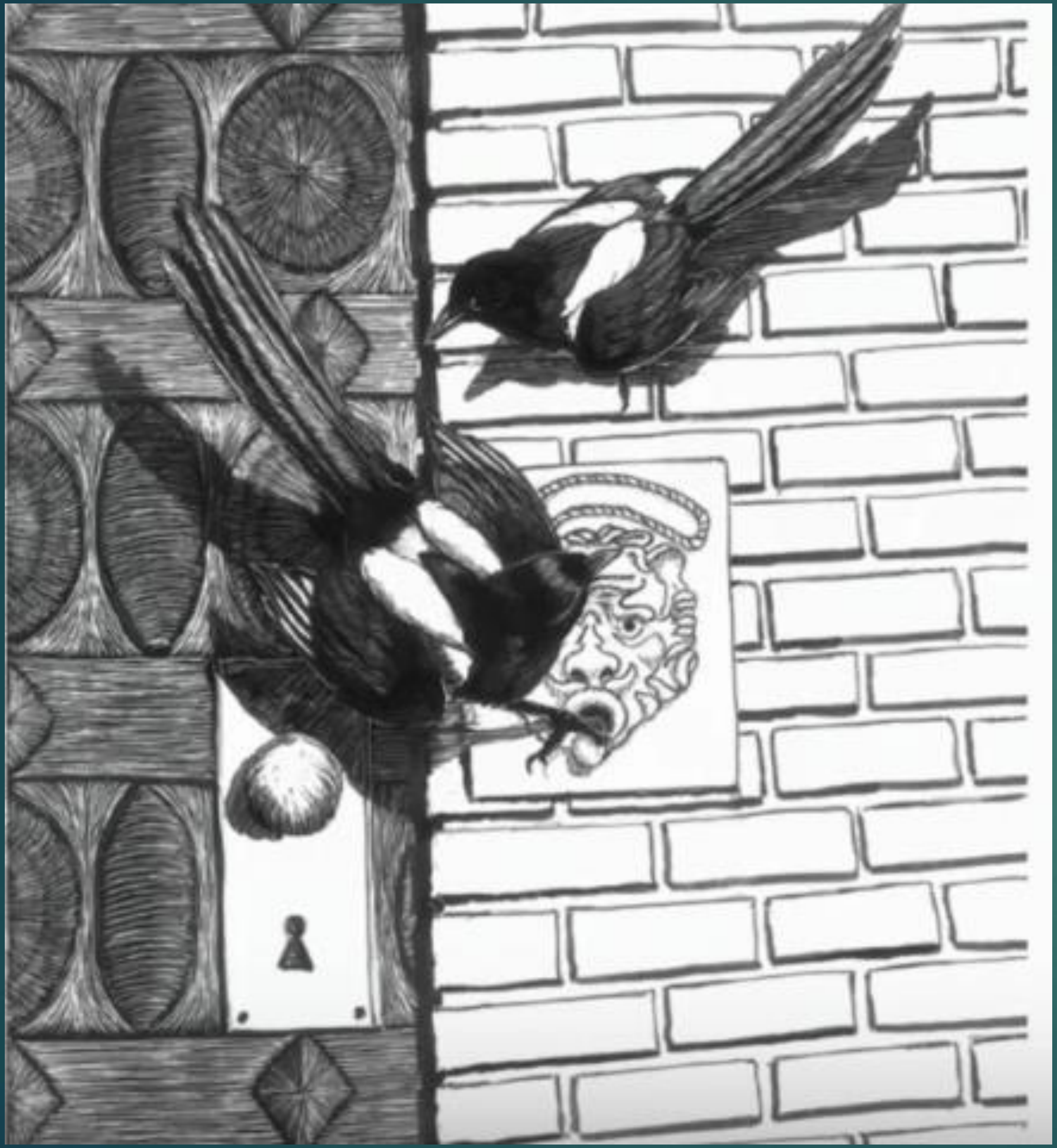
- They recorded frequency of individual behavioral innovations

- In both birds and primates, innovation rate was
  - positively correlated with the relative size of association areas in the brain in birds and the cortex and striatum in primates.
  - positively correlated with the distribution of tool use, as well as interspecific differences in learning.

- In birds, innovation rate is associated with the ability of species to deal with seasonal changes in the environment and to establish themselves in new regions, and it is related to the rate at which lineages diversify.

Innovation

- Interestingly, innovation did not correlate with caching behavior (tradeoff in anatomy space for problem solving vs memory?)
- Innovation rate is associated with
  - Invasion success,
  - evolutionary diversification,
  - cognitive measures like tool use and associative learning,
  - relative size of the brain and its main integrative areas
- Suggest a striking pattern of convergent evolution between primates and birds.



Magpie’s in Sweden were feed by a woman.

Would watch her in her window.
Would peck at her window.
Eventually started ringing her doorbell.

Did not like her husband who threw rocks at them.

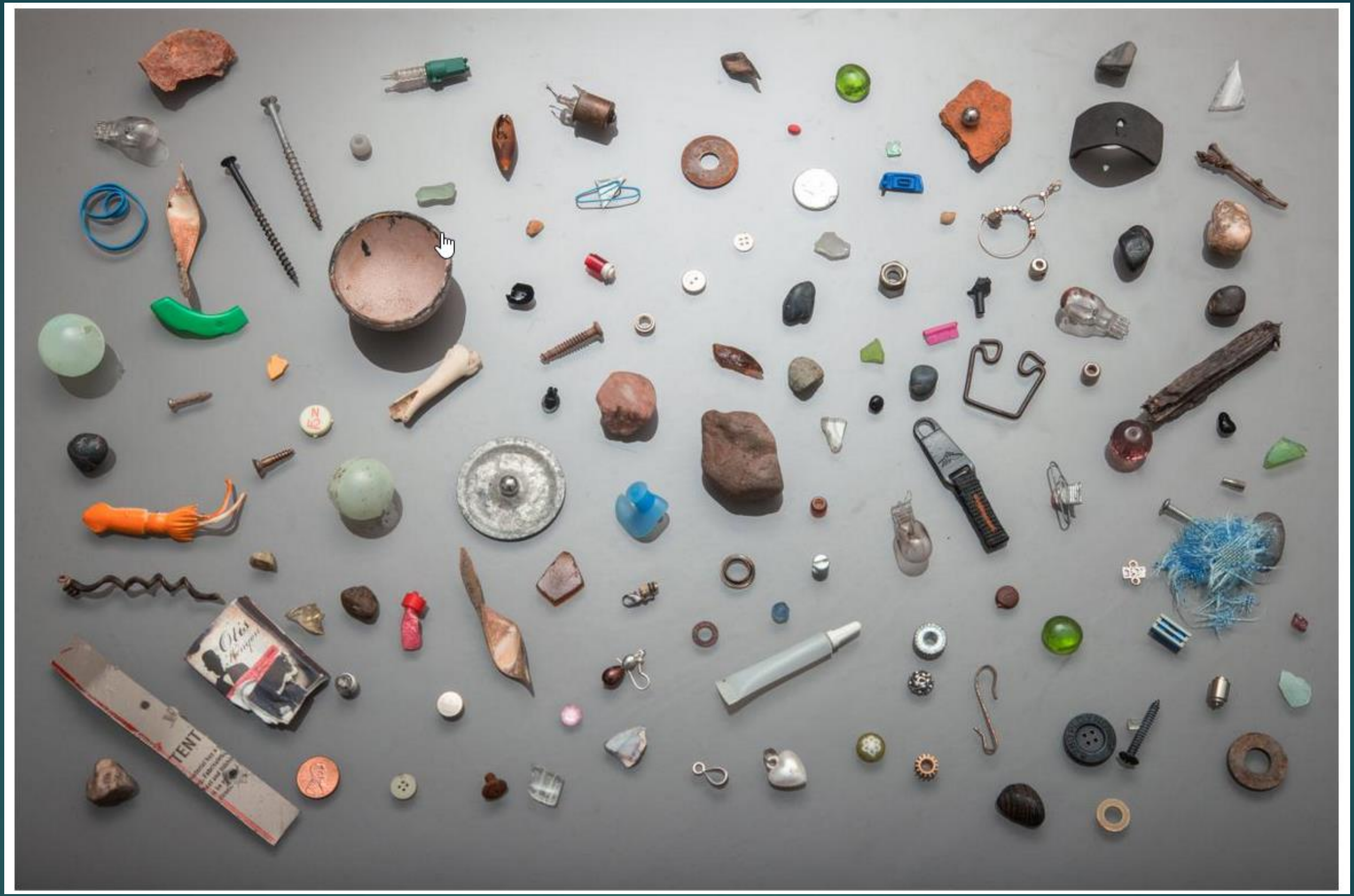
They crapped on his windshield on regular basis; only on the driver’s side

Corvids remember people who have been nice to them

- Corvids remember people who have been nice to them and can hold a grudge.
- Study: ravens trained to trade a low-quality snack (bread) for a high-quality snack (cheese). Then two humans brought the cheese to trade for the bread.
- One fairly gave the cheese when the crow handed over the bread. The other ate the cheese themselves after being given the bread.
- After an interval - two days, and then later one month - three humans entered the enclosure, the fair one, the unfair one, and a neutral control. The raven was given a piece of bread to trade. Most of the ravens chose to trade with the fair experimenter - indicating that they remembered being cheated out of delicious cheese and weren't falling for that again.

Collecting

- *Do crows collect shiny objects?*
- There is no evidence that crows keep collections of inedible objects (shiny or otherwise)
- New Caledonian crows keep their favorite stick tools cached in “toolboxes” so it appears that at least some species of crows do cache certain kinds of inedible objects!



The American crows in Gabriella Mann's Seattle Neighborhood love her, and the eight-year-old girl has the goods to prove it. Young Gabi Mann befriended crows in her Seattle neighborhood, setting out nuts and dog food. In exchange they brought her gifts, including a pearlescent plastic heart, one of her favorites.

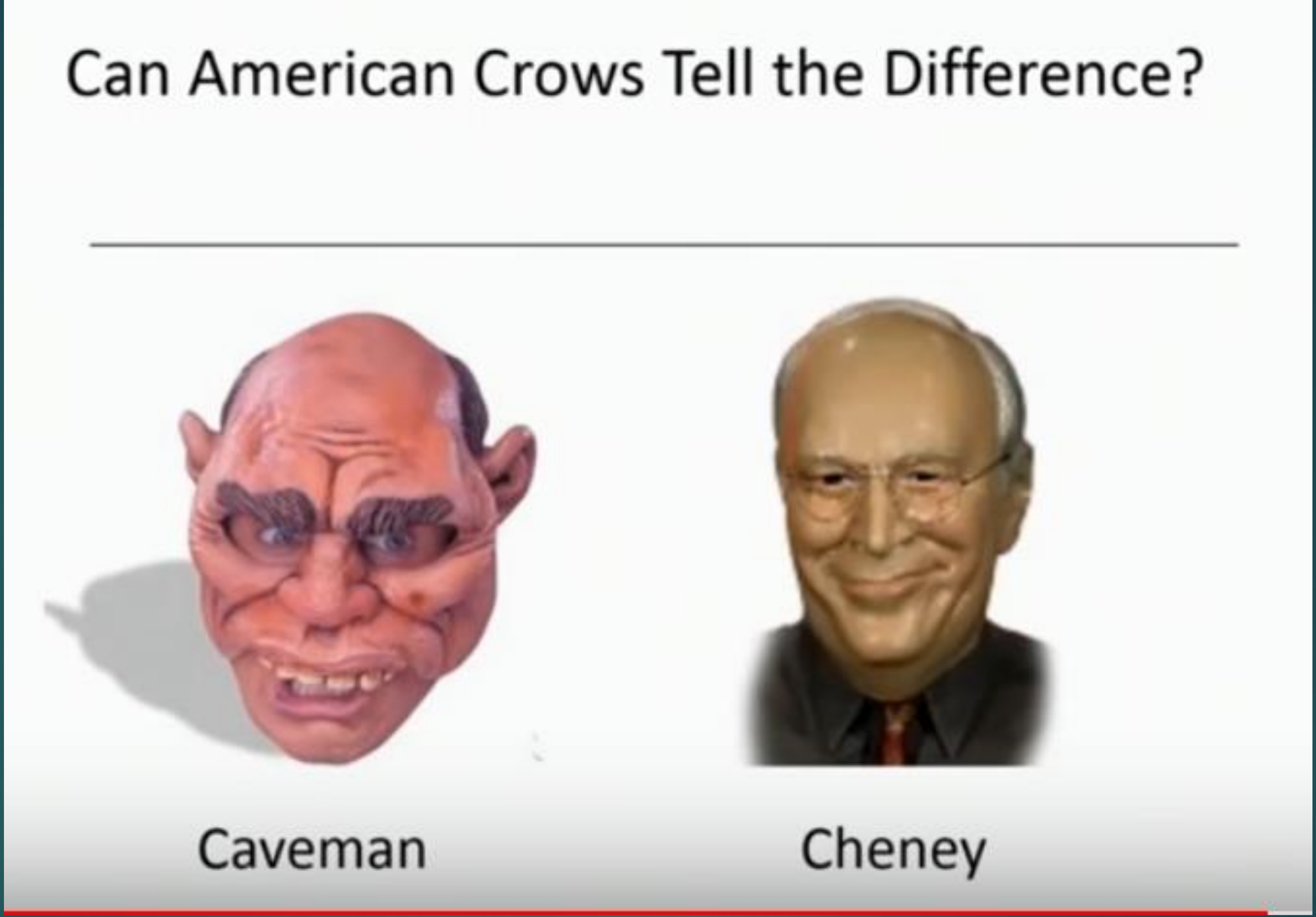
Gifts given to eight-year-old Gabi Mann by Seattle crows: at age 4, dropped a chicken nugget…now daily peanuts

Crows hold a grudge - and pass that grudge on to other crows

- If you think two crows watching you and cawing at each other are talking about you, you're probably right.
- Corvids can recognize individual humans.
- Crows remember faces and cars.
- Dr. Kevin McGowan of Cornell Univ. visited crow nests to tag birds. Thereafter he was always singled out for angry attacks by the crows.
- Dr. John Marzluff, Univ. of WA: mob those who harm them

N Mask

John Marzluff



Dangerous: carried taxidermed dead crow

Control researcher: no crow

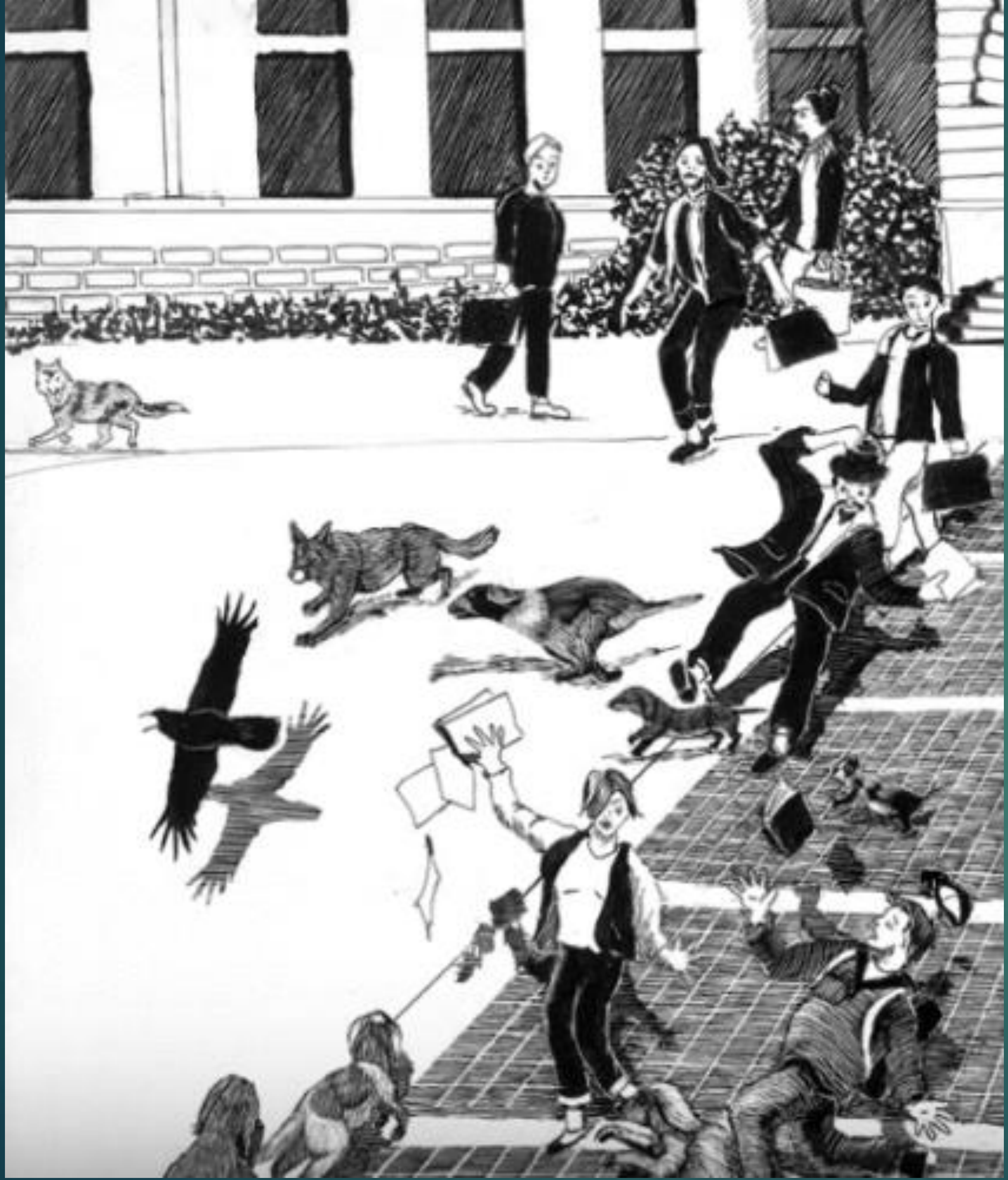
Grudges: facial recognition and generational memory

- Crows can pass on a grudge to their offspring — even to subsequent generations of crows harassed these masked scientists.
- Marzluff's group captured and tagged seven crows, and then let them go — while wearing creepy skin masks.
- Every time the scientists walked around campus with the masks the crows scolded and dive-bombed them. But not those wearing Cheney mask.
- And it was not only the seven captured crows, it was all the crows.
- Even successive generations of crows (now at 11 years) would display the exact same behavior when they encountered the masks. Clearly crows talk to each other, and they hold a grudge!

