Animals & Scale
Part 1

The Croods (2013)

The Croods is a film rich with fantastic, colorful creatures of all different sizes.

A challenge in creating such a world is to have mammals and birds that look and move in a way that's believable.

Size, Area, and Volume

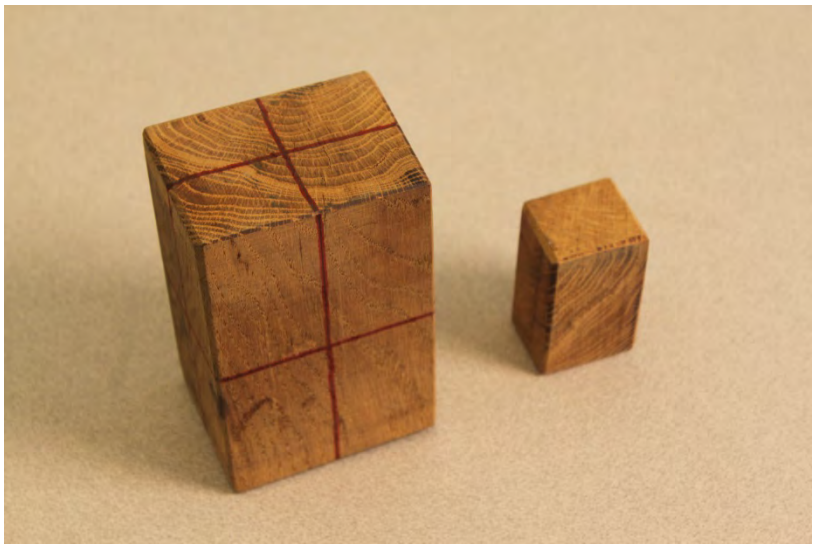
Area goes as:

$$(\text{Size}) \times (\text{Size}) = (\text{Size})^2$$

Volume goes as:

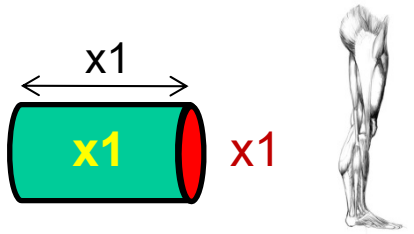
$$(\text{Size}) \times (\text{Size}) \times (\text{Size}) = (\text{Size})^3$$

Big cube is 2x the size so it has 4x the area and 8x the volume.

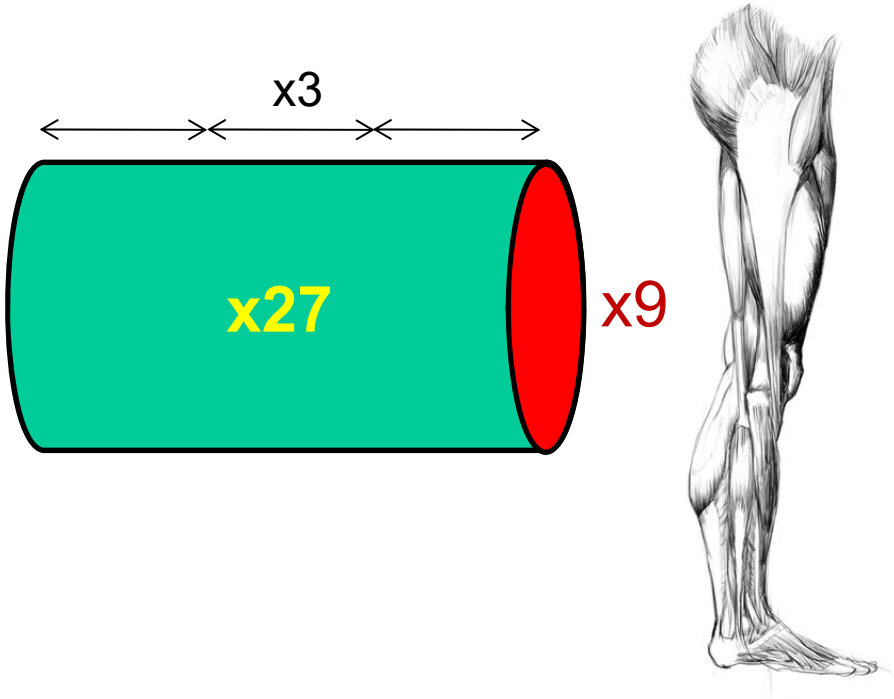


Size, Strength, and Weight

Strength scales as area,
Weight scales as volume.



