Phylum Chordata - Vertebrata
Birds

of all higher vertebrates, birds are probably best known

9700 species

→ 2nd most abundant vertebrate group

→ outnumber all other vertebrate groups except fish

smallest bird: bee hummingbird 1.8g (.06oz)

one of smallest warmblooded vertebrates

largest bird: elephant bird of Madagascar is most massive bird that ever lived

2 M tall, 450kg(~1000 lbs)

also: tallest was extinct moas of New Zealand

flightless bird, related to emus

12 ft (3.6 M) to 550 lbs (250kg)

birds are found in all habitats:

forests, deserts, mountains, praries, oceans

some live in caves in total darkness

some can dive to 140' to capture prey

birds are even found at the north and south poles

Origin of Birds

for over 50 MY amphibians and reptiles were the sole terrestrial vertebrates

before the Permian extinction, 250 MY ago, a branch of reptiles leading to birds an mammals arose

earliest fossil of a true bird ***Archaeopteryx*** (=ancient wing) 150 MY ago

first fossil discovered in 1861 –2 yrs after Darwin's origin of species

rare find since delicate bones and feathers don't fossilize well

if not for impressions of feathers would be classified as a small dinosaur

birds clearly evolved from dinosaurs

more similar to dinosaurs than dinosaurs are to turtles, snakes and lizards

following the rules of taxonomy they should be in same class (reptilia)

Archaeopteryx (=ancient wing)

~ size of crow
jaws had teeth
clawed fingers
reptilian skeleton

long reptile like tail

but

no keel for flight muscles
→ probably didn't fly
bones not thin and hollow as in modern birds
brain comparable to reptile not to larger bird brain

by cretaceous, fossils clearly indicate birds that could fly

by end of tertiary (3 MY ago) many modern families were already in existence

some were up to 12 ft tall

Origins of Flight

flight has several advantages over other forms of locomotion:

→permits sudden and rapid escape from predators

→ easier to find food, water, nesting areas, mates, etc

→fast straight line travel from place to place

→inaccessible places become accessible; opens up new niches

→ facilitates migrations over long distances

flight had evolved at least 4 different times in history of life:

insects: 330 MY(SN04); carboniferous
reptiles: 170MY pterosaurs; late jurassic ,
birds: 150MY; coexisted with pterosaurs for~90MY
bats: ~40MY (later Eocene)

birds didn't evolve feathers & wings "in hopes" of achieving flight

→there had to be an advantage at each state in its evolution

two major theories:

1. arboreal (gliding, trees down):

wings evolved in reptiles that climbed trees to hunt for insects

→ could glide to base of next tree

eg. used today by some woodpeckers

2. cursorial (running ground up):

wings evolved in running reptile perhaps as stabilizers

eg. archaeopteryx evolved from a running reptile: has running legs and feet, not perching

Body Form

in spite of the great diversity of birds they are amazingly similar in structure

birds evolved as flying machines

entire anatomy is designed around flight

overall shape and characteristics must insure that:

→center of gravity and propulsion systems are properly balanced

→ body is light yet strong enough for flight

small compact body; reduced weight; with all heavy organs close to center of gravity

Skin

bird skin is thin, light and flexible

→ the major functions of skin (insulation and protection from the elements is taken over by the feathers

loosely attached to body

directly attached to bone in several places
- skull and beak
- wing tips
- legs

no sweat glands

single oil gland at base of tail
→ preening

skin over most of body is covered by feathers

on legs only: scales instead of feathers

on head and neck in some birds
→ combs and wattles

often brightly colored "ornaments"

used for dominance or sexual signaling

other bare areas:

vulture head
→ keeps feathers clean while feeding on carcass

ostriches & relatives
→ unfeathered legs used for cooling after heavy exercise

arctic birds have NO bare areas

Feathers & Flight

wings and body covered by **feathers**

today, the single unique trait that identifies all birds

almost weightless but incredibly strong and tough

feathers smooth the surface and streamline the contour of the body

→ make flying more efficient

but origin of feathers was clearly not for flight

→ many dinosaurs apparently had feathers

primaries are the most critical in flying
→ their loss may prevent flight

feathers are **epidermal structures** derived from reptile scales

developing feathers closely resemble developing scales

scales elongate, edges fray

some dinosaurs clearly had feathers

feathers tend to grow in dense **tracts** with bare areas between

while growing feather has a blood supply

when fully grown blood supply is sealed off, and feathers are dead structures

feathers can be moved individually by muscles in skin (**arrector pili**)

consist of:

quill part of shaft below vanes

shaft (=rachis)

vanes

barbs & hooked barbules overlapping extensions of vane
preening "zips" barbs and barbules back together

kinds of feathers

contour feathers

most of the visible feathers
→ smooth and streamline body surface

flight feathers = contour feathers that extend beyond the body and used in flight

down feathers (plumules)

soft tufts without rachis

lack vane, barbs fan out, not hooked together

hidden beneath contour feathers

especially on breast and abdomen of water birds
to conserve heat

filoplumes (decorative feathers & bristles)

hairlike, degenerative feathers; simple shafts or with tuft of bristles at end

some decorative → displays

bristles →sensory

on head
around eyes
around mouth and nostrils

birds spend much time on feather maintenance:

preening → reconnects barbs & barbules

oiling → waterproofing

bathing

dust baths → to remove ectoparasites

feathers can be replaced individually as need or as a group by molting

Molting

feathers are shed regularly = **molting**

highly orderly process

(except for penquins who molt all at once)

frequency of molt depends on wear and tear and seasonal factors

most birds molt once/yr

usually late summer after nesting season

feathers must be shed gradually and symmetrically (matched pairs) to retain ability to fly

replacements emerge before next pair is shed

→ only ducks and geese are grounded during molting

→ wing clipping: removing critical flight feathers on one wing to prevent flight

Coloration:

among vertebrates, only tropical reef fish show the same intensity and diversity of color

a feather is naturally white

coloration due to:

a. Pigments

chromatophores impart colored pigments during feather development

→ color deposited in barbules as they form

melanins: black, brown, dull yellow, dull red

carotenoids: bright yellow, orange, many reds

porphyrin: bright green, some reds

b. structural color

coloration due to refraction or scattering of light rays

→ all blues, most greens and some purples of animals

eg. blue jays, indigo buntings, bluebirds

eg. there is no "color" in blue jay feathers

eg. Tyndall blue → caused by light scattering (refraction) from keratin layers

eg. there is no 'color' in blue jay feathers

eg. iridescence →due to interference patterns of light; light

interacting with bundles of hollow tubules inside feathers

color may change when viewed at different angles

eg. starlings & peacocks

color used for:

camoflage

eg. in many species, juveniles and females are camouflaged with melanin pigments

eg. arctic birds white in winter, darker in summer

breeding/communication

eg. males breeding plumage often brightly colored

warning

eg. toxins similar to that of poison frogs has been found in skin and feathers of some brightly colored New Guinea species of *Pitohui*

Skeletal System

some of the most important flight adaptations are

found in the skeleton

the skeleton is exceptionally **light and delicate** yet sturdy

frigate bird: 7’ wingspan→ skeleton = 4 oz
→ less than weight of feathers

vs humans 6’ skeleton (6-7’ armspan) weighs ~10 lbs

bones light and hollow with air sacs

Many bones are **fused** together to make them light, but still strong

skull is light, bones fused together

many vertebrae are fused together (not neck) for more rigid support of body

pelvic girdle is also fused and joined to stabilize legs for landing

anterior skull bones are elongated to form **beak** (or **bill)** covered with hardened skin attached to skull
→modified lips

since birds lose the use of their forelimbs their **beaks** are used as tools

long tubular beaks for nectar
sturdy wedge shaped to pry insects from bark
curved overlapping beaks to crack nuts and seeds
long upper beak that curves down over lower to tear flesh