RECOGNIZING FACES.
In 2006 wildlife biologist John Marzluff donned mask like this and captured and banded seven crows.

Today if Marzluff or another person puts on the mask, the crows in the area—not just the original seven—gather to scold, dive-bomb, and follow him.

The crows don’t pester people wearing other masks.



Crow collected a series of dogs with his calls at a college campus.
Class would get out at which point crow took off and dogs chased the crow, running into students.
Food is thrown about.

Was this a food tactic or just for fun?

Crow was spotted lecturing a group of dogs on campus of Univ. of Montana

Bird Memory

- Food caching champs: Jays and corvids
- Birds who hide seeds have the best spatial navigation and spatial memory, much more than humans.
- Nutcrackers harvest and <u>cache more than 30,000 pine seeds every autumn, distributing them in several thousand tiny caches they need to remember through the winter. Get them 9 months later, sometimes thru feet of snow.</u>

Caching and deception

- Food hoarding birds employ a number of strategies to protect their food

- These protection strategies are flexibly adjusted to another bird's ability to see the actual caching of the food. When observed by a another bird that is not their partner, scrub-jays and crows will prefer to cache in places that are not visually accessible to an observer, for example behind an occluding barrier.

- They will also attempt to conceal their caches as best as possible, for example by hiding them further away from an observer or avoiding well-lit areas. They prefer to cache in quiet compared to noisy substrate when a present bird can hear but not see them.

Caching protection: only if you have been a thief

- However, they cannot control what another bird has seen at the time of caching: once they are alone, scrub-jays will return to a caching site and move caches made previously (i.e. while they were being observed) to new locations that are now unknown to a potential thief
- Cache-protection behavior has further been shown to depend on the birds’ individual experience with stealing.
- Birds that have previously stolen themselves, that is, that have had the experience of being a thief, are more likely to show cache protection strategies.
- Young birds do not steal.

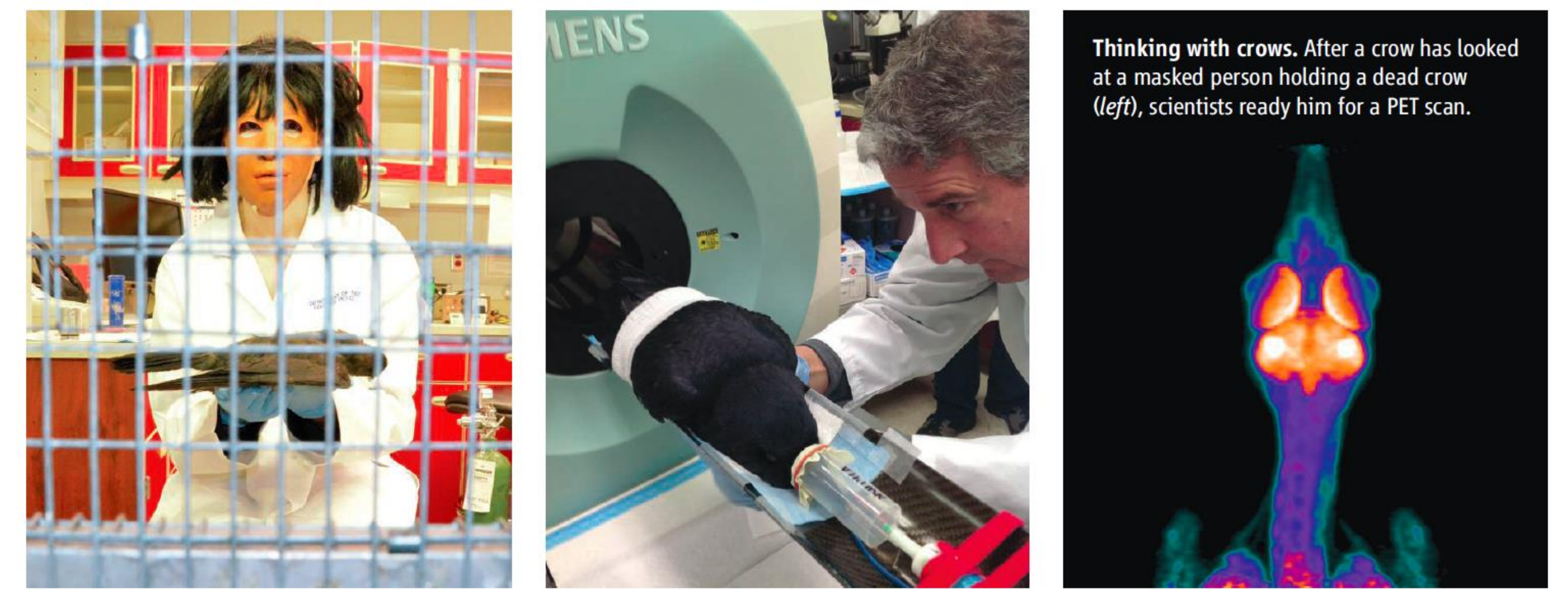
Crows have “funerals” for their dead

- When a crow dies, other crows are often observed gathering around and making a lot of loud noise - much like human wake.
- Current scientific conclusion crows gather around their dead fellows to learn about danger.
- “Funerals” are a teachable moment, in which the birds collectively make an association between potential danger and a particular spot or predator.
- They need only one experience to form a long-lasting memory of who or what can be trusted and who or what can’t and what is dangerous.

Crow “funerals”

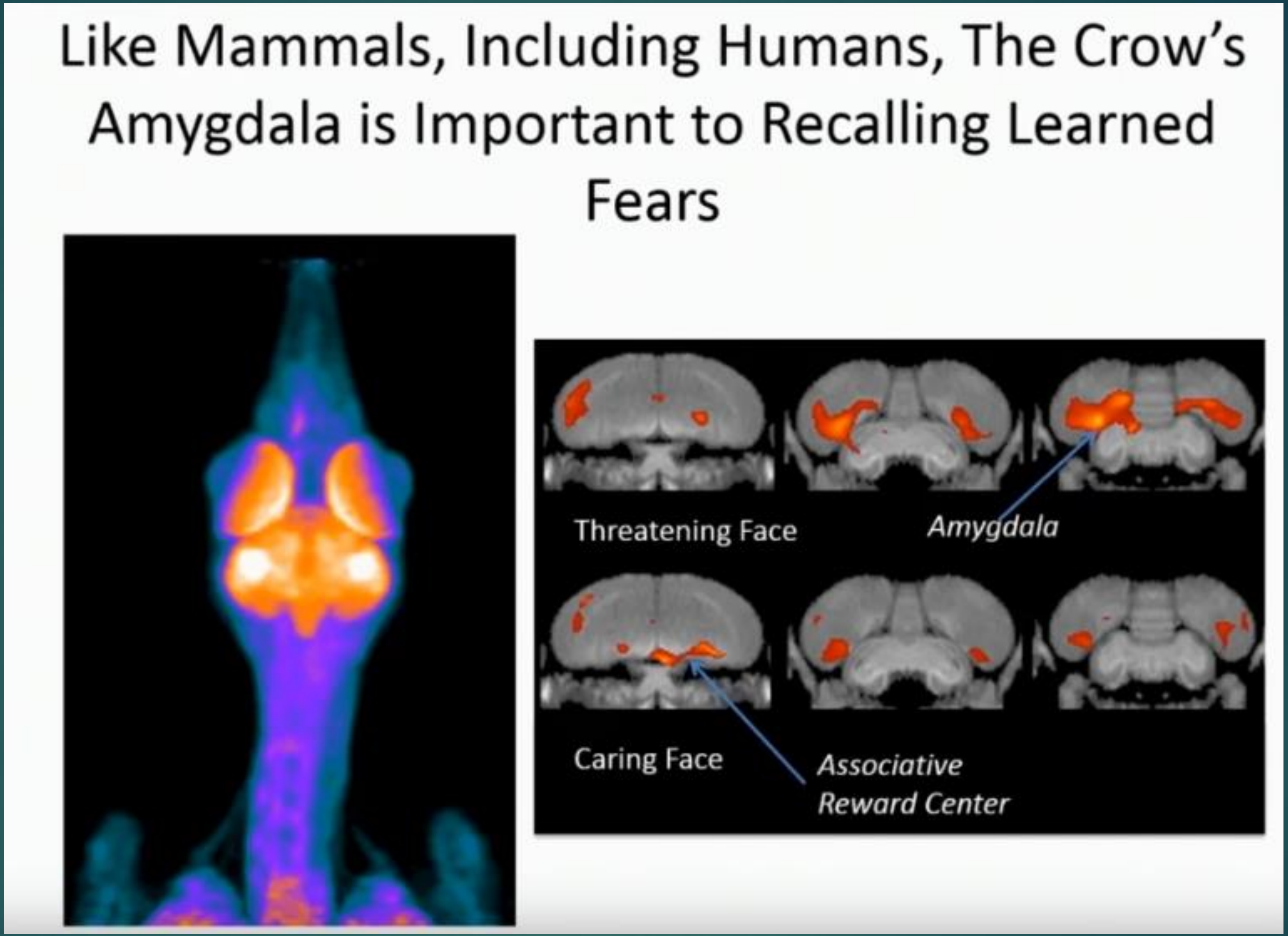
- Exposed to their dead, crows may touch, attack and attempt to have sex with the body.
- May be the result of hormonal fluctuations that cause some crows to become confused about how to respond to stimuli.

Pet scanning a bird experience



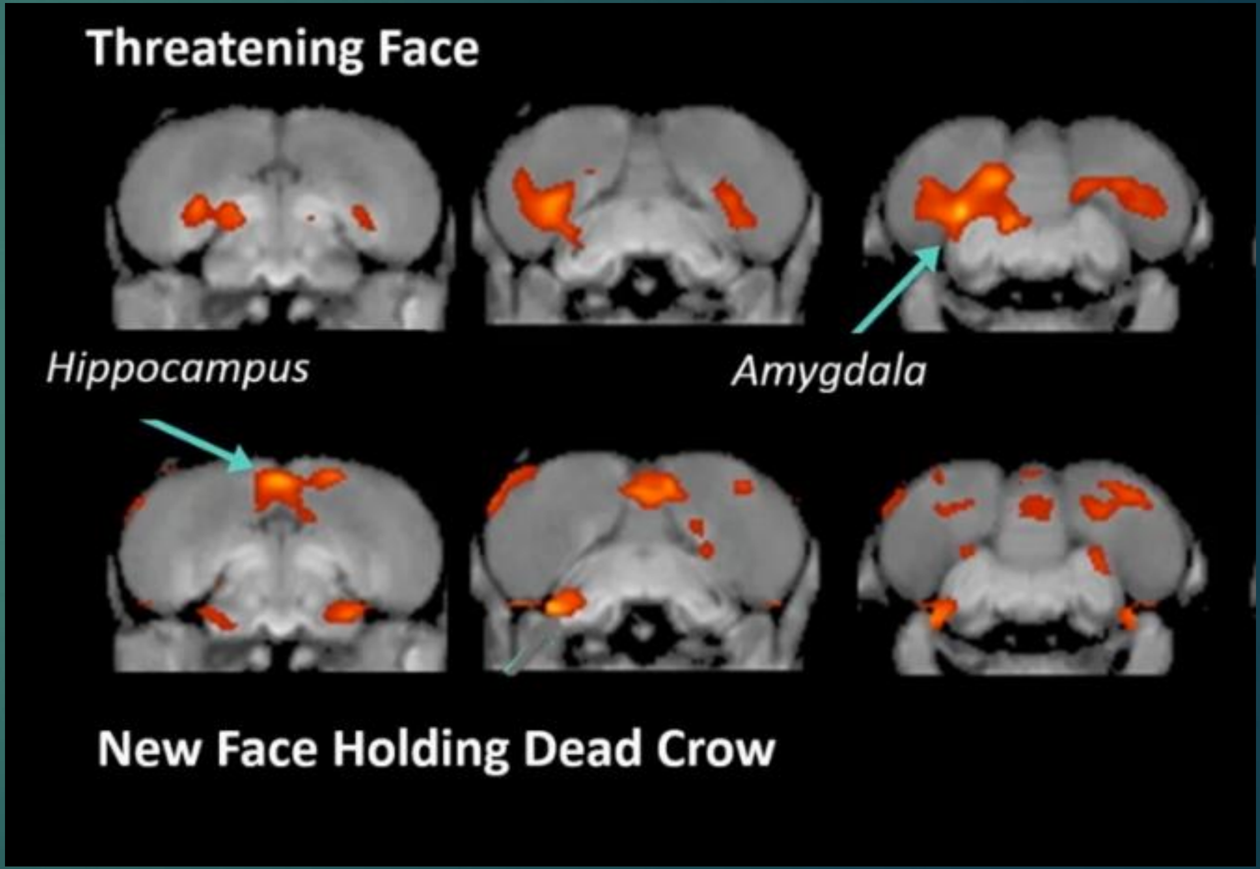
Thinking with crows. After a crow has looked at a masked person holding a dead crow (*left*), scientists ready him for a PET scan.

After viewing Caveman mask or a hawk



Right Amygdala activated by threatening face

Threat activates amygdala
Dead crow activates hippocampus



New face with dead crow triggers hippocampus

Learn about danger in environment.

Store new info about dead crow In hippocampus; does not trigger amygdala

Snowball, a sulphur-crested cockatoo, wowed YouTube fans—and neuroscientists—when he rocked in time to the Backstreet Boys' tune "Everybody" in 2007.

Cro-Bro

We can all get along together

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*** Sociality

Two crows were observed supporting an injured associate

Showing empathy

- Chickens are cognitively advanced. They live in hierarchical societies, track numbers and do basic math, and are likely to experience emotions, from boredom and frustration to happiness.
- And they show signs of empathy: If air is blown on chicks' feathers, which the birds don't like, their watching mother's heart rate goes up.

New Caledonian Crows: Social

- Social brain hypothesis: As with primates, complicated societies are the spur behind larger cortexes and complex cognition
- Birds' societies differ from those of mammals in a fundamental way: "The most basic social bond in mammals is between mother and infant, but in birds it's the pair-bond. It's a bond that develops through learning."
- Ravens begin trying to develop such social bonds when they're merely six months old, and before they're sexually mature.
- Most adult pairs are heterosexual, and the two adults work together to defend a territory for breeding and raising a family.
- Adults also form alliances with birds other than their mates to build social support networks. Ravens learn about each other—what other birds like or dislike, their personalities, who's brave and who's a coward—by watching them stash food and give and steal from one another.

Sociality

- Many corvid species separate into small family groups or "clans" for activities such as nesting and territorial defense. The birds then congregate in massive flocks made up of several different species for migratory purposes.
- Some birds make use of teamwork while hunting. Predatory birds hunting in pairs have been observed using a "bait and switch" technique, whereby one bird will distract the prey while the other swoops in for the kill.
- Social behavior requires individual identification, and most birds appear to be capable of recognizing mates, siblings, and young.
- Crows appear to be able to remember who observed them catching food. They also steal food caught by others.

Ravens use social ostracism to punish selfish peers

- These birds' complex societies include dozens of large interrelated families, with dominance hierarchies and ruling lineages. Ravens can understand other bird's rank by observation. Ravens have very complex societies with shifting political alliances.
- Ravens can't uninvite friends on Facebook, but they do exercise similar ostracism towards peers who did not cooperate.
- In a 2015 study, researchers from the University of Vienna gave ravens a task wherein they would only receive the reward if they cooperated, pulling on ropes to raise a platform which had two pieces of cheese, one for each raven.
- If one raven stole their companion's cheese, as well as their own, they were on the outs: the other raven would refuse to cooperate with them - but they would cooperate with other ravens who played fair.

Ravens keep an eye on social dominance

- A prerequisite for all such activities is an ability to intuit the networks to which other birds belong—and the intentions of any individual that might be encountered in their daily wanderings.
- Ravens stay alert for calls that indicate when a dominance rank reversal might have occurred.
- They also use their knowledge about social networks when under attack from a dominant raven. When their own kin are nearby, they try to alert them by issuing repeated distress calls, but they stay more silent when the bonding partner of the attacking bird is close.
- Because rank in a dominance hierarchy increases after bonding, birds track the bonding of others and intervene aggressively to disrupt their pairings. By doing this, they are likely to prevent others from forming new bonds and to keep competing birds from increasing in rank.

Social cognition: Dominance

- Neuronal responses relevant to social cognition such as dominance relationships were also found in the mesopallium and the nidopallium of crows.
- Crows form a stable dominance relationship with the repeatedly encountered, familiar individuals especially among males.
- Agonistic conflict occurs when two unfamiliar males encounter each other, and the encounter soon ends with submissive displays by one of the combatants. Once a win/loss outcome is determined in the first encounter, the loser male shows submission consistently and discriminatively to the opponent winner male in their subsequent encounters, indicating the formation of a dominance relationship.
- This relationship was found to involve social memory of the win/loss outcome at the first encounter and individual recognition of the opponent
- Results suggest that multiple nuclei of the mesopallium and the nidopallium are involved in stable social dominance

Social learning

- Social Learning: Crows learn new behaviors by watching other crows
- Example of opening a box by pulling out a ball or pushing it in
- Half the group watch one bird pull out the ball and they imitated
- Other half watch a bird pushing ball in and they did the same

Limits in social cognition in New Caledonian

- The NC crows in the wild can work within a team but do not understand that their partners can collaborate on a task to become, in effect, a "social tool" that assists in better accomplishing a goal.
- They look at objects that others manipulate but miss critical details of the other birds' behavior in comprehending the relevant action sequences.
- Instead they seem to visualize how a tool works and then reverse engineer it from memory rather than learning directly from others.
- Is such a limitation specific for New Caledonian crows, or does it also apply to other birds?