Leg that is x3 in length has muscles that are x9 the strength but with x27 the weight.

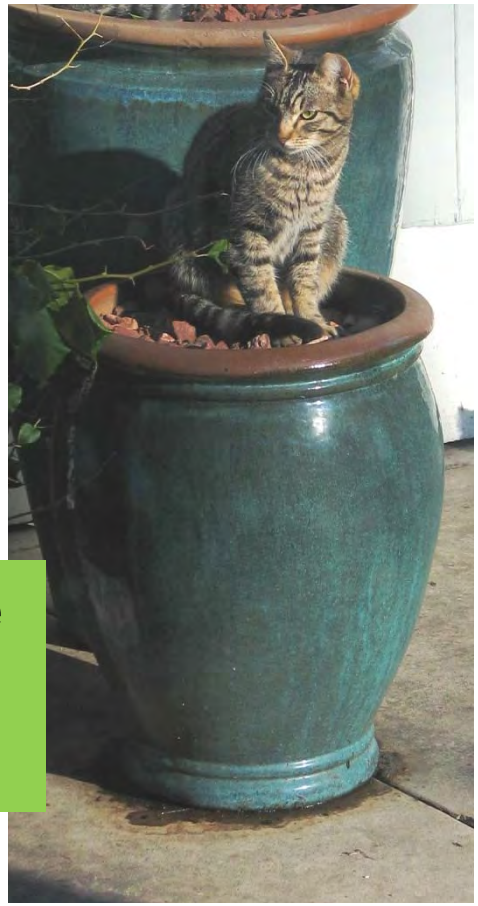


Jump Height

Muscle strength scales as area and leg length scales as body height however body weight scales as volume.

Jump height (actual) is **independent** of animal size.

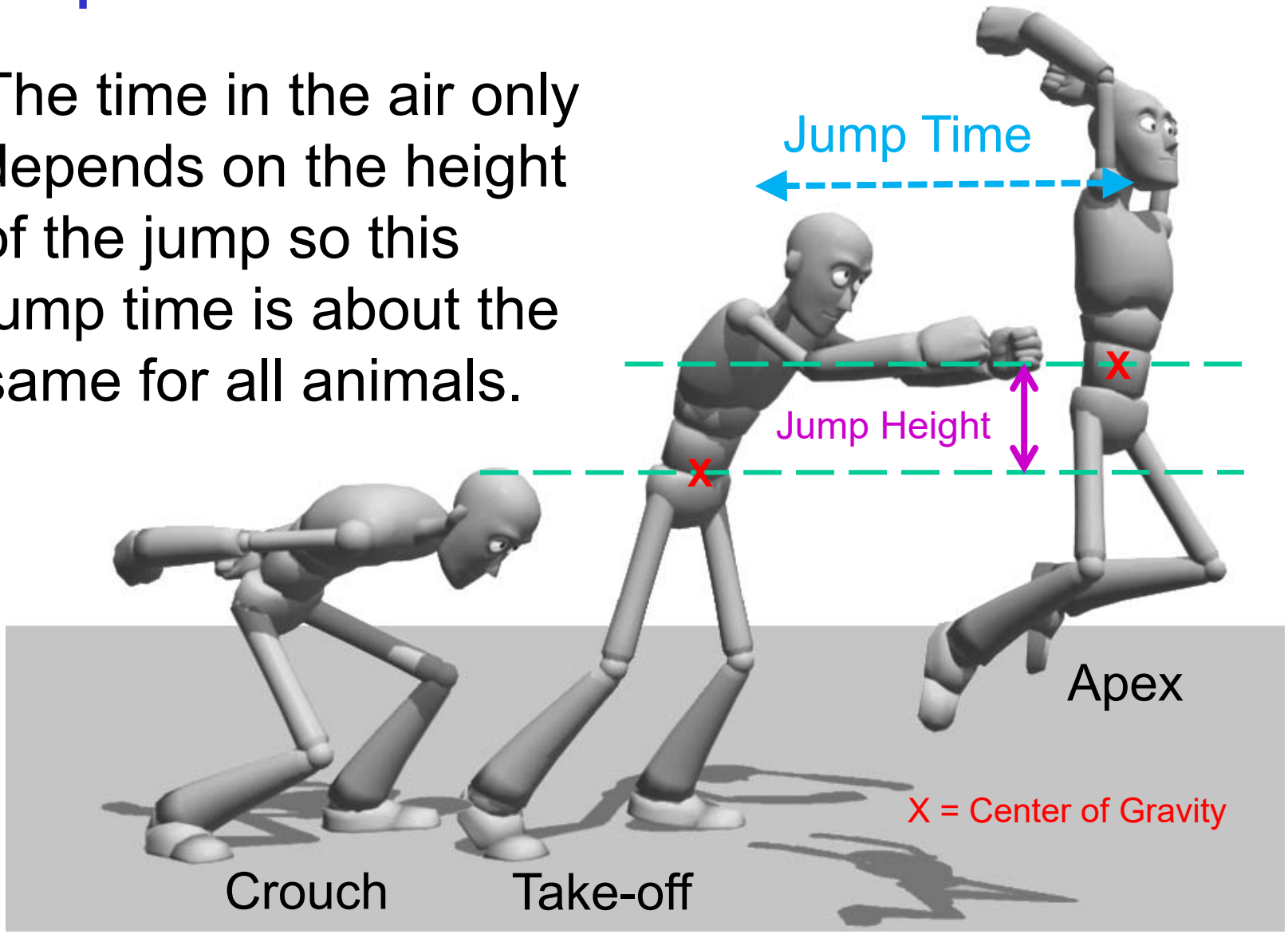
Relative jump height (compared with body size) is a physical cue of size.