neck is extremely flexible with more vertebrae than most vertebrates

most mammals have 7 vertebrae
birds have 11-25 vertebrae

the rest of the **vertebral column** is very rigid

fused ribs and interlocking vertebrae provide additional attachment sites for flight muscles

the major flight muscles attack to large **keel** on **sternum**

collar bones are fused (**wishbone**) and connected to shoulder blade for additional support of wings

the pelvic bones are also fused and fused to vertebrae to provide a stable support for landing and walking

while the limbs of birds are made up of the same bones found in the limbs of all vertebrates they are modified in a characteristic way:

the **pectoral appendage** forms 3 major joints that support the flying feathers

humerus - first wing segment; upper arm of us

radius & ulna - second wing segment; lower arm of us

carpometacarpus and phalanges - third wing segment of bird; hand of us

the **pelvic appendage** has 4 major joints:

femur - only slightly moveable
→ acts as shock absorber for landing

tibiotarsus - upper "leg" of bird; lower leg and foot of us

tarsometatarsus - lower "leg" of bird; foot of us

phalanges - feet of bird; toes of us

Movement

numerous muscles in neck provide provide tremendous agility

forelimbs modified into **wings**

breast muscles are the flight muscles

flight muscles (breast muscles) often very large % of body weight

eg. pigeon up to 50%

not so in gliders and soarers

main muscle mass is near a bird's center of gravity

wings have to be large enough to generate enough lift to support birds weight

→ direct relationship between body wt and wing area

largest bird that can fly is the great bustard *Otis tarda*

→22 kg (~10 lbs)

arched wing creates concave depression on underside

creates upward suction as wing passes through air

when flyng in flocks birds use each others energy like fish in shoals

takes advantage of lift turbulence created by the motion of those in front of them

kinds of flight:

wings are designed to facilitate a particular kind of flight

launching

gliding and soaring
use up drafts to stay airborne

flapping flight
complex "figure-8" pattern

hovering

maneuvering
smaller faster wings

swooping

diving

swimming

Flight Speeds:

cruising speeds are usually ~40 km/hr (25 mph)

peregrine falcon can reach 190 km/hr (120 mph)

many birds can hover at 0 mph

feet nearly devoid of muscles

→ greater agility

→ since mostly bone, tendons & tough skin

very resistant to freezing damage

when perching, toes lock around branch

→ prevents bird from falling off while sleeping

early birds had long reptilian tail

modern birds have replaced tail with up to 1000 tail feathers; each under individual muscular control

Digestive System

first birds were probably **carnivores**

→ probably fed mainly on insects

head & beak very flexible & versatile; used like a tool or limb:

bird gave up "hands" millions of years ago and now use **beak/bill** in their place:

eg. catch bugs, shatter seeds, crush shells, drill holes, dismemeber carcasses, snare fish

eg. attack enemies, build nests, preen, impress mates and feed young

birds lives revolve around their beaks

beaks of birds are highly adapted for their feeding type

eg. crows →generalized type has strong, pointed beak
eg. woodpecker → straight, hard, chisel like
eg. hummingbird → long tubular, ~20% birds feed on nectar
eg. seagull → basketlike sac below beak

contrary to conventional "wisdom" birds are voracious feeders due to **high metabolic rate**

hummingbird has the fastest metabolic rate of all birds

eg. 12x's MB of pigeon & 25x's MB of chicken

hummingbird may eat 100% body wt/day

crop:

in many birds there is an enlargement at lower

end of the esophagus = **crop**

stores food to provide a continuous supply of energy during flight

used to store food for regurgitation to feed young

in pigeons, doves and some parrots: crop not only stores food but produces "bird milk"

breakdown of epithelial lining
much higher fat content than cow milk

→ feed young for a few days after hatching

gizzard:

modern birds have no teeth

grinding is done in gizzard

muscular with hard keratinized plates to help grind food

some birds "eat" pebbles to aid this process

some birds of prey form **pellets** of undigested material (bones and fur) and regurgitate them

eg. owl pellets

birds have very efficient digestion

eg. shrike - can completely digest a mouse in 3 hours

eg. thrush - berries pass completely through GI tract in 30 minutes

Respiration

birds & mammals are **warm blooded** (homeothermic)