Geese: small brains but social

- Geese are social and have social hierarchies; cooperate

- Seven colors are ranked hierarchically for food treat.
- Geese can learn hierarchical value of colors for discovering food: always choose highest value color if have choice of 2 containers
- Ability to rank in a hierarchy is an example of inferential thinking: card A is higher than card B, B higher than C, so A is higher than C

- In flying in V formation, they afford each other help in wind drag; ride vortex of air of wings in front of them; they often switch position

Working together to get food

Keas, alpine parrots from New Zealand's South Island, are known for their curiosity, a hallmark of intelligence. Here at a research aviary in Austria, four keas (one not visible) figured out that to retrieve treats inside a wooden tower, they must cooperate by simultaneously pulling chains on opposite sides.

Cooperation

Raven social strategies

- Young ravens that do not have a bonding partner or territory form temporary flocks that congregate at major food resources, such as an animal carcass.
- When large predators defend their food caches, ravens call in other flock members to engage in diversionary tactics for gaining access to the food.
- To prevent pilfering, they also implement devious strategies to stop other birds from observing their food stores.

Ravens

- Likewise, ravens observe other birds to steal any unattended caches.

- Breeding pairs also defend a territory against other ravens. During such fights, mates as well as nonbreeders with developed social networks have considerably higher chances to win competitions and save their food caches.

Mating: females more adulterous

- As far as mating goes, we refer to crows as being socially monogamous but genetically promiscuous, as is the case with most birds.
- This means mated pairs will typically stay together for life, but extra pair copulations are not unusual, most often by females.
- In NY study: extra couple couplings occur in 36% of pairs, and resulting in 19% of hatchlings.

Like humans, these big-brained birds may owe their smarts to long childhoods

- Long parental care may explain how corvids have managed to achieve their smarts.
- To study the link between parental care and intelligence in birds,, created a database detailing the life history of thousands of species, including more than 120 corvids.
- Compared with other birds, they found corvids spend more time in the nest before fledging, more days feeding their offspring as adults, and more of their life living among family.

N. Uomini et al., 2020; Amanda Heidt, Science, 2020

Extended parenting and the evolution of cognition

- Relative brain size covaries with cognitive skills
- Some species display cultural learning, with an emphasis on family life.
- Extended parenting (protracted parent–offspring association) is pivotal in the evolution of cognition: it combines critical life-history, social and ecological conditions allowing for the development and maintenance of cognitive skillsets that confer fitness benefits to individuals.
- This novel hypothesis complements the extended childhood idea by considering the parents' role in juvenile development

Natalie Uomini, et al., 2020

Extended childhoods

- Uomini and her colleagues have spent years studying Siberian jays and New Caledonian crows, two corvid species with extended childhoods that are known to be smart.
- Young birds learned new tasks more quickly by watching their parents. Adults were quite tolerant, allowing juveniles to practice and supplementing their food while they learned.
- Young crows and jays often remained with their parents for up to 4 years—the equivalent of about 2 decades in human years—growing more skilled at mentally challenging tasks all the while.
- The experiments strongly suggest parenting helps shape bigger brains,

Parenting

- Corvids have larger body sizes, longer development times, extended parenting and larger relative brain sizes than other passerines.

- Critical role of life-history features on juveniles’ cognitive development: extended parenting provides a safe haven, access to tolerant role models, reliable learning opportunities and food, resulting in higher survival.

- The benefits of extended juvenile learning periods, over evolutionary time, lead to selection for expanded cognitive skillsets.

Extended developmental learning periods

- Previous work showed that enlarged brain size evolved in species with a
  - larger body size,
  - larger group sizes,
  - longer reproductive lifespan,
  - more reliance on social learning and
  - more variable environments.
- These data are largely in line with the cognitive buffer hypothesis, which proposes that larger brains provide more abilities that help to survive unfavorable conditions

Cognitive consequences of extended parenting

- Prolonged parenting is associated with a higher neuron density in the telencephalon of their neocortex across species

- Thus, extended parenting fosters an expansion of the cognitive skillset via an increase in neuron density of critical brain regions

- Expanded cognitive skillsets due to:
  - enlarged brains
  - reliance on sociocultural learning of skills,
  - enabled by extended development periods in species with prolonged parenting
  - access to tolerant role models in a safe haven

Importance of parents for survival training

- Predation by goshawks is the main reason for mortality in Siberian jays, especially affecting juveniles.
- Juveniles do not respond to perched predators when encountering them on their own, but when other group members start mobbing a perched predator, particularly retained offspring immediately copy the behavior of their parents.
- Natural mobbing events are very brief, as mobbed predators quickly move off, so that unrelated non-breeders have much fewer opportunities than retained offspring to observe mobbing.

Importance of parents for survival training

- However, in experimental settings where predator models are presented, mobbing could last as long as 4 min, providing also unrelated non-breeders with learning opportunities. Consequently, all juveniles survived their first winter of life
- A life history involving extended parenting is a critical support for learning:
- Parents provide their offspring with a safe haven, access to food and reliable learning opportunities, which together boost the long-term survival of retained offspring

Corvids

- Corvids are among the largest passerines (song birds), and have much larger relative brain sizes.
- The incubation time is longer than the passerine mean, and the time spent in the nest is almost double the mean for other passerines.
- Importantly for learning, offspring have extended periods beyond fledging where they remain associated with their parents compared to other passerines.
- Finally, a high number of corvid species breed cooperatively (alloparental care).

Extended bird parenting

- Bird species with extended family life have larger telencephalons.
- But how does extended parenting affect learning, and importantly, survival?
- Siberian jays: the species does not breed cooperatively (i.e. only parents incubate and feed young), despite the fact that offspring can remain with their parents for years after fledging, which is associated with cooperative breeding in most species.
- Siberian jay groups consist of a breeding pair, retained offspring and/or unrelated non-breeders. The latter are forced by the socially dominant retained offspring to disperse from the natal territory one to two months after fledging and settle in another group.
- Retained offspring can remain up to an age of 4 years with their parents, which is well beyond the mean lifespan of 2.2 years

Fission-fusion society

- Ravens—like humans, chimpanzees, elephants, and dolphins—live in a "fission-fusion society," meaning that the larger flock splits apart in the day as individuals fly to other valleys in search of food, new territories, or companions.

- There are only seven to 10 mated pairs in Bugnyar's Alpine study group. The hundreds of other birds roost together in small groups at night, where they groom each other, play, squabble, and exchange information.

- In contrast, the breeding pairs rarely leave the area. All keep track of other birds' relationships as they try to figure out when it's most advantageous to aid or intervene with others. The ravens must learn how to form social bonds and how to use these like tools if they are to successfully reproduce.

Ravens use gestures to communicate

- Before babies learn to speak, they communicate using gestures. Pointing at objects they want, for example.
- Outside of primates, this means of communication had never been observed in another species - until researchers observed wild ravens doing it.
- They use their beaks like hands,
- Recorded 38 interactions between pairs of ravens, 25 of which involved the raven picking up an object and showing it to their companion, and 10 of which involved ravens offering an object to their companion.
- "These distinct gestures were predominantly aimed at partners of the opposite sex and resulted in frequent orientation of recipients to the object and the signallers.
- Subsequently, the ravens interacted with each other, for example, by example billing or joint manipulation of the object,

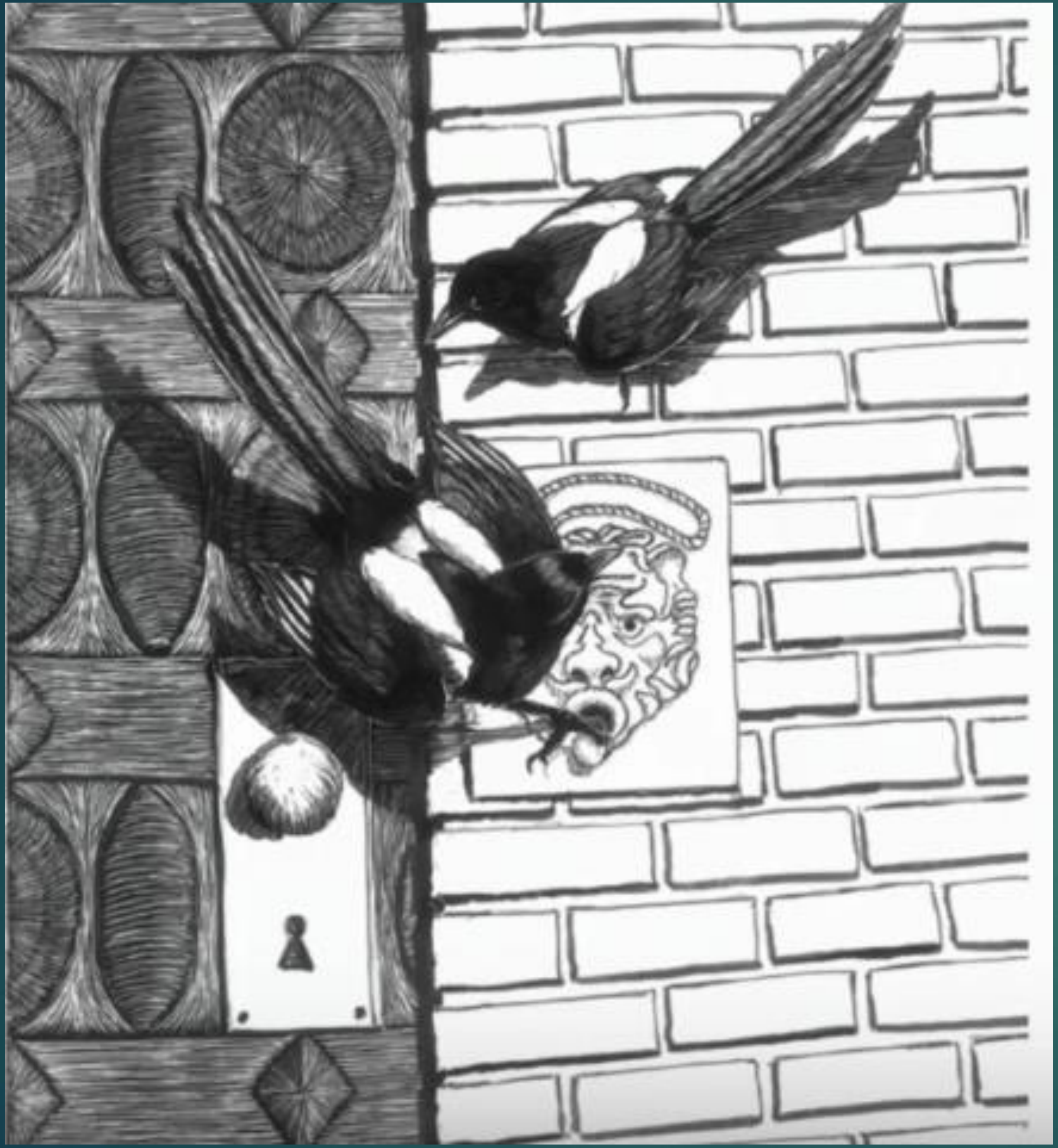
Are friendly and helpful

Helpful parrots

African grey parrots Nikki and Jack exchanging tokens with one another to share food.

Truly social parrots

- African grey parrots voluntarily and spontaneously help familiar parrots to achieve a goal, without obvious immediate benefit to themselves
- African grey parrots and blue-headed macaws: Both parrot species traded tokens with an experimenter for a nut treat.
- But only the African grey parrots were willing to transfer a token to a neighbor parrot, allowing the other individual to earn a nut reward, even if the other individual was not their friend.
- 7 out of 8 African grey parrots provided their partner with tokens spontaneously--in their very first trial.
- Parrots provided help without gaining any immediate benefits and seemingly without expecting reciprocation in return.



Magpie’s in Sweden were feed by a woman.

Would watch her in her window.
Would peck at her window.
Eventually started ringing her doorbell.

Did not like her husband who threw rocks at them.

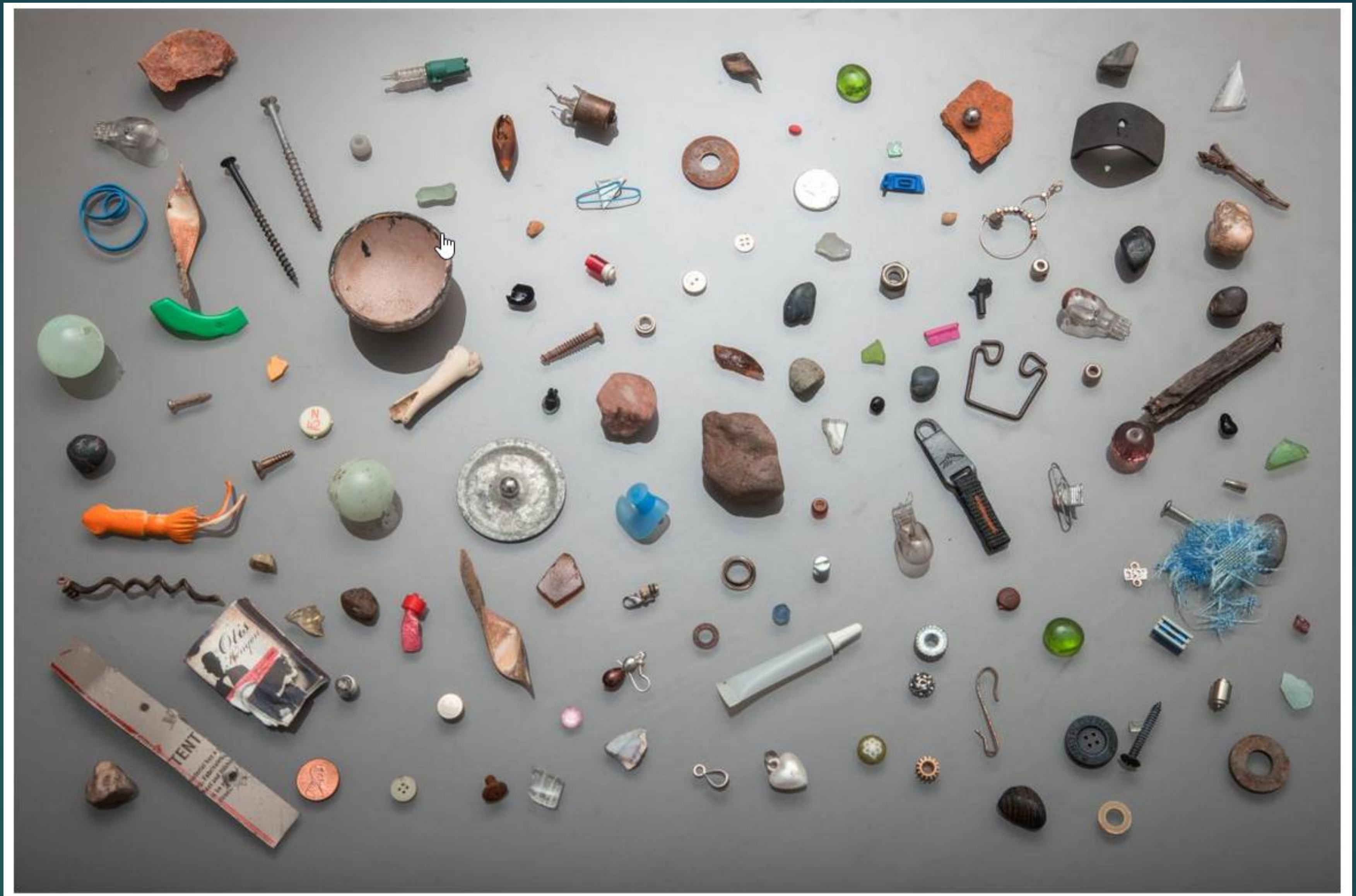
They crapped on his windshield on regular basis; only on the driver’s side

Corvids remember people who have been nice to them

- Corvids also remember people who have been nice to them and can hold a grudge.
- Study: ravens trading a low-quality snack (bread) for a high-quality snack (cheese), which they'd been trained to do. Then two humans brought the cheese to trade for the bread.
- One fairly gave the cheese when the crow handed over the bread. The other ate the cheese themselves after being given the bread.
- After an interval - two days, and then later one month - three humans entered the enclosure, the fair one, the unfair one, and a neutral control. The raven was given a piece of bread to trade. Most of the ravens chose to trade with the fair experimenter - indicating that they remembered being cheated out of delicious cheese and weren't falling for that again.

Collecting

- *Do crows collect shiny objects?*
- There is no evidence that crows keep collections of inedible objects (shiny or otherwise)
- New Caledonian crows keep their favorite stick tools cached in “toolboxes” so it appears that at least some species of crows do cache certain kinds of inedible objects!



The American crows in Gabriella Mann’s Seattle Neighborhood love her, and the eight-year-old girl has the goods to prove it. Young Gabi Mann befriended crows in her Seattle neighborhood, setting out nuts and dog food. In exchange they brought her gifts, including a pearlescent plastic heart, one of her favorites.

Gifts given to eight-year-old Gabi Mann by Seattle crows: at age 4, dropped a chicken nugget…now daily peanuts

Facial recognition

- In Bellevue, Washington, a bus driver who routinely fed crows at home nearly lost her job because the flock started following her to work.