My cat and I can both jump about the height of this pot, which is a third of my body size but about equal to his.

Jump Time

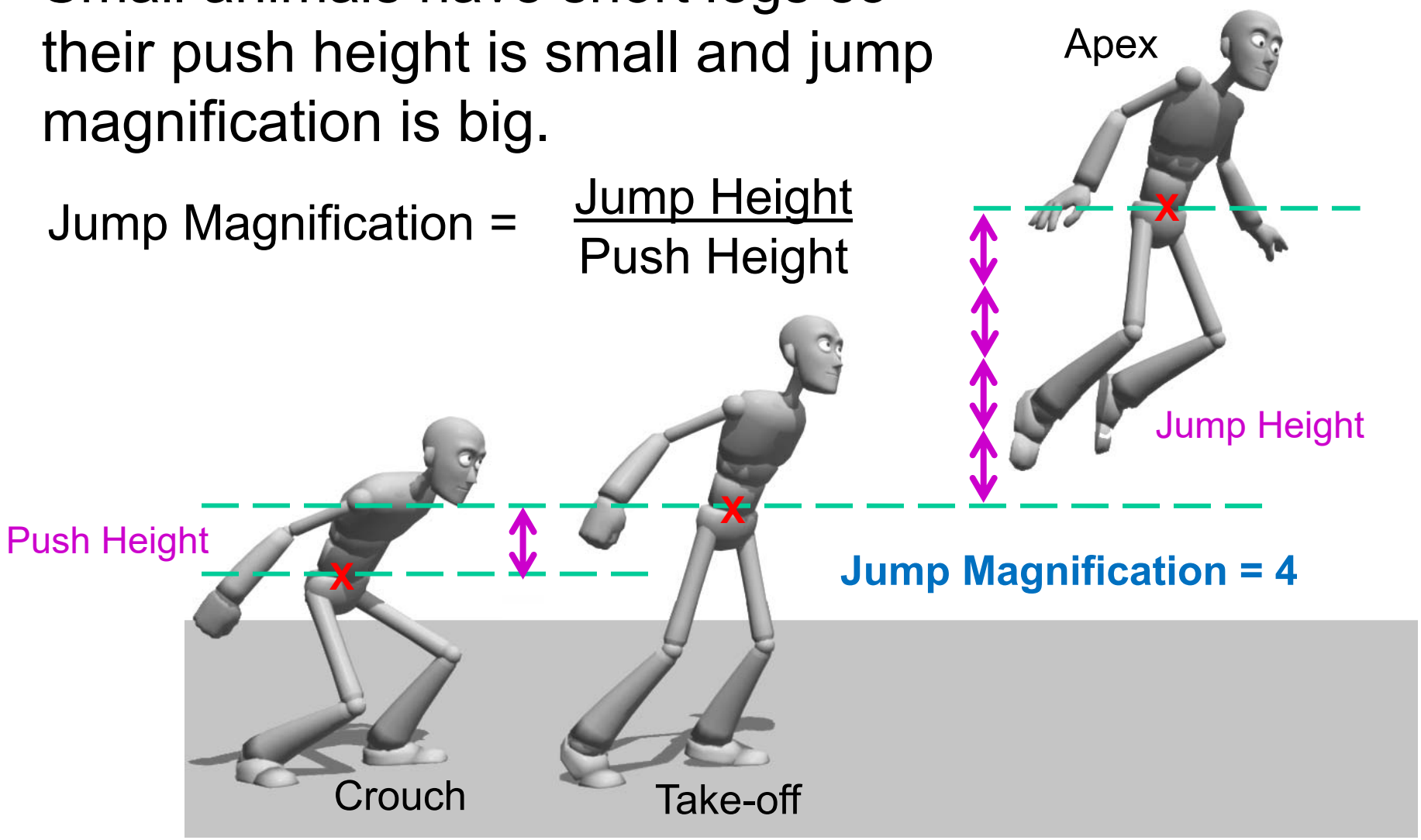
The time in the air only depends on the height of the jump so this jump time is about the same for all animals.