→ they maintain a constant body temperature independent of environment

flight is energy intensive; requires a consistently high metabolism

higher than land mammals (eg. 110º vs 98º F)

have fast heart rate

eg. hummingbirds 1000 bpm (humans 70bpm)

respiratory system is specially adapted to meet this metabolic demand

→ very different from other vertebrates

bird lungs are different than those of mammals:

instead of microscopic **sacs** (=alveoli0 that fill with air with each breath,

bird lungs contain microscopic tubes, open at both ends (=**parabronchi**)

in addition to **lungs**, birds have extensive system of **air sacs** in body

usually consists of 5 **air sacs** connected to **lungs**

branches throughout the body and enters larger bones

→air goes through lungs on exhale while new air is coming into air sacs

in alveoli of mammals new air mixes with old in blind ended sacs

in parabronchi fresh air is constantly moving through tubes

doesn't get diluted with old air

→ much more efficient gas transfer

air sacs and **lungs** often make up 20% of body volume (humans lungs=5%)

these air sacs also serve as an **air conditioning system**

→ cool bird during vigorous flight

eg. pigeon produces 27x's more heat flying than at rest

bones with air sacs help to **lighten weight** of bird

even provides a little **buoyancy**
→ hot air rises

Syrinx

most birds have a larynx (voice box)

but don't use it to generate sounds

they do have a **syrinx**

a cartilaginous chamber at the base of the trachea with muscle controlled membranes which they use to make familiar bird songs

membranes on each side can produce separate sounds to generate chords or harmonies when singing

Circulation

similar to mammals:

4 chambered heart

2 completely separate circuits: pulmonary & systemic

heart is relatively large

very fast heartbeat (humans ~70-75bpm at rest):

eg. turkey 93 bpm

eg. chicken 250 bpm

eg. blackcapped chicadee 500 bpm

→ exercise to 1000 bpm

actual blood pressure is similar to mammals of similar size

Nervous System & Senses

brain is same relative size as mammals

cerebellum is relatively larger than in mammals or reptiles

→ coordination of flight muscles

eyes are perhaps the most important sense organ

disproportionately large; compare orbits in skulls

no eye muscles
→ all space is filled with eyeball

cant move eyes to track objects

→flexible neck compensates

platelike **sclerotic ring** strengthens and focuses eyes

some birds of prey have 2 **foveas** (areas of greatest visual acuity - mammals have one)

Pecten is a thin, greatly folded tissue extending from the retina toward the lens.

unique structure in birds eyes

supplies nutrients and oxygen throughout the vitreous humor

this reduces the number of blood vessels in the retina.

With fewer blood vessels to scatter light coming into the eye vision is enhanced

predatory birds such as eagles and hawks have the largest and most elaborate pecten of all the birds.

generally:

predatory birds have eyes in front of head

→ **stereo vision** = depth perception

vegetarian birds have eyes that look out to sides

→ greater field of view

visual acuity of hawk is 8x's that of humans

best vision in animal kingdom:

→ can clearly see crouching rabbit >1 mile away

eyes have **nictitating membrane** (reptile trait)

in some water birds this membrane acts as a "contact lens" to help birds focus underwater

hearing is also well developed in birds

have retained single middle ear bone (**columella**)

do have short outer ear canal

better **cochlea** (but long and straight)

senses of **smell** and **taste** not very well developed

eg. vultures

Excretion

kidney is similar to that of reptiles

contains **nephrons** which filter blood and remove metabolic wastes

water is conserved by excreting insoluble **uric acid** as main nitrogen waste

takes 20x's more water to get rid of urea than to get rid of uric

acid

metabolic wastes are passed directly to cloaca

birds have no bladder

water is reabsorbed in cloaca

the white, paste-like uric acid that remains is eliminated along with feces through the **cloaca**

like reptiles, marine birds have **salt glands** that empty through nostrils to get rid of excess salt

