

RAPTOR ACADEMY

# Raptor Pre-release Conditioning and Release



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## Introduction to Principles of Flight and Exercise

- Anatomical Adaptations That Allow Flight
- Physics and the Laws of Flight
- Principles of Exercise

March 12, 2019

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## Learning Outcomes



- To have knowledge of the key anatomical adaptations that allow flight
- Understand the two main laws of flight and how they explain flight abnormalities in raptors undergoing rehabilitation
- List the five basic principles of exercise and understand how they pertain to reconditioning raptor patients

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## Anatomical Adaptations That Allow Flight

The majority of bird species have adaptations that allow flight. These include specialized features of:

- Bones
- Muscles
- Body systems
- Feathers
- Wings

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## Anatomical Adaptations That Allow Flight: Bones

Compared to other animals, birds have relatively fewer bones.

Animal	Number of Bones
Human	206
Chicken	120
Bald eagle	103

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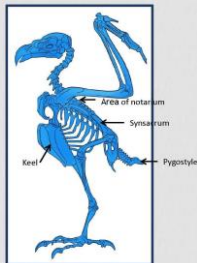
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## Anatomical Adaptations That Allow Flight: Bones

A beak replaces teeth.

Bones are fused in the vertebral column to form supportive plates.

There are fewer bones in the wrist and ankle joints.




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## Anatomical Adaptations That Allow Flight: Bones

Bird bones:

- Are lightweight
- Have thin cortices
- Are filled with air spaces
- Are strengthened by internal bony struts



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## Anatomical Adaptations That Allow Flight: Muscles

The majority of muscles are centralized, located near the bird's core (center of gravity).

Compared to mammalian muscles, on a gram-for-gram basis, avian muscles are four to six times stronger!



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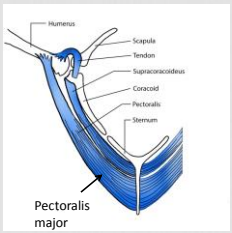
## Anatomical Adaptations That Allow Flight: Muscles

**Pectoralis Major**

Large superficial muscle

Originates on the keel and inserts on the ventral humerus (under side)

Contraction generates the downstroke



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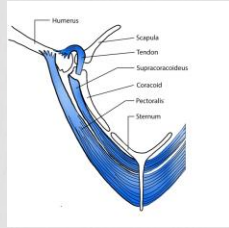
### Anatomical Adaptations That Allow Flight: Muscles

#### Pectoralis Minor (Supracoracoideus)

Smaller muscle beneath the pectoralis major

Originates on keel, ends in a tendon that inserts on the dorsal humerus (top side)

Contraction generates the upstroke



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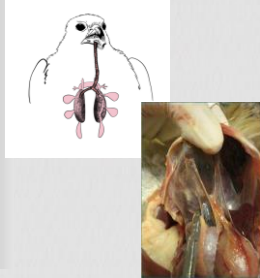
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### Anatomical Adaptations That Allow Flight: Body Systems - Respiratory

- Small efficient rigid lungs with air capillaries for gas exchange
- Air sacs - warm and humidify air to improve diffusion in lungs



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### Anatomical Adaptations That Allow Flight: Body Systems - Cardiovascular

Efficient in O<sub>2</sub> delivery to cells. Compared to mammals:

- Larger heart relative to body size
- Greater cardiac output
- Heart pumps blood at faster rate (150bpm vs 70bpm of humans)



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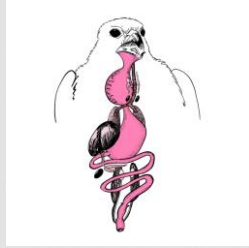
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### Anatomical Adaptations That Allow Flight: Body Systems - Digestive

- Two part stomach
- Intestine length varies with the nutritional value of their primary prey
- Well developed ceca in owls




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### Anatomical Adaptations That Allow Flight: Body Systems - Urogenital

Gonads enlarge during the breeding season and then recede



Male – 2 enlarged testes



Female – single ovary

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### Anatomical Adaptations That Allow Flight: Feathers

Flight feathers evolved to allow different styles of flight.

Feather function can be explained by the laws of flight.




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## Anatomical Adaptations That Allow Flight: Wing Shape

A bird's wing is naturally shaped as an airfoil.



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## Questions?