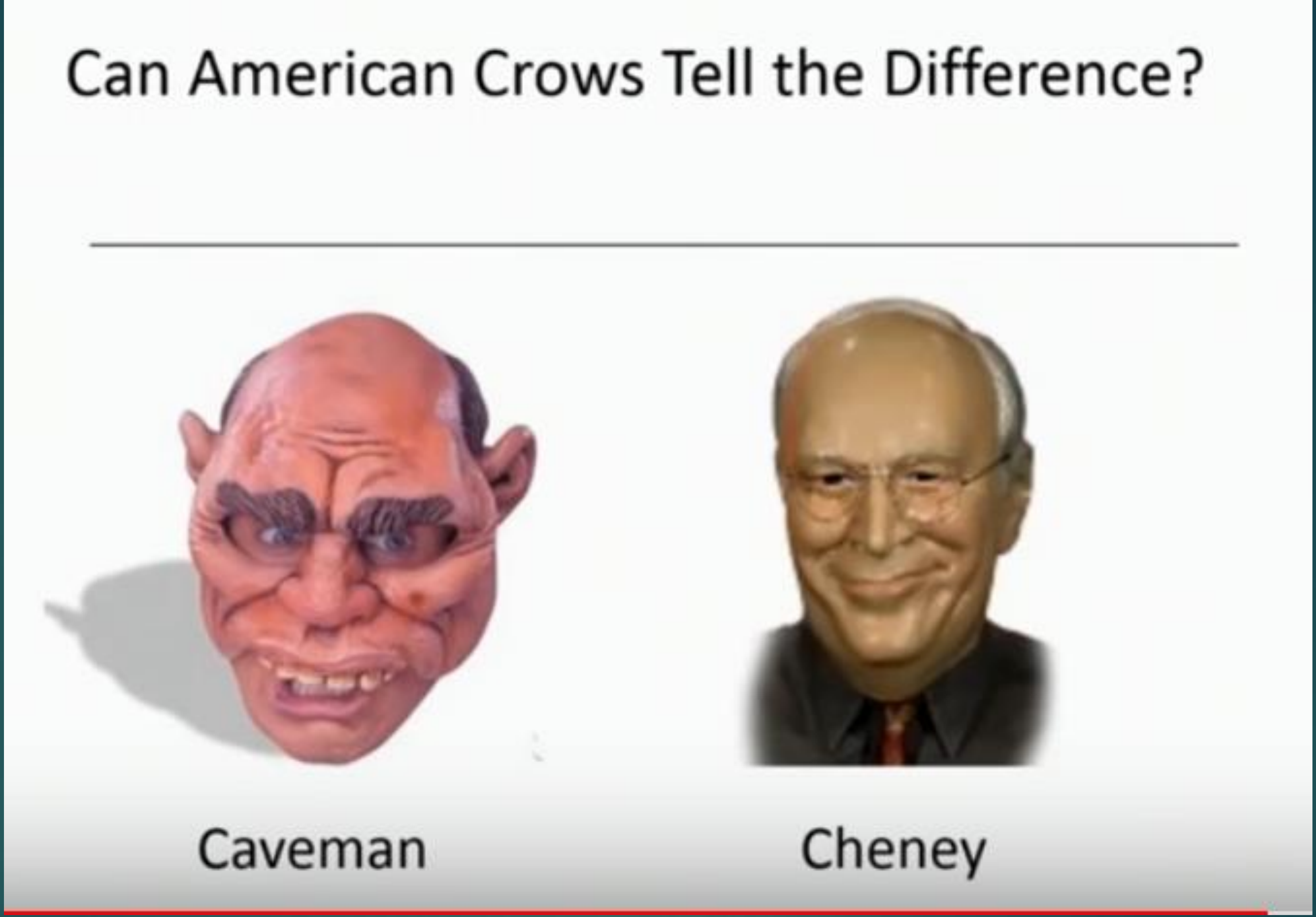
- Researchers have learned that if you capture local crows as part of a study, the crows weren't easily fooled twice. If they went back to recapture birds, they had learned to recognize and fear specific researchers

Crows hold a grudge - and pass that grudge on to other crows

- If you think two crows watching you and cawing at each other are talking about you, you're probably right.
- Corvids can recognize individual humans.
- Crows remember faces and cars.
- Dr. Kevin McGowan of Cornell Univ. visited crow nests to tag birds. Thereafter he was always singled out for angry attacks by the crows.
- Dr. John Marzluff, Univ. of WA: some crows give gifts to specific people who feed them; and mob those who harm them

N Mask

John Marzluff



Dangerous: carried taxidermed dead crow

Control researcher: no crow

Grudges: facial recognition and generational memory

- Crows can pass on a grudge to their offspring — even to subsequent generations of crows harassed these masked scientists.
- They captured and tagged seven crows, and then let them go — while wearing creepy skin masks.
- Every time the scientists walked around campus with the masks the crows scolded and dive-bombed them.
- And it was not only the seven captured crows, it was all the crows.
- Even successive generations of crows would display the exact same behavior when they encountered the masks. Clearly crows talk to each other, and they hold a grudge!

RECOGNIZING FACES.
In 2006 wildlife biologist John Marzluff donned mask like this and captured and banded seven crows.

Today if Marzluff or another person puts on the mask, the crows in the area—not just the original seven—gather to scold, dive-bomb, and follow him.

The crows don’t pester people wearing other masks.

Grudges: crows never forget a face

- Cognitive Implications:

- Facial recognition: recognize individual humans, who have helped/feed or done them wrong.

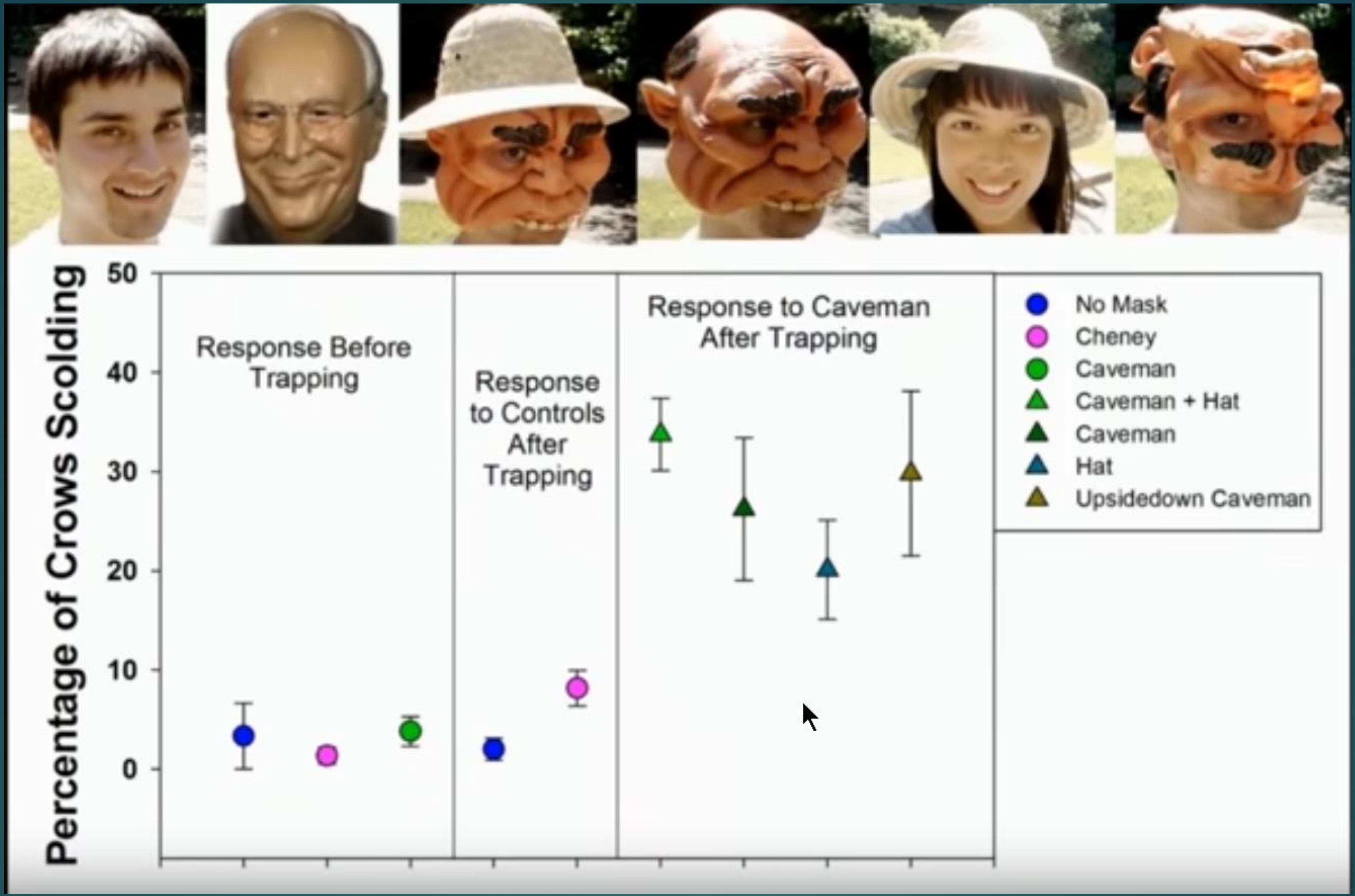
- Generational threat memory: crows recalled 11 years later: an enemy by hearsay -- crows teach each other - pass information on to their chicks and other crows.

Facial recognition

- Prior to trapping less than 5% of the crows scolded the person wearing the "dangerous" caveman mask used in some experiments.
- After trapping up to 66% of the birds would become upset when they saw the dangerous mask and start scolding, mobbing, and dive-bombing the wearer.
- It didn't matter who wore the mask; the birds appeared to ignore differences in age, height, gender, ethnicity and walking gait-they just focused on the faces.

Never forget

- In contrast, the birds essentially ignored researchers wearing "neutral" masks not associated with trapping-such as Dick Cheney's rubber double. "For once, Dick Cheney got to play the nice guy,"
- Within two weeks after trapping, around 26 % of crows scolded the human wearing the danger mask. Around 15 months later, 30 %.
- Three years after the initial trapping event, with no action towards the crows since, the number of scolding crows had grown to 66 %.
- Nearly all of the birds originally trapped by the caveman are likely dead by now, yet the legend of Seattle’s Great Crow Satan still grows.
- Bird lab workers wear masks when working with crows—so they won’t be mobbed later.



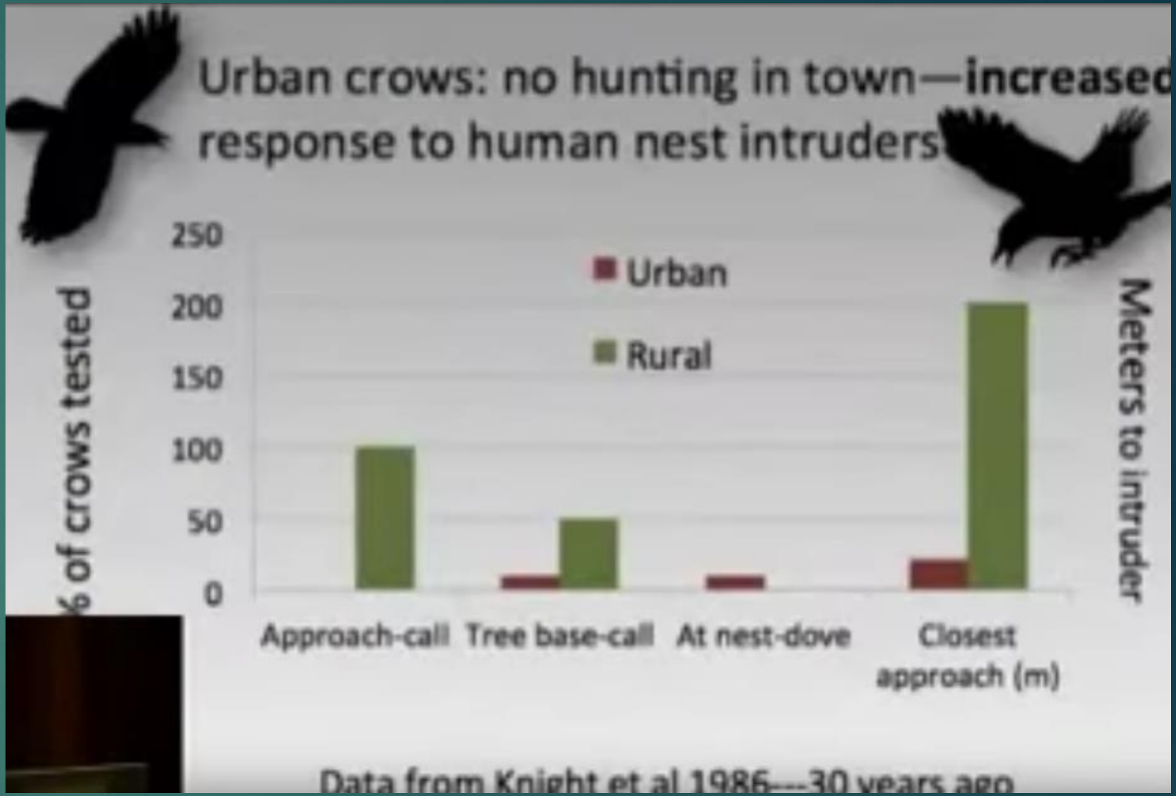
7 taggings of crows by N mask; scolding of N mask with or without hat, or upside-down mask

Mobbing

- Mobbing: owls, hawks, eagles, cats, racoons – esp. during nesting season

- Crows know in town that you won't shoot them & approach more closely

- 1990-2013 study: cultural transmission; Fewer crows mob researchers approaching nests

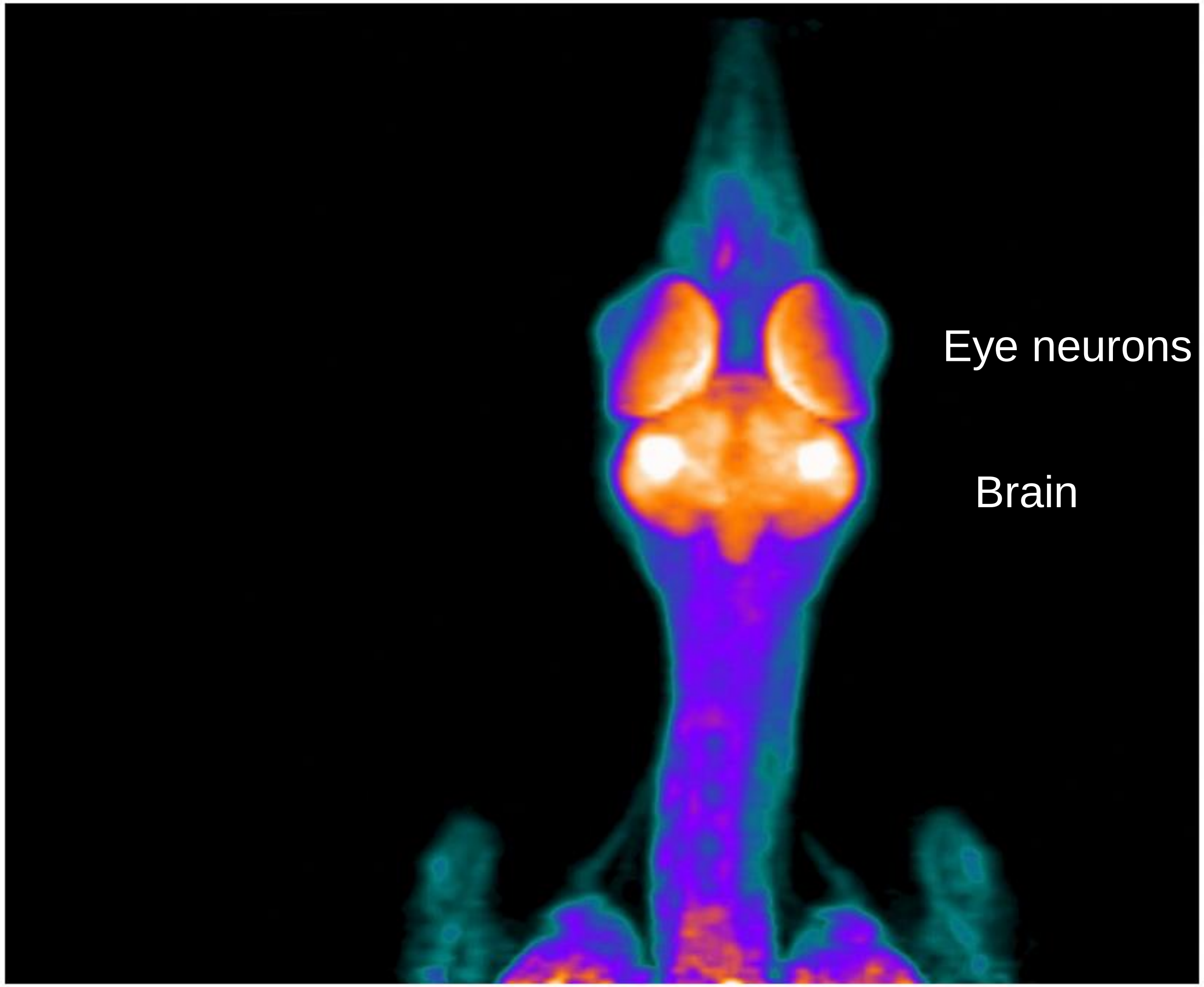


Mobbing

- In the wild, they will mob and dive bomb hawks, owls, herons, and other intruding birds
- Some crows seem to instigate mobbing as a form of play or entertainment, even harassing cats or dogs.