Reproduction, Nesting & Egg Laying

birds are **dioecious**

to save weight:

→in males testes enlarge only during mating season

→females only have left ovary; not paired

Nesting

selection of territory usually occurs a few weeks before nesting season

male selects nest location

males sing, drum and hoot

males sometimes very colorful during breeding

season, dull rest of time

many develop seasonal ornamentation

eg. inflated skin pouch on throat

solitary species defend fairly large area

gregarious species that nest in colonies defend a very small area

sometimes this seasonal instinct to defend territory becomes obsessive

eg. robin or cardinal that returns day after day to struggle futility with its reflection in a window pane

nest varies from simple depression to weaver birds communal nests for 100's of birds

eg. typical nest of smaller bird is cup shaped "basket" lined with finer material

eg. barn and cliff swallows mold nests of mud from softened pellets

most birds void outside of nest

Internal fertilization

most birds are monogamous while mating

but after mating they go their own ways

most no transfer organ →press cloacas together

a few birds have erectile penis with external groove to guide sperm into females cloaca

Eggs

all birds lay eggs (=oviparous)

not sure why they never evolved to bear live young (=viviparity)

live bearing did evolve in ***all*** other vertebrate groups:
- fishes
- amphibians - at least twice
- reptiles - 100's of separate times
- mammals - once

one argument is that it would be difficult for a pregnant bird to fly

but: bats can

all eggs have hard shells with lots of microscopic pores

shell is soft when formed hardens before being layed

egg size & shape

largest: known bird egg is from extinct Elephant bird (*Aepyornis*) of Madasgascar

13" long, 9.5" dia; 2 gallon volume

smallest: some hummingbird species <1/4th "

abnormal eggs:

a. runt egg

→yolk smaller than normal

→ parasite or debris in oviduct triggers egg fomation missing yolk all together

b. double yolk
rarely 3 yolks

c. egg within an egg

enforced return up the oviduct

Parental Care

usually female incubates eggs

12-30 days needed for incubation

incubating birds develop "incubation patches"
loss of feathers
thickening of skin
greater blood supply to area to maintain temp

in hot areas birds must shade eggs

after hatching young are fed by **regurgitation**

Migrations

regular extensive seasonal movements of birds

between summer and winter regions

origins: more northerly birds were forced south as winters got colder

enables bird to live in optimal climate all the time
generally breed in northern latitudes
overwinter in southern latitudes

as north and south ranges moved further apart due to continental drift the migration routes got longer and longer

just less than half of all birds migrate

(for 1000's of years thought most hibernated)

Why Migrate?

migration increases the amount of space available for breeding

→ reduces aggressive territorial behavior

avoids climate extremes favors homeostasis

→ less energy needed to maintain internal stability

north in summer

→ long summers, abundance of insects to rear

young, not many predators

much variation in methods of migration

most birds migrate at **night**,

esp smaller birds

mainly before midnight and immediately before dawn

→ protection from predators

→ can spend day feeding

some larger birds migrate in day

eg. hawks, shore birds, black birds, pelicans, bluejays

most fly at <3000'

very rare to find one >5000'

most travel at 20-50 mph

some 80-100mph

ancients thought they migrated in 1 night
→ would have required speeds of 180-240 mph

main timing factor is **changes in day length**

Arctic tern has longest migration route:

nests from Mass to Greenland and Alaska

spends winters off shores of Anarctic near Falkland Islands

→ experiences more hours of daylight than any other bird

only crossing the equator does it esperience long nights

navigation cues:

1. visual

   follow familiar migratory routes

   most migratory birds have **well established routes**

2. earth's gravitational field

3. celestial cues

4. sun's position in sky & 'time sense'