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## Physics and the Laws of Flight

*Bernoulli's Principle + Newton's Third Law*



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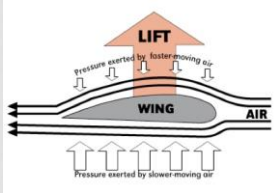
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### Physics and the Laws of Flight *Bernoulli's Principle*

The shape of an airfoil increases the speed of airflow over the top surface.



From how do airplanes fly? [http://fden-2.phy.uak.edu/211\\_fair2010/web/dr/devon\\_fitapatrick/home\\_page.html](http://fden-2.phy.uak.edu/211_fair2010/web/dr/devon_fitapatrick/home_page.html)

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### Physics and the Laws of Flight: *Bernoulli's Principle*




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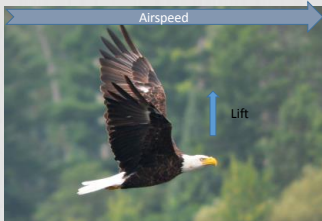
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### Physics and the Laws of Flight: *Newton's Third Law:*

For every action, there is an equal and opposite reaction.




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### Physics and the Laws of Flight: *Newton's Third Law*



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### Physics and the Laws of Flight

If a bird can lower the pressure above its wing to match/exceed its weight, it will become airborne.

What happens if raptors are overweight?



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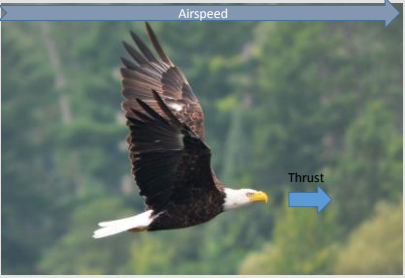
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### Physics and the Laws of Flight: *Newton's Third Law*



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### Physics and the Laws of Flight: *Newton's Third Law*



The diagram shows a bald eagle in flight against a background of green trees. A blue arrow labeled 'Airspeed' points to the right above the eagle. A blue arrow labeled 'Drag' points to the left below the eagle. A blue arrow labeled 'Thrust' points to the right below the eagle.

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RAPTOR ACADEMY

### Physics and the Laws of Flight: *Newton's Third Law*



The diagram shows a bald eagle in flight against a background of green trees. A blue arrow labeled 'Airspeed' points to the right above the eagle. A blue arrow labeled 'Drag' points to the left below the eagle. A blue arrow labeled 'Thrust' points to the right below the eagle. A blue arrow labeled 'Lift' points upwards from the eagle's wings. A blue arrow labeled 'Weight' points downwards from the eagle's body.

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### Questions?



The logo features a stylized owl with large eyes, wearing a blue graduation cap with a tassel.

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### Physics and the Laws of Flight: Feathers

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### Flight Feathers in Wings: Remiges

#### Primary flight feathers:

- Each wing has 10
- Differ in general structure to allow species-specific flight maneuvers

Notches/slots  
Emarginations



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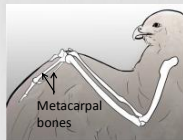
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### Flight Feathers in Wings: Remiges

#### Primary flight feathers:

- Attach to metacarpal bones via ligaments
- Can be individually separated
- Create thrust during the downstroke



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### Flight Feathers in Wings: Remiges

Adaptations to an owl's primary flight feathers that create silent flight:

- Comb-like bristles on the leading edge
- Porous, flexible fringes at the ends of barbs on the trailing edge
- Downy forest-like covering over the ventral surface




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### Flight Feathers in Wings: Remiges

Secondary flight feathers:

- Each wing has 12-15
- Relatively short and broad; uniform in shape




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### Flight Feathers in Wings: Remiges

Secondary Flight Feathers:

- Attached to the ulna by ligaments
- Cannot be separated
- Help to generate lift during the upstroke




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### Flight Feathers in Wings: Alula Feathers

#### Alula Feathers

- Attached to the thumb (near the wrist)
- Elevate to redirect airflow and prevent a stall



Photo by Sue Weiler

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### Flight Feathers in the Tail: Rectrices

- The majority of raptor species have 12 (6 pairs).
- Two central feathers (deck feathers) are immobile.
- The other 10 can be separated and rotated to create desired flight effects.



Deck feathers

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### Physics and the Laws of Flight: Wings and the Angle of Attack

The angle of attack is the angle formed between the oncoming air and the plane of the wings.