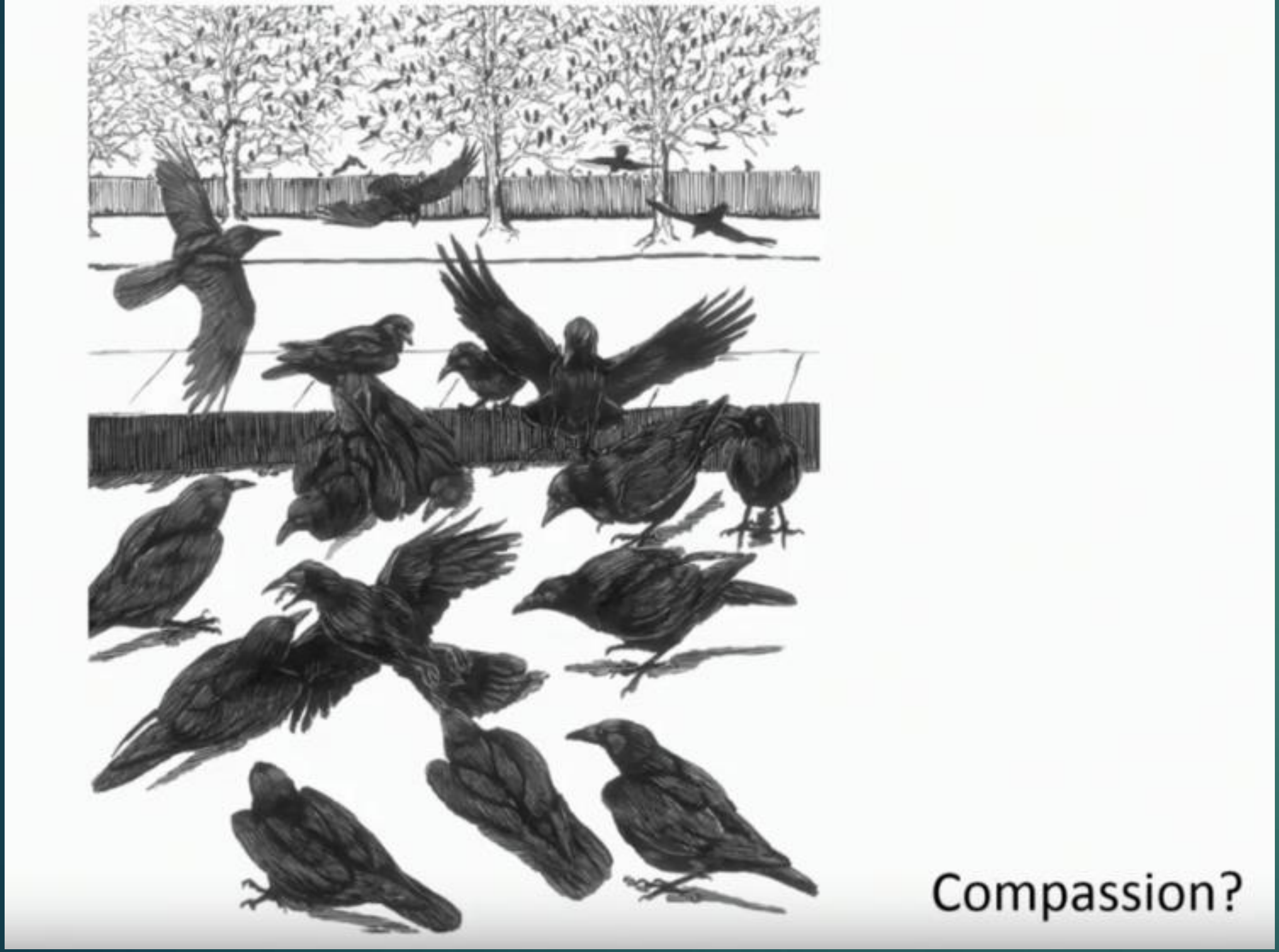
Pet scanning a crow

Pet scan of a crow’s brain



PET scan of a crow's brain: Courtesy of Robert Miyaoka/Dept. of Radiology/University of Washington

Crow "Funerals"



When crows see a corpse of one of their own species, they often gather around the dead bird, cawing noisily and then silently departing.

Is it grief? Fear? A corvid Irish wake?

Crow “funerals”

- Exposed to their dead, crows may touch, attack and attempt to have sex with the body.

- May be the result of hormonal fluctuations that cause some crows to become confused about how to respond to stimuli.

Crows have “funerals” for their dead

- When a crow dies, other crows are often observed gathering around and making a lot of loud noise - much like humans, really.
- Current scientific conclusion crows gather around their dead fellows to learn about danger.
- “Funerals” are a teachable moment, in which the birds collectively make an association between potential danger and a particular spot or predator.
- They need only one experience to form a long-lasting memory of who or what can be trusted and who or what can’t

Funeral study

- First Study: fed wild crows in the same spot for three days. (It turns out they have a particular fondness for Cheetos.)
- Next she staged one of three scary scenarios to instigate a gathering:
  - a masked volunteer holding an evidently dead crow (actually a stuffed specimen);
  - a masked volunteer standing near a lifelike taxidermy Red-tailed Hawk (a dangerous crow predator);
  - a masked volunteer near both the hawk and the crow.
  - In all cases, crows formed mobs of a dozen or so angry, raucous birds.
- The following three days, the birds were measurably slower to approach the place for handouts. Many of them also remembered the masks associated with the dead crow.
- When someone wearing one of those masks showed up weeks later with no taxidermy props, the crows scolded and sometimes mobbed.

Response to different dangers

- Pet scanning shows that the hippocampus is activated by the sight of a person holding a dead crow..
- Sight of a person who previously captured the crow, a person holding a dead crow and a taxidermy-mounted hawk activated distinct forebrain regions (amygdala, hippocampus and portion of the caudal nidopallium, respectively).
- Conclusion: aspects of mobbing behavior are guided by unique neural circuits that respond to differences in memory formation and multisensory discrimination-required to appropriately nuance a risky behavior to specific dangers.

Funerals

- First studies by Ms. Swift and Dr. Marzluff of crow behavior toward corpses involved the presence of a potential mortal threat, whether a human being, a stuffed red tail hawk or both.
- At the sight of a dead crow near possible predators, the birds swarm in large numbers, emitting a cacophony of caws, but never touch the body.
- The researchers had called the activity a crow “funeral,” and surmised that such gatherings are how the birds learn about and process danger.
- But there’s more to how crows react to the dead than avoiding harm.

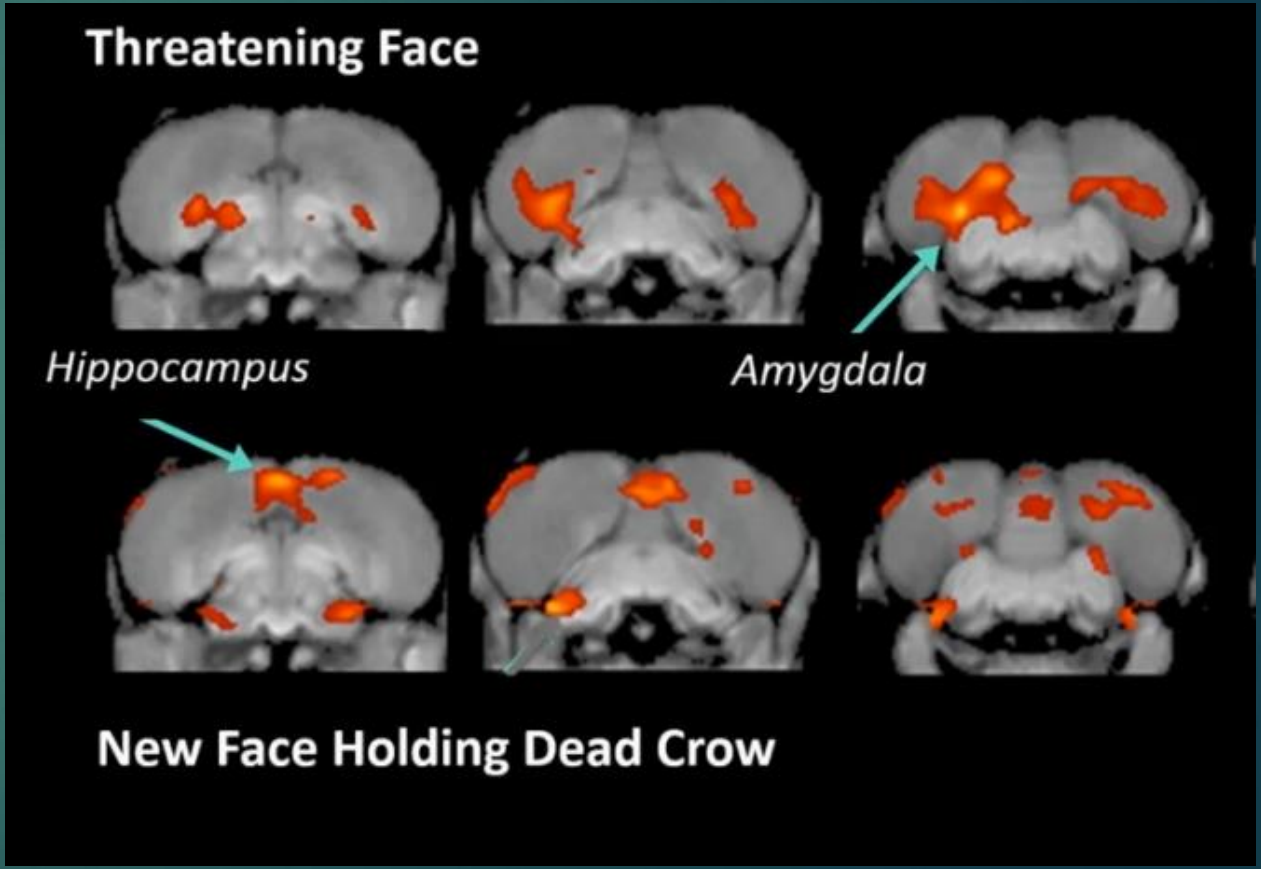
Kaeli Swift and John M. Marzluff, 2018

Necrophilia?

- For the new study the researchers removed the predator element from the equation. After identifying the territory of an adult pair of crows in a Seattle neighborhood, they placed a cadaver on a sidewalk or other exposed area and retreated about 65 feet away.
- Among the hundreds of crows observed during the study, the majority merely cawed loudly and dive bombed at the corpse without touching it.
- But 24 % of the winged subjects pecked, pulled at or dismembered the body. In 4 % crows attempted copulation
- Consistent with a danger response hypothesis, our results show that alarm calling and neighbor recruitment occur more frequently in response to dead crows than other stimuli, and that touching dead crows is atypical.
- Occasional contacts, which take a variety of aggressive and sexual forms, may result from an inability to mediate conflicting stimuli. Suspects over-charged hormones are largely at play.

Crow funerals: if shown similar decoy in lab, under brain scanning, memory centers light up; have same stress hormones

Threat activates amygdala
Dead crow activates hippocampus



New face with dead crow triggers hippocampus

Learn about danger in environment.

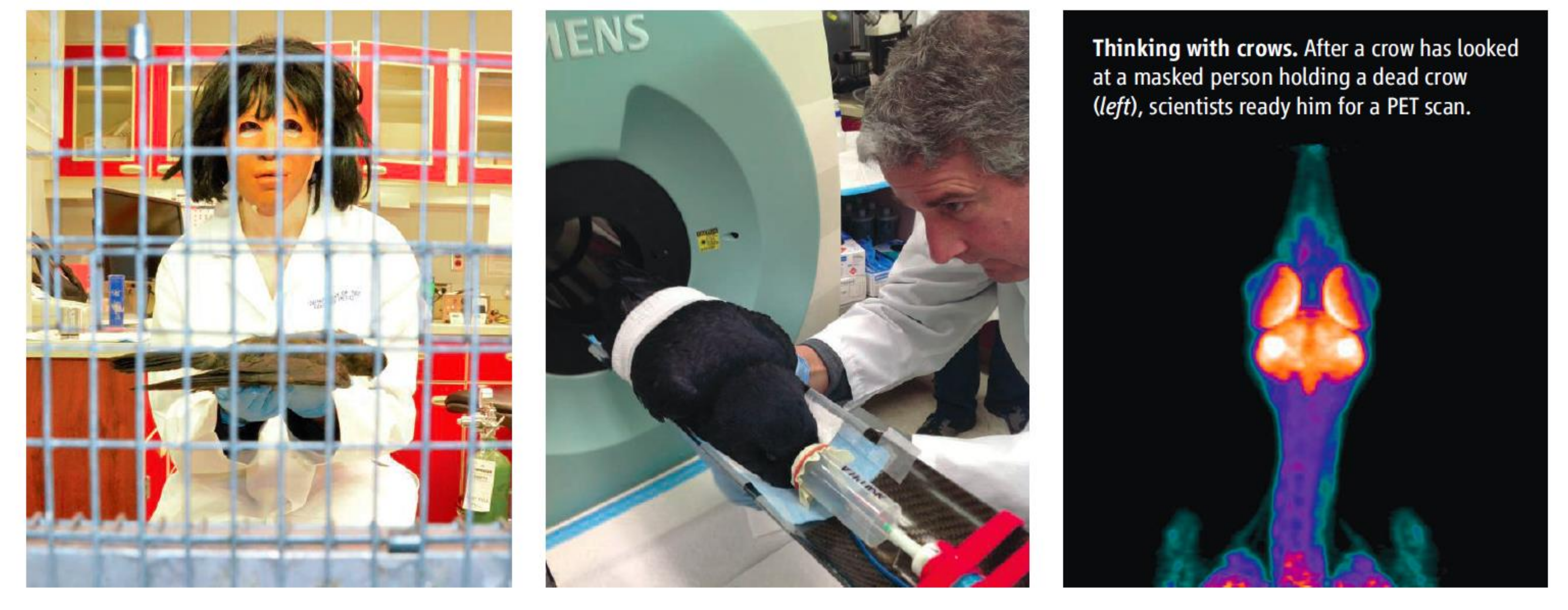
Store new info about dead crow In hippocampus; does not trigger amygdala

Pet scanning a crow

- Pet scanned the bird. the brain of a wild bird in the act of thinking about—or processing—a real-life, threatening event.

- When looking at someone holding a dead crow—but not when looking at a hawk—crow activated its hippocampus and cerebellum, regions involved in learning and memory.

Pet scanning a bird experience



Thinking with crows. After a crow has looked at a masked person holding a dead crow (*left*), scientists ready him for a PET scan.

Pet scan

The birds are kept in place on a tray by gauze straps and given oxygen and anesthesia.

PET scans showed that when this crow looked at the person holding the dead crow, learning and memory parts of the brain were active.

The crow was learning the features of the masked face, not simply reacting to a known danger.

Learning about danger: After feeding crows in a spot for 3 days, She shows up and stands for 30 minutes

Treated her as threat over next 6 weeks when she showed up without dead crow

Crows also learned significance of place: would not return there for food

But in absence of predator, dead crow…and weird wake

Wake: science is about replication

- Were above unusual behaviors representative? No
- 100s of retrials of this scenario with new pairs
- Behaviors: alarm, aggression/pecking, sexual arousal
- Contact of any kind with dead: sexual, aggressive, exploratory = 30% of time
- Sex: 4% of time
- These atypical behaviors during early part of breeding season
- More common are silent vigils of 10 to 60 birds
- Danger learning appears to be the significant component

Crows known to take calculated risks

Calculated risks: Crow did not want to give up his jackrabbit meal and calculated that he would fit under the truck and ducked down; did this for 2 cars in a row

Crows and human language

- Largest songbirds in the world.
- All corvids can mimic human language
- Crows can learn words in language of their owner, documented in multiple languages. Crows speak in English, Russian, German, French.
- Augustus Caesar purchased ravens that routinely spoke, hailing him with praise as “*the victorious commander*.”
- Birds can be taught commands such as “come,” “go,” and “stay” as easily as a dog.
- One learned “Here boy. Come on boy. Here boy. Let’s go.”

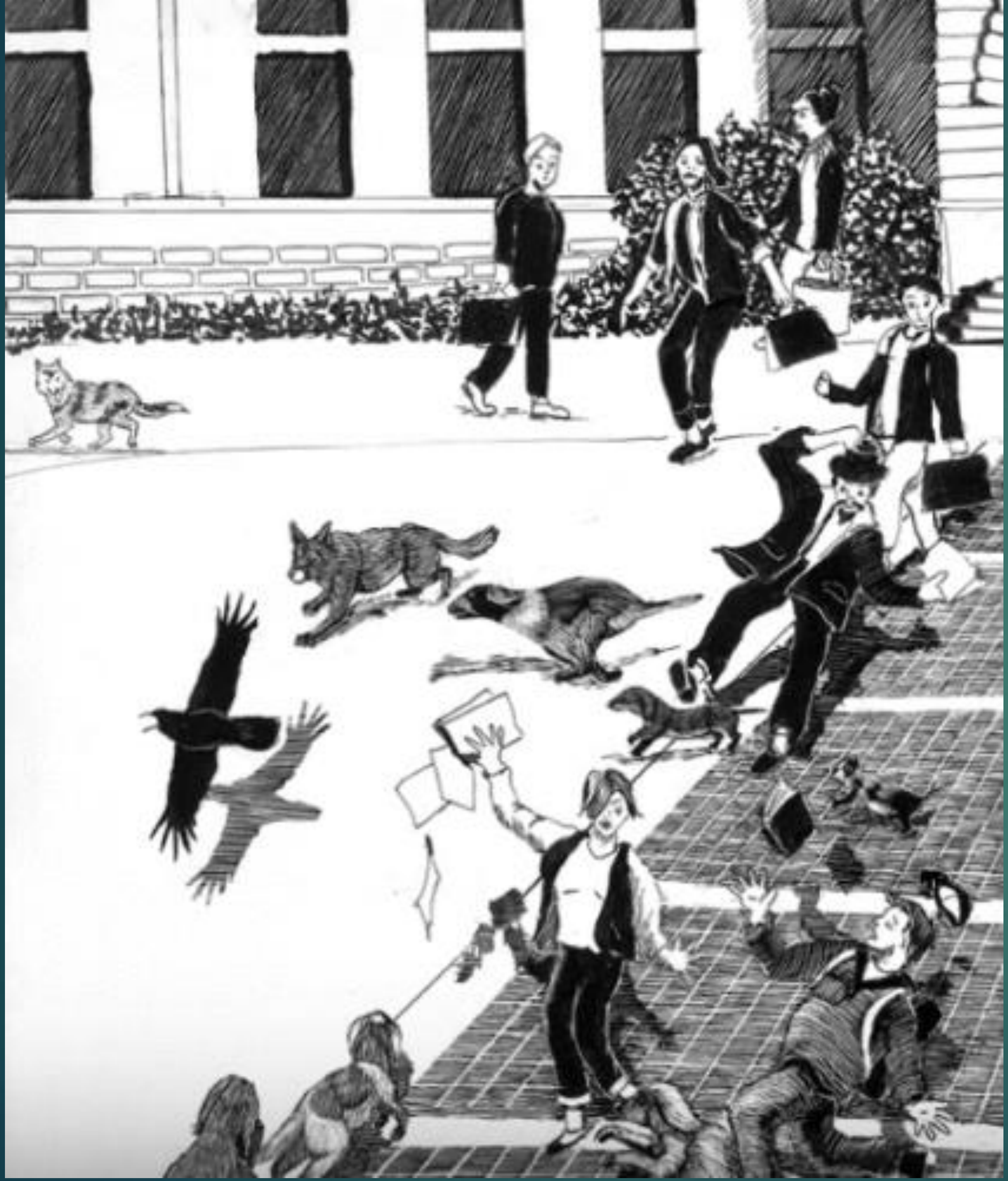
Large-billed crows are able to discriminate between human languages

- Ability to discriminate between languages: In a newly released study conducted by Schalz and Izawa (2020), eight wild large-billed crows were captured in major cities around Japan and subsequently housed in aviaries at Keio University where they were cared for by fluent Japanese speakers.
- As with the carrion crow study, when these crows were presented with playback of a more familiar acoustic style—in this case a Japanese speaker—they didn't show a strong reaction.
- Play them what was likely a completely unfamiliar language—Dutch—and the crows were rapt. Or at least they acted more vigilant and positioned themselves closer to the speaker. In other words, large-billed crows were able to discriminate between human languages without any prior training!