Classification of Birds

birds today are divided into 2 major groups with 27-28 orders:

1. flying birds
   largest group of these are **perching birds**
   → comprise >1/2 of all bird species

2. flightless birds (ratites)

   originally from flying forms

   flightlessness almost always evolved on islands with few predators

   lost use of wings; keel and flight muscles degenerate

   → lived with few predators in isolated areas

   tendency to become quite large

   eg. moas of New Zealand to 500 lbs

   eg. elephant bird of madagascar is largest bird that ever lived

   2 M tall, 450kg(~1000 lbs)

   developed very powerful legs

   → can achieve very fast running speeds

   eg. emu ~ 30 mph,

   eg. ostrich ~ 42 mph and up to 60 mph

swimming birds:

most have webbed feet

- birds with webbed feet for paddling have legs far back on body and tend to be clumsy walkers

those that dive skillfully are usually not very good fliers

some chase prey underwater by paddling with wings

gentoo penquin → 22mph

Bird Ecology

1. pollination

eg. hummingbirds
- do not have a highly developed sense of smell
- but do have excellent sense of vision
- frequently bright red or yellow flowers
- little if any odor
- fused petals with nectary
- produce copius quantities of nectar
- long floral tubes prevent most insects from reaching the nectar
- eg. fuschias, petunias, morning glories, salvias, cardinal flowers, trumpet creepers, columbines, penstemons

2. disperse seeds

eg. edible fruits
- attracts birds or mammals
- may eat whole fruit or spit out pits
- if swallowed seeds resistant to digestive juices
- squirrels and birds bury fruits and seeds
- nuts stored underground are forgotten

eg. passively carried by animals
- hooks or spines to catch in fur or on skin
- in mud on feet of birds, etc.
- burs, beggars ticks, devils claw, etc.

3. pest control

eg. Birds eat many things: beetles, flies, spiders, earthworms, rotting fish, offal, poison oak berries, weed seeds, etc

eg. raptors & owls - eat mice, rats, snakes

Human Interactions

1. extinct or endangered species due primarily

to human activities

2/3rds of bird species are declining in numbers

eg. about 20% of world's bird species have gone extinct in historic past

eg. Passenger Pigeon (Ectopistes migratorius)

inhabited eastern N America

200 yrs ago was the world's most abundant bird

→ 3-5 Billion

→once accounted for ~1/4th of al N Am birds

→ 1830's Audubon saw a single flock estimated at 10 miles wide and 100's miles long (~1 Bill birds)

were easily slaughtered for meat

→ they wouldn't fly away if threatened

over 20 yrs of hunting and habitat loss at end of 1800's the population was decimated

last wild bird was shot in 1900

last individual (Martha) died at the Cincinnati Zoo in 1914

eg. Ivory Billed Woodpecker

2. introduced pests

eg. starling

eg. house sparrow

eg. brown tree snake → Guam 1950 caused extinction of 9 of 18 native bird species; 3 sp of bats and several lizards

3. Domesticated Birds and Bird as Pets

some birds have been truly domesticated:

eg. fowl, geese, ducks, pigeons

a few are semidomesticated

eg. hawks and falcons

earliest domestication ~1700 BC in Persia

Europe ~300 BC

12% of pet sales are birds (19% dogs; 5% cats)

5 M live birds are sold worldwide

in US (1980's): 500,000 birds sold as pets

European Countries →buy 3/4th 's of live birds

illegal trade:

bird collectors will pay $10,000 for a rare hyacinth macaw from Brazil

$12,000 for a pair of golden-shouldered parakeets from Australia

mortality rate of live animal trade is enormous:

~50 animals caught or killed for every live animal that gets to "market"

4. bird watching

more lucrative than bird hunting

5. hunting

91 M birds are hunted each year worldwide

5 M birds are used for research each yr

500,000-700,000 seabirds killed as bycatch