A bird creates different angles during different flight maneuvers.

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### Physics and the Laws of Flight: Wings and the Angle of Attack

As the angle increases so does lift; there is a point where the angle is so high, it creates a stall.

Birds create a stall to land, and elevated alula feathers help them to land slowly and smoothly.



www.shutterstock.com - BDC730

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### Physics and the Laws of Flight

Wing Loading (size)  
Wing Aspect Ratio (shape)

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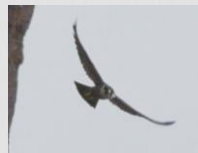
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### Physics and the Laws of Flight: Wing Loading

Wing loading (kg/m<sup>2</sup>) = Body weight/wing area



Low wing loading — Northern Harrier  
(*Circus cyaneus*)



High wing loading — Peregrine falcon  
(*Falco peregrinus*)

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## Physics and the Laws of Flight: Wing Aspect Ratio

Wing Aspect Ratio = wing span (length)/ wing cord (width)



Low aspect ratio



High aspect ratio

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## Questions?



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## Principles of Exercise

Exercise functions to maintain and/or improve physical fitness. There are five basic principles of exercise:

1. Overload
2. Regularity
3. Recovery
4. Balance
5. Variety

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### Exercise Principles: The Overload Principle

To increase fitness, muscles must be stressed past normal daily activities and progressed from the previous session.



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### Exercise Principles: Regularity

For exercise to increase fitness, it must occur on a repeating regular schedule.



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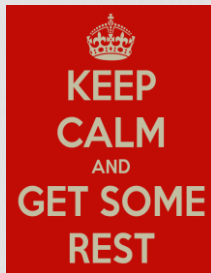
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### Exercise Principles: Recovery

Exercise causes tissue breakdown. Rest allows rebuilding to occur and is termed "anabolism."

Anabolism occurs during breaks from overload



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### Exercise Principles: Balance

There are two general categories of exercise:

- 1. Cardio
- 2. Resistance




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### Exercise Principles: Variety

Balance is achieved by a variety of different exercises.




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### Fitness Levels

#### Health fitness

Necessary for maintenance activities such as flying to a feeding platform, bathing, getting up to the perch, etc.




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## Fitness Levels

**Performance fitness**

Necessary for athletic activities such as sustained flight and active foraging



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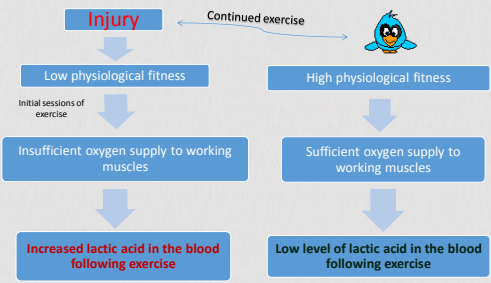
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## Determining the Level of Fitness



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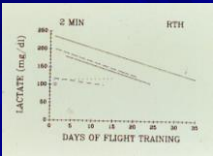
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## Physiological Assessment

Accumulation of lactic acid in the blood following exercise reflects dependence on anaerobic metabolic pathways – inadequate oxygen supply to working muscles



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## Physiological Assessment

As a bird's aerobic condition improves with exercise, it can sustain prolonged periods of flight with minimal accumulation of lactic acid in the blood.

Days of Flight Training	10 MIN (mg/dl)	RTH (mg/dl)
0	140	100
5	120	85
10	100	70
15	85	55
20	70	40
25	55	25
30	40	15
35	30	10

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### Summary of Biochemical Energy Production: Increased Exertion

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    graph TD
      A[Muscle glycogen] -- Glycolysis --> B[Glucose]
      B --> C[Pyruvate]
      C -- aerobic +O2 --> D["CO2, H2O, energy"]
      C -- anaerobic -O2 --> E["Lactic acid ↓ pH of blood and muscle cells"]
      E --> F[Fatigue]
  
```

High fitness: strong body systems to deliver oxygen to muscles

Low fitness: weak body systems to deliver oxygen to muscles

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## Resources

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Kerlinger, P. 1989. Flight Strategies of Migrating Hawks, University of Chisago Press, IL.

Terres, J. 1994. How Birds Fly. Stockpole Books, Mechanicsburg, PA.

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Questions?



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