Language

- Some ravens at the Tower of London also speak to tourists, commanding those who stray to "*keep to the path*."
- Crow would fly up to the top of a magnolia tree, wait for someone to pass by, then cry, "Help! Help!" Fire dept. would be called. Owners warned to stop him.
- Ravens *cluck* like hens at the sight of a predator, *trill* at each other when ready to battle for a privileged spot at a carcass, and *beg* for mercy from a dominant.
- Some raven calls are even referential; the *haaa* call refers only to meat.

Corvids have language



Crow collected a series of dogs with his calls at a college campus.
Class would get out at which point crow took off and dogs chased the crow, running into students.
Food is thrown about.

Was this a food tactic or just for fun?

Crow was spotted lecturing a group of dogs on campus of Univ. of Montana

Social eye gaze: object permanency – 3-4 yo child; pay close attention to what others are looking at or pointing at

Caching protection: only if you have been a thief

- However, they cannot control what another bird has seen at the time of caching: once they are alone, scrub-jays will return to a caching site and move caches made previously (i.e. while they were being observed) to new locations that are now unknown to a potential thief
- Cache-protection behavior has further been shown to depend on the birds' individual experience with stealing.
- Birds that have previously stolen themselves, that is, that have had the experience of being a thief, are more likely to show cache protection strategies.
- This result suggests that birds with pilfering experience project their own experience onto others.

Crow: straight and hooked wire

Snowball, a sulphur-crested cockatoo, wowed YouTube fans—and neuroscientists—when he rocked in time to the Backstreet Boys' tune "Everybody" in 2007.

Dance to the music

*** Avian Memory

Vocal Learning

- Songbirds show many advanced vocal learning. They learn sounds, names, syntax and songs from mentors, then practice them and alter them. The name given to them is used their entire life.

- Early studies showed that a similar gene in both bird and human brain circuits, FOXP2, is critical for human speech and is utilized by songbirds.

- FOXP2 is one of 55 genes found in these studies that are similar in humans and the songbirds. They are different in other animals.

Songbirds: singing and naming

- Songbirds learn songs, grammar and syntax from a mentor, like humans, and then practice them.
-
- Songbirds name their children, who are known by that sound for life.
-
- Songbirds prefer singing in harmonic series similar to humans even though anatomically they could sing many other ways.

- They choose to sing in a particular key and with consonant intervals, octaves, fifths and fourths like humans. Songs are used for mating and defending territory

- Songbirds use different language dialects like humans.

- Songbird's brains have brain circuits that identify a particular song. They have circuits to produce different songs in different circumstances.

Learning and memory in avian brains

- Song learning is auditory-vocal learning of a complex sequence of sounds in male songbirds.
- Song is not an innate vocal repertoire but acquired by imitating a song produced by another bird, called a tutor, through the sensory and the sensory-motor stages
- In the sensory learning stage, a bird hears a tutor's song for a few weeks during which the tutor song is memorized.
- In the sensory-motor learning stage, the bird starts to imitatively sing the song but its acoustic structure is unstable and dissimilar to the tutor song.
- Through practices of singing for weeks, the song becomes stable and similar to the tutor's song by the correction based on hearing the bird's own voice.

Bird Memory

- Food caching champs: Jays and corvids
- Birds who hide seeds have the best spatial navigation and spatial memory, much more than humans.
- Other researchers revealed the remarkable memories of Clark's nutcrackers, scrub jays, and chickadees.
- Nutcrackers harvest and cache more than 30,000 pine seeds every autumn, distributing them in several thousand tiny caches they need to remember through the winter. Get them 9 months later, sometimes thru feet of snow.
- Clark's nutcracker: can locate cached seeds, conceal them from rivals; retrieve those first that are likely to spoil

Human WM = 5 +/- 2

- In primates including humans one of the core components of higher cognition is working memory (WM), the neural system for short-term storage and manipulation of information.
- Many higher cognitive abilities, for instance planning and cognitive flexibility, are critically dependent on WM and the capacity of WM is closely correlated with individual fluid intelligence
- The working memory capacity of two carrion crows in a working memory paradigm that is virtually identical to a paradigm recently used with primates.
- Overall, the birds and the monkeys show a remarkably similar capacity of about four items.

Episodic memory

- Crows remember where and when they hide different types of food. They are aware that some of the food is still edible and some has been hidden too long and go to only edible food. This means they remember how long ago they buried them and how long they are good for.
- Crows have complex memories of experiences including a description of what happened and the time and place.
- Experiments: After burying the different types of food, if the bird is given completely new information about how long they will last, they will adjust their behavior related to the already buried item.
- This represents flexibility in the form of declarative memory. Since these studies, some similar memory results were obtained for rats, mice, chimps and cuttlefish, but these other animals don’t include the flexible aspect of the research.
- Crows are able to plan for breakfast the next day despite many different circumstances. They prepare food for tomorrow when they know they will not be given breakfast without any past training.

Episodic memory

- Episodic memory, once thought to be unique to humans, is also within the capabilities of birds.
- Scrub jays (*Aphelocoma coerulescens*) demonstrate it for the location, content, and relative time since caching particular food items.
- Episodic memory has also been convincingly demonstrated in pigeons.

Caching: Seed hiding

- Scrub jays remember the “what, where, and when” of specific caching events (episodic-like memory).

- This representation of the time since caching is essential for the efficient recovery of perishable food items

- Food storers are sensitive to the social context of caching, because caches are susceptible to pilfering. A number of corvids observe other birds caching and demonstrate excellent observational spatial memory for the location of another bird’s caches

Numerical ability

- Cormorants used by fishermen in Southeast Asia may be able to count:
- Fishermen who allowed the birds to eat every eighth fish they caught. Once their quota of seven fish was filled, the birds stubbornly refuse to move again until their neck ring (prevents the birds from swallowing larger fish) is loosened. They ignore an order to dive and even resist a rough push or a knock, sitting glum and motionless on their perches.
- Meanwhile, other birds that had not filled their quotas continued to catch fish as usual. One is forced to conclude that these highly intelligent birds can count up to seven
- Parrots can count up to 9; crows up to 6.

Corvid counting

- Ditz and Nieder (2015) trained crows to count the number of items on an LCD screen and recorded single-neuron activities correlative to numerical processing.
- NCL neurons were found to be activated selectively to numbers of dots; neuronal activities correlated to crow's behavioral response rather than the number of dots *per se.* Such tight correlation between neuronal activity and behavior suggest NCL neurons are involved in the crow's internal recognition process of the dot number rather than the external physical property of the dot picture.

Corvid number perception encodes number neurons

- Nieder and graduate student Helen Ditz looked at crows' ability to remember quantities, or numerosity, and whether neuronal activity in their NCL reflected the number of objects in a viewed image.
- They hypothesized that this area would be involved in perceiving quantity because, in primates, the PFC signals quantity when monkeys perform a numerosity task.
- The researchers showed the birds images that contained anywhere from 1 to 5 dots, the size and position of which were different each time so as to control for memory.
- Regardless of the dots' size and position, their quantity got encoded: Specific NCL neurons reacted to specific numbers, and activity in the NCL reflected the crows' behavior.

** Object permanence

Object permanence

- Macaws as well as carrion crows have been demonstrated to fully comprehend the concept of object permanence at a young age.
- Macaws will even refute the "A-not-B error" (objects that are hidden still exist and have **not** disappeared).
- If they are shown an item, especially one with whose purpose they are familiar, they will search logically for where it could be feasibly placed.
- One test for this was done as follows: a macaw was shown an item; the item was then hidden behind the back of the trainer and placed into a container. Without the macaw seeing, the container it was placed in, along with another container and multiple objects, were spread upon a table simultaneously. The specific container that the item was stored in out of the macaw's sight was one that the macaw had never observed before. The macaw searched this some, then another container, then returning to open the correct container to demonstrate knowledge of and the ability to search for the item.

Object constancy

- Object constancy requires a high level of cognitive complexity. It has been demonstrated to Piagetian stage 4a (constancy of a disappeared object if a grasping or approach movement toward it has been initiated at the time of disappearance) in ring doves and to stage 5 (constancy over sequential, multiple disappearances) in magpies.
- African grey parrots (*Psittacus erithacus*) and other psittacine birds demonstrate object constancy to Piagetian stage 6, which includes the ability to follow complex displacements of a disappeared object, as well as to form a mental representation of the object.
- Parrots behave in a manner consistent with surprise and anger when an unexpected, different object is used to surreptitiously replace the disappeared object

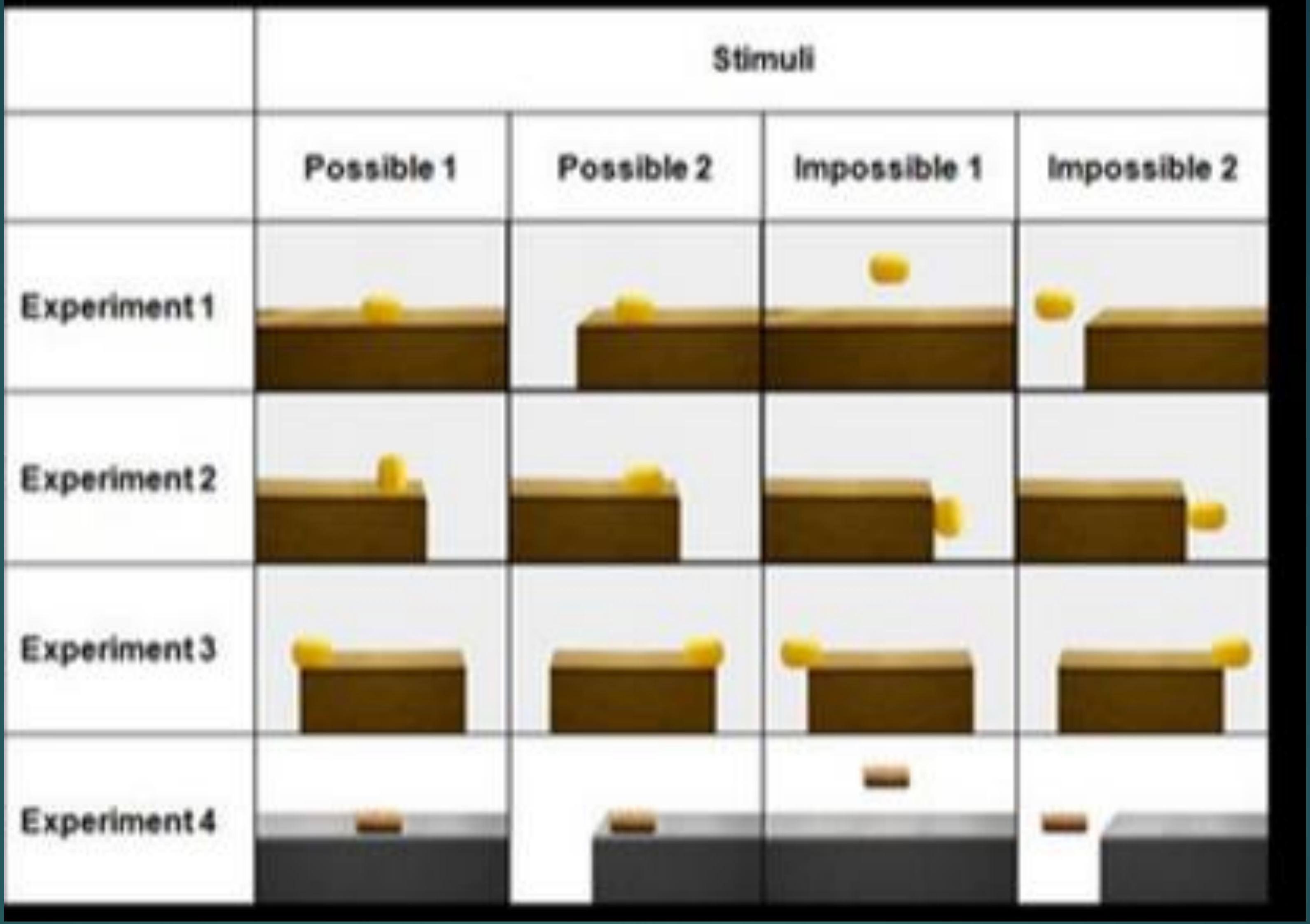
Decision making in a crow brain

- For the study, the crows were trained to perform a series computerized memory tests. An image would flash on the screen and then disappear. Next, two more images would appear. One was the same as the first while the other was different. Some portions of the test required the crows to find a match with the first image and other sections wanted the image that was different. After a brief training period the crows were able to do the test effortlessly, even when unfamiliar images were used.
- While the crows were busy selecting images, researchers were mapping the birds' neurological function. They discovered that there was a great deal of activity in the nidopallium caudolaterale, which is somewhat analogous to the human prefrontal cortex. This is the region of the brain where higher-thinking occurs and executive decisions are made.
- The researchers also noticed activity in different areas based on if the crow was supposed to pick the item that was the same while a different area was used when the selected image was supposed to be different.
- After a while, the researchers could use the bird's brain activity and see what it was going to select before the bird had a chance to submit its choice.

Great-tailed grackles (a blackbird): behavioral flexibility

Physics: object should fall if unsupported

- Rooks comprehend basic principles of physics at the same level as a 6-month-old baby—and beyond that of chimpanzees
- Infants and other primates know that an object will fall if something is not holding it up; they stare for longer than normal at images of a ball or banana floating in midair, for example, suggesting they know that something unusual is going on.
- Rooks do the same. The researchers set up a peephole for the birds to peer into. (Rooks are natural peeping Toms and will spy through small holes or cracks looking for other rooks.)
- On the other side were images depicting eggs in various situations, both possible and impossible. Some eggs rested on a table, whereas others floated above it. In a more subtle twist, the researchers added a picture of an egg hovering in the air while its side or bottom touched the table's side.
- In all of the image sets, the rooks peeked about 50% longer at the impossible pictures than they did at those with the egg properly supported by the table.
- Babies gradually develop similar reactions by 6 months of age, whereas chimps grasp only some parts of the concept of support without recognizing the physical impossibility of an egg "supported" by the side of a table.



Other researchers have reported crows solving puzzles that require knowledge of physical support without going through a period of trial and error.

Spatial and temporal abilities

- The *detour test*, where a glass barrier between the bird and an item such as food is used in the setup. Must go around to get food.

- Most mammals discover that the objective is reached by first going away from the target. Whereas domestic fowl fail on this test, many within the crow family are able to readily solve the problem.

Planning for the future by western scrub-jays

- Jays make provision for a future need, both by
  - preferentially caching food in a place in which they have learned that they will be hungry the following morning and
  - by differentially storing a particular food in a place in which that type of food will not be available the next morning.
- Jays can spontaneously plan for tomorrow without reference to their current motivational state, thereby challenging the idea that this is a uniquely human ability.

Pigeon as art critic

- A recent experiment by Shigeru Watanabe showed that the utterly un-artistic pigeon could be taught to identify “good” and “bad” children’s artwork.
- Remarkably, when pigeons are suitably trained, they too can learn a variety of visual categories.
- We train the animals to report these visual categories by placing them into an operant conditioning chamber (or Skinner box), a common psychological testing apparatus. There, the pigeons are shown photographs on a computer monitor and they receive grain when they correctly respond in a kind of computer game which requires that they peck one key when they are shown a picture of a cat, etc. After training, the pigeons can also generalize these categorization responses to new photographs that they have never before seen,
- To test the art discrimination abilities of pigeons, Watanabe first asked people to classify children’s artwork as either “good” or “bad.”
- In an average of only 22 sessions, all of the pigeons that were so trained learned to respond most of the time to “good” artwork and not to “bad” artwork.

Pigeons

- Pigeons learned to distinguish between four-letter English words and nonwords, which were composed of combinations of one vowel and three consonants.
- Pigeons mastered that task and transferred their knowledge to new sets of words and nonwords by using spelling strategies akin to those practiced by primary school pupils.
- Overall, pigeons can achieve cognitive performances on these tasks similar to those of corvids and parrots in some but not all tasks.
- Even when successful, they need much longer to learn a task and require more training to grasp an abstract rule.
- Not all birds are as clever as a crow or a parrot. But pigeons are brainier than once thought.

Pigeons: fabulous visual pattern learners

- While European magpies, ravens and New Caledonian crows have brain weights of about 5.5, eight and 14 grams, respectively, pigeons’ brains weigh in at about two grams—comparable to the weight of a rat’s brain. But even pigeons are brainier than assumed.
- Lorenzo von Fersen and Juan Delius demonstrated that pigeons can memorize 725 abstract patterns and use transitive inference logic. (An example: You can deduce that Jennifer is taller than Sarah if it is known that Jennifer is taller than Sonia and Sonia is taller than Sarah.)
- Transitive inference (TI) is a form of deductive reasoning that allows one to derive a relation between items that have not been explicitly compared before. In a general form, TI is the ability to deduce that if Item B is related to Item C and Item C is related to Item D, then Item B must be related to Item D.

Abstract general rules

- Corvids also demonstrate superior abilities in other transfer problems. One case is the ability of some corvids (pinyon jays and western scrub jays) to solve transitive inference problems (A 9 B 9 C 9 D), in which the birds are trained on an ordered set of various pairwise comparisons (such as Aþ B–, Bþ C–, etc.).
- What is common to these various transfer tasks—from learning sets to transitive inference—is the ability to abstract general rules or relationships that transcend the basic learning experience.
- Abstraction might be an important process underlying this flexibility.

New Caledonian crows reason about hidden causal agents

- Here, we show that tool-making New Caledonian crows react differently to an observable event when it is caused by a hidden causal agent.
- Eight crows watched two series of events in which a stick moved.
- In the first set of events, the crows observed a human enter a hide, a stick move, and the human then leave the hide.
- In the second, the stick moved without a human entering or exiting the hide. The crows inspected the hide and abandoned probing with a tool for food more often after the second, unexplained series of events.
- This difference shows that the crows can reason about a hidden causal agent, about cause and effect.


New Caledonian crows reason about hidden humans
Watch later
Share
0:36 / 3:06
YouTube

Bartering

- Ravens are not habitual tool users, and bartering has never been observed in the wild.
- The experiments were mainly chosen because they replicate key experiments with primates .
- Specifically, we tested whether ravens can make decisions for an event 15 min into the future (experiment 1), and over longer intervals of 17 hours (experiment 2). We additionally tested whether ravens can exert self-control when making decisions for the future (experiment 3).
- Corvids have shown evidence of planning their food hoarding, although this has been suggested to reflect a specific caching adaptation rather than domain-general planning.
- Here, we show that ravens plan for events unrelated to caching—tool-use and bartering—with delays of up to 17 hours, exert self-control, and consider temporal distance to future events.

Can Kabadayi, Mathias Osvath , 2017

Planning

- This study suggests that ravens make decisions for futures outside their current sensory contexts, and that they are domain-general planners on par with apes.
- In the tool conditions, including self-control, the ravens were at least as proficient as tool-using apes.
- In the bartering conditions, the ravens outperformed orangutans, bonobos, and particularly chimpanzees.
- The first trial performances show that the ravens' behaviors were not a result of habit formation, and that they perform better than 4-year-old children in a comparable set-up.

Analogies: matched vs mismatched pairs

- Study: crows can use analogies to match pairs of objects.
- To reach that conclusion, the scientists trained crows to recognise whether two objects were identical or different,
- Once all the birds were good at matching objects, researchers showed the crows images of pairs of objects, matched pairs or mismatched objects with different shapes or colors.
- The researchers wanted to see if crows could figure out the relationship between pairs of objects and then choose a pair with the same relationship: matched or mismatched.

Analogies

- For instance, a crow looking at a mismatched pair would then select the mismatched pair from their response choices. Nearly 78 per cent of the time, the birds succeeded. The birds recognized that the relationship between the two pairs of objects was the same. In other words, they were making analogies.
- First trained crows to match items that were the same as each other (same color, same shape, or same number). Next, the birds were tested to see if they could match objects that had the same *relationship* to each other. For example, a circle and a square would be analogous to red and green rather than to two oranges. The crows grasped the concept the first time, without any training in the concepts of "same and different."

Matching

*** Tool use and manufacture

Tool use: finches

- Darwin in 1835 noticed that Woodpecker finches in the Galapagos Islands would use cactus spine or trim sticks and twigs to the proper length for use as tools to forage for insects.

- In captivity, a young Española cactus finch learned to imitate this behavior by watching a woodpecker finch in an adjacent cage

Tool making

- Tool manufacture, long regarded as an exclusive province of primates, has now also been observed in a corvid species.

- New Caledonian crows (*Corvus moneduloides*) fabricate tools for use in gaining access to food, both in the wild and in captivity.

- In the wild, these crows have developed specific designs in their tool manufacture using *Pandanus* leaves, which are then shared with other birds through cultural transmission.

Cognitive abilities

- New Caledonian crows from the South Pacific, mostly live on grubs that they retrieve from crevices
- In 1996 Gavin Hunt, then at Massey University in New Zealand, reported that New Caledonian crows manufacture two different tool types with which they capture their prey.
- Other experiments demonstrated that the crows can solve diverse problems by reasoning about underlying causal relationships.

Onur Güntürkün, SciAm, January 1, 2020

New Caledonian crows

- New Caledonian crows have the largest relative brain size among corvids, suggesting selective pressures on some aspects of cognitive performance.
- Compared to other corvids, they have significantly larger brain areas subserving learning, action sequencing and fine motor control functions, all of which support the tool-making and tool-use behaviors enacted by New Caledonian crows
- In experimental settings, New Caledonian crows have been shown to excel at problem-solving, physical cognition and causal reasoning in tests such as the trap-tube, string pulling and Aesop’s fable tasks

Crows can fashion tools

- But what do crows do if there's nothing available? Turns out they just make their own,
- They were observed snapping twigs from trees, then stripping it of bark and leaves, and fashioned the node into a hook. They then used these tools to probe into small spaces for food.
- Value their tools and don't simply discard them after a single use.

Tool making

- Only four species are known to *make* tools: humans, chimpanzees, orangutans - and New Caledonian crows.

- Although other corvid species have learnt to make and use tools in labs, only the crows found on the Pacific island of New Caledonia have been found to make tools in the wild.

- With their beaks, the crows sharpen forked twigs into hooks for scooping larvae and worms out of holes in wood.
- Why do they, but no other crow species, use tools. One of few from isolated island with low predation risk & no woodpeckers who compete for embedded insects.

New Caledonian Crow (NCC) tool use

- The NCC's *tool kit* includes:
  - straight stick tools,
  - hooked stick tools
  - complex shapes of barbed leaf,
  - grass-stem probing for lizards and
  - candle-nut dropping onto rocks are described.
- Different populations of NCC have differing tool kits

NCC: 4 modes of tool use

- NCC show four modes of tool use in nature and four in captivity.
- *Drop objects*. Wild NCC drop candlenuts (*Aleurites moluccana*) from notched branches onto rocks below, in order to crack them open. Such standardized (aimed?) release from a specific launching site seems to be unique to NCC
- *Pry, apply leverage*. Crows in captivity bend segments of wire to make a hooked tool, by using the lip of a glass cylinder as a fulcrum.

NCC tool use

- *Insert and probe*. Wild crows insert elongated segments of various kinds of vegetation (leaf, petiole, stem, twig) into cavities or crevices, in order to extract prey items (e.g. long-horned beetle larvae) contained therein.

- *Use to Reach*. Captive crows use probes to retrieve objects from behind barriers or to investigate novel, artificial objects, but this has not been seen in nature.

- *Jab*. NCC use grass-stems to dislodge lizards from crevices.

Tool Use by the Numbers

- Approximate number of known animal species: 1,371,500
- Number of animal species observed using tools: 284
- Number of animal species observed making or modifying tools: 42
- *Number of animal species known to make multiple kinds of tools (humans, chimpanzees, orangutans, capuchin monkeys, and New Caledonian crows): 5*
- Number of animal species known to make hooked tools *(humans and New Caledonian crows): 2*

Chimpanzees vs NCC

- Study of 36 aspects of tool use:
- A chimpanzee shows tool-use *multi-functionality* by using a melon-sized stone as: hammer, missile, or social signal enhancer.
- How do NCC compare? They too show four modes in nature, but apparently one (multifunctionality) only in captivity.
- In nature, NCC make tools of leaf, twig or stem to fish out insect prey, and some are clearly *crafted*, involving at least two steps.
- Most notable is the sculpting of hook tools, a form of non-human extractive technology shown only by NCC

Chimps vs Crows in tool use: Chimps win

Summary of chimpanzee (*Pan troglodytes*) and new Caledonian crow (*Corvus moneduloides*) compared on five aspects of tool-use (from [25]). (First number before comma is types seen in nature, second is for captivity.)

species	components of elementary technology (n = 5)	modes of tool use (n = 22)	modes of tool making (n = 4)	functions of tool use (n = 7)[a]	modes of associative technology (n = 5)
chimpanzee	5,5	20,22	4,4	6,6	5,5
New Caledonian crow	5,4	4,4	3,3	2,2	0,2

NCC keep their made tools

- New Caledonian crows even take steps to avoid losing their carefully crafted tools. They sometimes stash their hooks in holes, or simply stand on them, when they aren't in use.

- Corvids use found objects as tools. Ravens and crows drop nuts on to flat rocks to crack the shells - and nearly all corvids seem to have a knack for solving physical problems.

New Caledonian tool use

Grub target of tool use: long-horned beetle larvae.
Latter grab stick with pincers.

New Caledonian Crow using stick to pull out grub

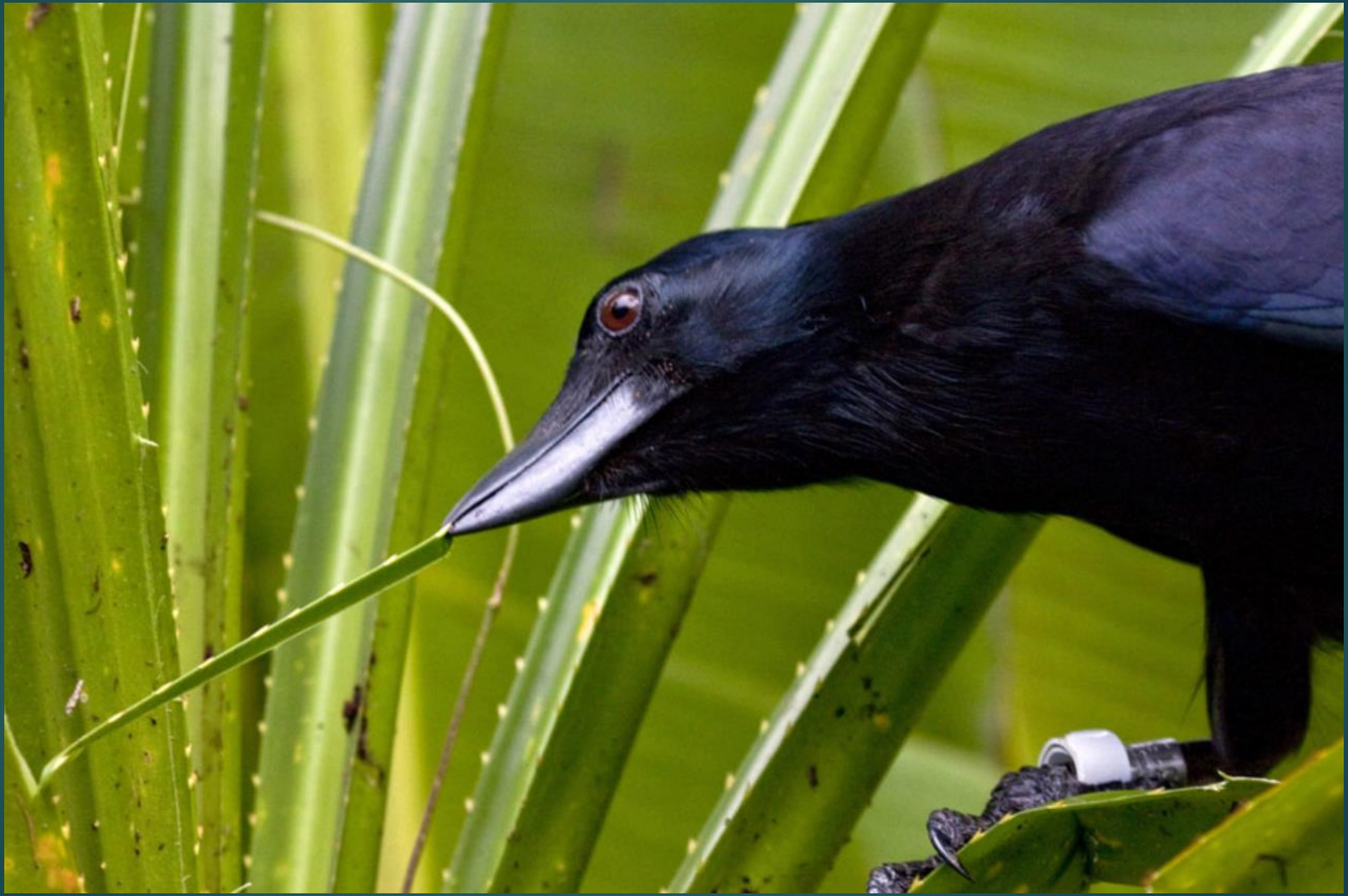
Hawaiian Crow: This crow found a great twig

NCC: How to catch a grub

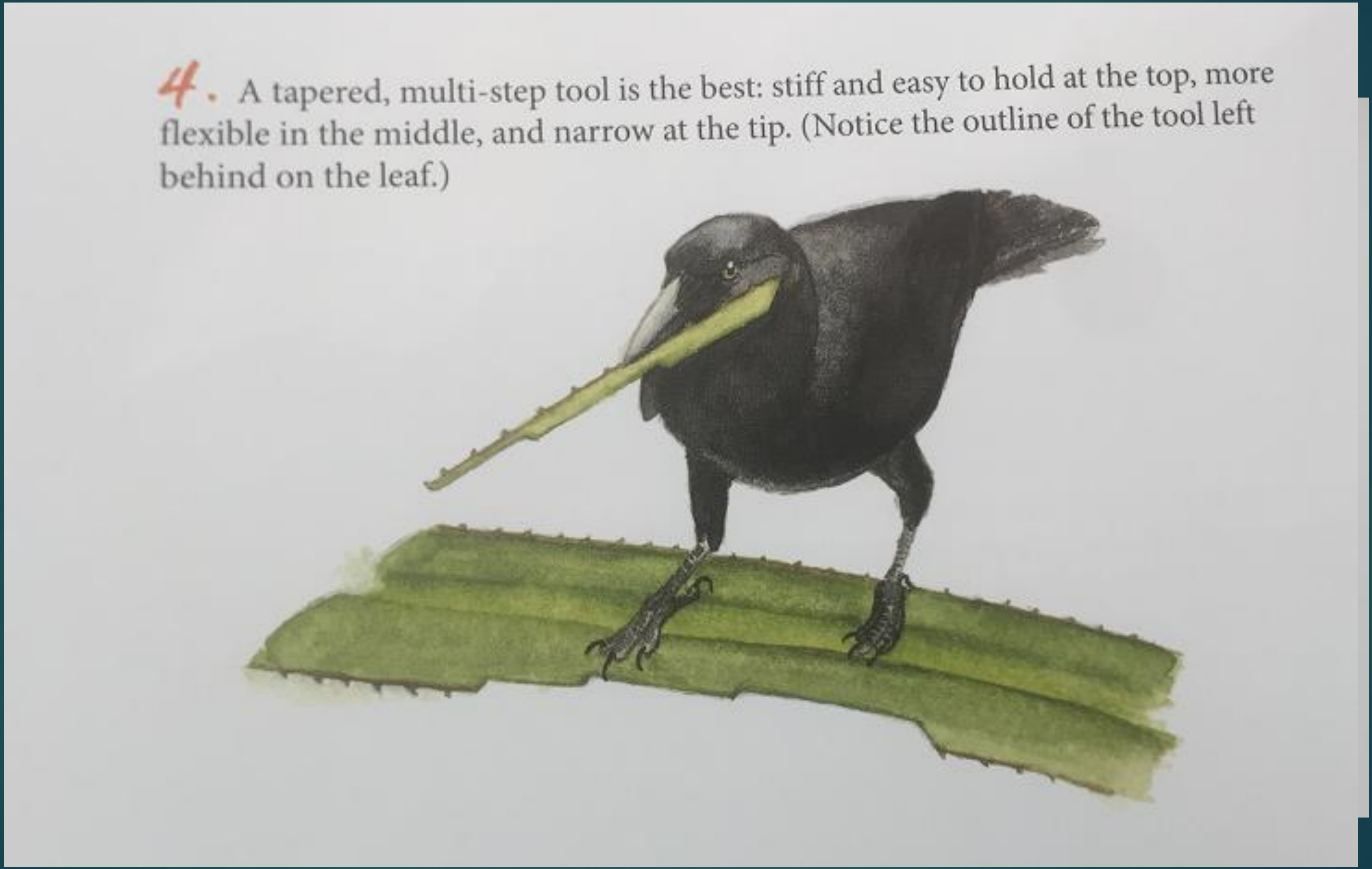
NCC tool types

Pandanus plant on New Caledonia

Tearing off 3 tier tool from Pandanus plant



3 step tool: *Pandanus* leaves



Captive NCC

- Hand-raised, naive juvenile NC crows:
  - spontaneously used available twigs as tools to retrieve otherwise unreachable food items
  - when presented with *Pandanus* leaves, spontaneously used them to manufacture tools for this same use.

Tool use: Reaching

Hooker

▲ Betty the crow astonished scientists by deliberately bending a straight wire into a hook and using it to extract food from a container in a 2002 experiment by Oxford University researchers. Photograph: PA

Hooking: tool bending is part of New Caledonian crows' natural behavior.

- While young birds in the wild normally learn this technique from elders, a laboratory crow named "Betty" improvised a hooked tool from a wire with no prior experience, the only known species other than humans to do so.
- New Caledonians have evolved to make hooked tools from soft twigs as part of their usual foraging activity
- Most birds trapped sticks underfoot before bending the tool shaft by their bill; one pushed tools against the logs to flex them; another wedged them upright into holes before pulling the shaft sideways.
- It turns out the twigs that wild crows select for making their tools are pliable.
- Rooks can make hooks too; but not in wild

New Caledonian crows

- New Caledonian crows, which have been observed making several types of tools out of sticks, may be able to build tools from memory — even if they have only seen the tool itself and haven't ever seen the tool being constructed.
- Also able to learn from each others' tools.
- This suggests that crows can form a "mental template" of tools based on other crows' tools and their own past tools, which would explain why New Caledonian crows' tools could have improved over time.

Also the Hawaiian crow: tool use

- The Hawaiian crow has not only been observed gathering tools, but also creating and modifying them
- 93 percent of mature ‘Alalā used tools, and all seven of the naïve juveniles experimented with tools, even though they were never taught.

Crow: straight and hooked wire

Teaching young

When Little Feather's parent drops its tool, Little Feather picks it up and the adult bird takes it back. As they watch Mom or Dad, young crows are probably learning essential survival skills.

Token creation: cut paper to correct shape

First observed parrot spontaneous use of stick

** Are corvids capable of theory of mind?

Ravens are smart enough to be paranoid

- 2016 study: concluded that ravens possess Theory of Mind: ability to recognise mental states within themselves, and extrapolate that others have mental states, too, and that those mental states in others may differ from their own.
- Fears over surveillance, being watched, figure large in the bird world. Ravens hide their food more quickly if they think they are being watched, even when no other bird is in sight.
- Implies they may attribute mental states such as knowledge to others.
- To test this idea, ravens were trained to use a peephole to watch a human hiding food in an adjoining room. Then they were put in the second room with the food, and observed in two conditions: with the peephole closed, and with the peephole open and a loudspeaker playing raven cries.

Peephole

- First, a raven was given food with another raven in the next room, with the window open or covered, to see how quickly it caches its prize. With the window open, the birds hid their food more quickly and avoided going back to conceal it further.
- Then individual ravens were then trained to use the peephole to see where humans were putting food in the other room. The idea here was to allow the bird to realize it could be seen through the peephole.
- Finally, they gave ravens food with the window covered but the peephole open, and played sounds from a speaker in the next room so that the raven might think another bird was there.

Peephole: thinking about what other ravens are thinking about

- In the last setup, the ravens hid their food more quickly – within around 8 seconds rather than 14 – than they did when the window and peephole were both covered, and returned less often to conceal the stash. Both, presumably, in fear of being seen by a peeping rival that may steal that food later on.
- The results suggest ravens can generalize from their own perceptual experience to infer the possibility of being seen by others who are not visibly present.
- They attribute visual access to others, which is certainly one aspect of a theory of mind,

Ravens: attempt to deceive other ravens

- Social competence is also needed in other settings. A raven will track when it is being observed and another bird could have spied its cache.
- Ravens seem to understand what others can or cannot see and even assess another bird's level of knowledge.
- If necessary, ravens deceive potential cache thieves by leading them to an empty place where they pretend to have food stockpiled.

Social capacities: Gaze

- Another advanced behavior of crows involves gaze and gesture.
- Eye signals occur throughout their social group but most often with close relatives and friends.
- They look at a hidden supply of food and their close companions will know where it is and go to it.
- They, also, respond to human gaze and gestures if they aren't threatening.
- These cues from human gaze to find food are much faster if the bird knows the human.
- Crows will use their companion's gaze ahead of humans who they don't trust. They use different human cues in the same way—one eye, two eyes, eyes open or closed, and different facial directions. Therefore, they generalize about the state of the human's attention.

Gaze following

- Gaze following in primates, dogs and goats. One hypothesis is that gaze following is a general behavioral feature of social species. Persons with autism have impaired gaze following.
- When Austrian researchers hid food behind a partition, ravens found it, apparently by noticing where the humans were looking and following their gazes to the hidden food.

Social eye gaze: object permanency – 3-4 yo child; pay close attention to what others are looking at or pointing at

** Food caching

Food caching

- If have more food than they can eat, they hide the food.
- But only if they are not being observe by other crows or jays.
- If observed, will go hide it somewhere else.
- Remember dozens to hundreds of hidden caches
- Crows: if they hide food, and an honest researcher looks at their hidden food but leaves it alone, whereas another researcher steals it. Next time, if they see the honest one, they will leave their food visible, but will hid it out of sight if see stealer.

Caching: Hiding food

- The ability to hide food requires highly accurate spatial memories.
- Corvids have been recorded to recall their food's hiding place up to nine months later.
- It is suggested that vertical landmarks (like trees) are used to remember locations.
- There has also been evidence that Western Scrub-Jays, which store perishable foods, not only remember where they stored their food, but for how long. This has been compared to episodic memory, previously thought unique to humans

Caching and Theory of mind

- Theory of mind is capacity to understand that others have desires and intentions that are different from one's own.
- Corvids seem to understand that other birds have minds like theirs, and their decisions often take into account what others might know, want or intend,
- Humans don't develop it until late in childhood.
- For one thing, it may help prevent food theft. Crows and ravens often hide food in caches and retrieve it later.
- You can actually see them watching both the other birds that they are with and the humans, and if they sense that they have been seen, they will take that food and they'll go and hide it somewhere else

Avian Theory of Mind and counter espionage by food-caching western scrub-jays

J. Dally, et al., 2009

- Food-caching scrub-jays hide food for future consumption and rely on memory to recover their caches at a later date. These caches are susceptible to pilfering by other individuals, however.
- Consequently, jays engage in a number of counter-strategies to protect their hidden items, caching most of them behind barriers, or using shade and distance as a way of reducing what the potential pilferer might see.
- Furthermore, after being observed by a potential pilferer at the time of caching, jays re-hide food in new places.

Food caching: understanding another’s perspective

- Importantly, however, jays only re-cache food
  - if they have been observed during caching
  - only if they have stolen another bird's caches in the past.
- Naïve birds that have no thieving experience do not do so.
- The inference is that jays with prior experience of stealing others' caches engage in experience projection, relating information about their previous experience as a pilferer to the possibility of future cache theft by another bird.
- These results raise the intriguing possibility that re-caching is based on a form of mental attribution, namely the simulation of another bird's viewpoint.

Caching protection: only if you have been a thief

- However, they cannot control what another bird has seen at the time of caching: once they are alone, scrub-jays will return to a caching site and move caches made previously (i.e. while they were being observed) to new locations that are now unknown to a potential thief
- Cache-protection behavior has further been shown to depend on the birds’ individual experience with stealing.
- Birds that have previously stolen themselves, that is, that have had the experience of being a thief, are more likely to show cache protection strategies.
- This result suggests that birds with pilfering experience project their own experience onto others.

Caching protection: only if you have been a thief

- However, they cannot control what another bird has seen at the time of caching: once they are alone, scrub-jays will return to a caching site and move caches made previously (i.e. while they were being observed) to new locations that are now unknown to a potential thief
- Cache-protection behavior has further been shown to depend on the birds' individual experience with stealing.
- Birds that have previously stolen themselves, that is, that have had the experience of being a thief, are more likely to show cache protection strategies.
- This result suggests that birds with pilfering experience project their own experience onto others.

Theory of mind

- Caching behaviors and strategies indicative of theory of mind have been reported:
  - scrub jays that had previously cached food items while observed by another jay were given an opportunity to remove and recache the food without being observed; only jays who themselves had stolen from other birds recached their own food items in this situation.
  - Likewise, ravens have been found to engage in deliberately deceptive maneuvers designed to lure a other dominant bird away from the concealed food

Gaze perception & ToM

- If stranger is looking at grub that crow wants, crow will wait a long time before grabbing the grub
- But if strangers looks away from grub, crow will grab it immediately
- Implies theory of mind: understanding intentions of another

Masters of deception: hiding things

- Crows are quite sophisticated in protecting their hidden supplies.
- Most animals can only take hidden food by observing the bird in the act of hiding them. Crows remember exactly where others hide the food and return later to get it.
- They hide their food behind objects when they are being observed. They understand hiding in shady areas and at a distance and only use these techniques when being observed.
- They understand hiding without noise if anyone can hear them, but not see them.

Deception

- When completely alone, crows hide food in areas which make a lot of noise. They use this noise making to flesh out whether someone is around that can hear them and draw attention.
- When they notice that a specific bird saw them, they will observe from a distance, come back and move the supply to a new location.
- They don’t hide from their close family and mates.

Caching and deception

- California scrub-jays (*Aphelocoma californica*) are have extensive observational-spatial memory. That is, individuals are proficient in remembering caches made by their other birds, and thus are able to steal them.

- Food hoarding birds employ a number of strategies to protect their food

- Experimental studies show that these protection strategies are flexibly adjusted to another bird's ability to see the actual caching of the food. When observed by a another bird that is not their partner, scrub-jays will prefer to cache in places that are not visually accessible to an observer, for example behind an occluding barrier.

- They will also attempt to conceal their caches as best as possible, for example by hiding them further away from an observer or avoiding well-lit areas. They prefer to cache in quiet compared to noisy substrate when a present bird can hear but not see them.

Katharina Friederike Brecht, 2017

Scrub jays who steal: Takes a thief to know a thief

- Scrub jays don't instinctively re-hide nuts from other spying jays; they only begin to move their stash after they stole nuts from their fellows.
- Suggests that jays might understand what another bird was thinking and plotting
- Crows: If it sees another animal is watching, the crow will pretend to hide its treasure, but will really stash it in its feathers. The crow then flies away to find a new secret spot.
- If a crow sees another crow hiding its prize, it knows about this little game of bait-and-switch and won't be fooled. Instead, it will follow the first crow to discover its new hoard.

Examples of Theory of Mind

- Little green bee-eater: may be able to see from the point of view of a predator.

- The brown-necked raven has been observed hunting lizards in complex cooperation with other ravens, demonstrating an apparent understanding of prey behavior.

- A male Eurasian jay takes into account which food his bonded partner prefers to eat when feeding her during courtship feeding rituals.

- Such an ability to see from the point of view of another individual and to attribute motivations and desires had previously been attributed only to the great apes and elephants.

ToM: Little Green Bee eater

- Study suggested that green bee-eaters may be capable of interpreting the behavior of human observers.
- They showed an ability to predict whether a human at a particular location would be capable of spotting the nest entrance and then behaved appropriately to avoid giving away the nest location.
- The ability to look at a situation from another's point of view was previously believed to be possessed only by primates.[

Corvid Re-Caching without 'Theory of Mind': A Model

- Two explanations have been offered for corvid re-caching when observed.
  - 1- corvids have theory of mind, or
  - 2 - they apply behavioral rules learned in daily life

- New theory explains re-caching as side-effects of stress and the resulting memory errors.

- Inspired by experimental data, we assume that re-caching is not motivated by a deliberate effort to safeguard specific caches from theft, but by a general desire to *cache more*.

- Re-caching is brought on by stress, which is determined by the presence and dominance of onlookers, and by unsuccessful recovery attempts.

•Elske van der Vaart , et al., 2012

Corvid Re-Caching without 'Theory of Mind'

- Study: in two simulation experiments similar to those done with real birds with a kind of 'virtual bird' (computer simulation), whose behavior depends on a set of basic memory assumptions about corvid cognition.

- The 'virtual bird' acted as the real birds did; its re-caching reflects whether it has been watched, how dominant its onlooker was, and how close to that onlooker it has cached.

- It <u>had only a single behavioral rule: A preference for caching far away from other birds; learned from experience</u>. This happens even though <u>it cannot attribute mental states.</u>

- Thus, our simulations indicate that <u>corvid re-caching can be explained without sophisticated social cognition.</u>

Alternatives to Theory of Mind in Animals

- There is still an open question of whether corvids re-cache by using behavioral cues or by attributing mental states.
- Behavior reading ability: corvids rely predominantly on certain regularities in another bird's environment and the *effect* of their behavior rather than on their actual mental state.
- Theory that animals are able to attribute visual perspective and knowledge to others is not the most parsimonious explanation for their performance.
- Rather corvid react to some form of behavioral and contextual cues that they have learned about in previous encounters with other birds.

Katharina Friederike Brecht, 2017

Alternatives to Theory of Mind in Animals

- It is possible that human theory of mind and corvid theory of mind-like abilities rest on different mechanisms: humans seem to be very tuned to a range of different cues of agency, such as the perception of biological motion.
- Although corvids might be sensitive to other birds and to how other birds are related to and interact with objects in their world, they do not seem to be sensitive to cues such as agency, that, in humans, have been associated with social cognitive ability.

** Mirror Test

Self Awareness: Mirror test

- The mirror test gives insight into whether an animal is conscious of itself and able to distinguish itself from other animals by determining whether it possesses or lacks the ability to recognize itself in its own reflection.
- Mirror self-recognition has been demonstrated in European magpies, making them one of only a few animal species to possess this capability.
- Whether or not corvids can recognize themselves in a mirror is debated. So far, there are two positive report of corvids passing the mirror mark test: When presented with a mirror, both magpies and Indian house crows showed mark-directed behavior.
- No mirror self recognition in kea and Goffin's cockatoos: did not find support for mirror self recognition in parrots.

Self awareness

- The mirror test allows scientists to determine whether birds are conscious of themselves and able to distinguish themselves from other animals by determining whether they possess or lack the ability to recognize themselves in their own reflections.
- Mirror self-recognition has been demonstrated in European magpies, making them one of only a few species to possess this capability. However, in 1981, Epstein, Lanza and Skinner published a paper in the journal *Science* in which they argued that pigeons also pass the mirror test. A pigeon was trained to look in a mirror to find a response key behind it which it then turned to peck—food was the consequence of a correct choice (i.e., the pigeon learned to use a mirror to find critical elements of its environment)

- Next, the bird was trained to peck at dots placed on its feathers; food was, again, the consequence of touching the dot. This was done without a mirror. Then a small bib was placed on the pigeon—enough to cover a dot placed on its lower belly. A control period without the mirror yielded no pecking at the dot. But when the mirror was shown, the pigeon became active, looked into it and then tried to peck on the dot under the bib.
- Untrained pigeons have never been able to pass the mirror test. However, pigeons do not normally have access to mirrors and do not have the necessary experiences to use them. Giving a pigeon this experience in no way guaranteed it would pass the mirror test, since the pigeon never pecked dots on its own body in the presence of the mirror (until the final test).

Mirror recognition

- Colored piece of paper on throat: The sticker-extracting behavior occurred only when the bird could see a salient mark on her plumage in the mirror. Because several other magpies we tested behaved in a similar fashion, we concluded that Eurasian magpies seemed to understand that they were seeing their own reflection in the mirror.
- Other than humans, only a few mammals with large brains such as chimpanzees, orangutans, Indian elephants and bottlenose dolphins had at the time demonstrated similar evidence for self-recognition. The ability of magpies to recognize themselves in the mirror is just one of many aspects of complex cognition that have recently been demonstrated in corvids and parrots.

Mirror recognition?

- Despite this, pigeons are not classified as being able to recognize their reflection, because those that did were trained to do so and the animal must be able to do this without human assistance: it must also be shown that the birds are able to do this in the wild with no experience, just on their own intelligence. But even when an animal is trained to do this, it is still unknown if they are self-aware, or are just repeating the same movements and commands that they were taught so that they may receive a treat as a reward after they have correctly completed their task

Carrion Crows (*Corvus corone corone*) Fail the Mirror Mark Test Yet Again
Katharina F. Brecht, et al., 2020

- The mirror mark test is generally considered to be an indicator of an animal's ability to recognize itself in the mirror. For this test, an animal is confronted with a mirror and has a mark placed where it can see the mark only with the help of the mirror. When the animal extensively touches or interacts with the mark, compared with control conditions, the mirror mark test is passed. Many nonhuman animal species have been tested, but few have succeeded. After magpies and Indian house crows passed, there has been a sustained interest to find out whether other corvids would pass the mirror mark test.

Mirror test

- Here, we presented 12 carrion crows (*Corvus corone corone*) with the mirror mark test. There was no significant increase of mark-directed behavior in the mirror mark test, compared with control conditions. We find very few occasions of mark-directed behaviors and have to interpret them in the context of self-directed behavior more generally. In addition, we show that our crows were motivated to interact with a mark when it was visible to them without the aid of a mirror. We conclude that our crows fail the test, and thereby replicate previous studies showing a similar failure in corvids, and crows in particular. Because our study adds to the growing literature of corvids failing the mirror mark test, the issue of mirror self-recognition in these birds remains controversial.

Subjective experience in corvids

"Do you see what I see: subjective consciousness in crows"

- Kaeli Swift, Ph.D: Crows exhibit a two-stage process, where neuronal activity during Stage I mostly reflects the intensity of the physical stimulus, followed by a second spike in activity that reflected their subjective perception.
- The patterns of neuron activity in Stage II were so consistent, that the researchers could predict whether the crows would say they saw the light or not by looking at this activity alone.
- Most importantly, while the responses of the two birds were the same if the light intensity was bright and unambiguous, when shown faint lights, the two birds responded differently. Meaning that despite being shown the exact same stimulus, the two birds had different subjective experiences of whether they had seen it or not. There were also instances of false positives, where the birds indicated that they had seen a light that wasn't really there. In these cases their brains behaved during Stage II just as they did when they had actually seen a bright light.
- This is important because it further demonstrates that the brain activity the researchers were measuring correlated with the crows' subjective experience, rather than as a result of the intensity of the stimulus itself.

Subjective consciousness

- What this shows us is that carrion crows have the neurological substrates that support subjective consciousness, and it indeed appears that they have individual experiences of stimuli.
- It does *not* show us, despite many articles to the contrary, that they are "self-aware" or engage in metacognition (the ability to "ponder the contents of their own minds").
- Furthermore, it underlines that despite the differences between mammalian and avian brains, the two are remarkably functionally analogous, at least with respect to some species. In fact some have gone as far as to say that this and other studies indicate that the continued assertion that birds do not have a cerebral cortex is outdated and wrong.

Has Success Spoiled The Crow?

- The Puzzling Case File on the World's Smartest Bird
- in David Quammen's Natural Acts
- “You know the pattern. High intelligence, large promise. Early success without great effort. Then a certain loss of purposefulness. Manifestation of detachment and cruel humor. Boredom. Finally the dangerous spiral into drug abuse.
  But maybe it's not too late for the corvids. Keep that in mind next time you run into a raven, or a magpie, or a crow. Look the bird in the eye. Consider its frustrations. Try to say something stimulating. “

Cro-Bro

We can all get along together

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