Jump Magnification

Small animals have short legs so their push height is small and jump magnification is big.

$$\text{Jump Magnification} = \frac{\text{Jump Height}}{\text{Push Height}}$$

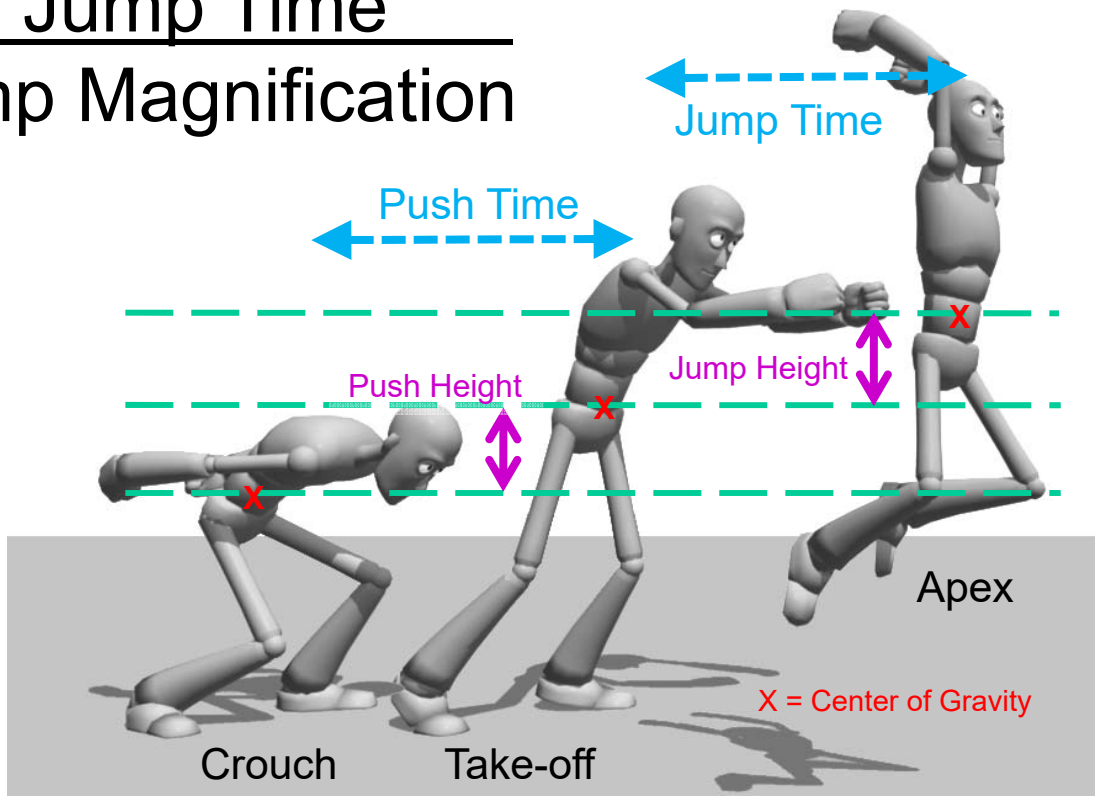


Timing the Push

Small animals jump with a large jump magnification so their push time is short.

$$\text{Push Time} = \frac{\text{Jump Time}}{\text{Jump Magnification}}$$

My cat is a third of my size so his push height and push time are about three times shorter than mine.

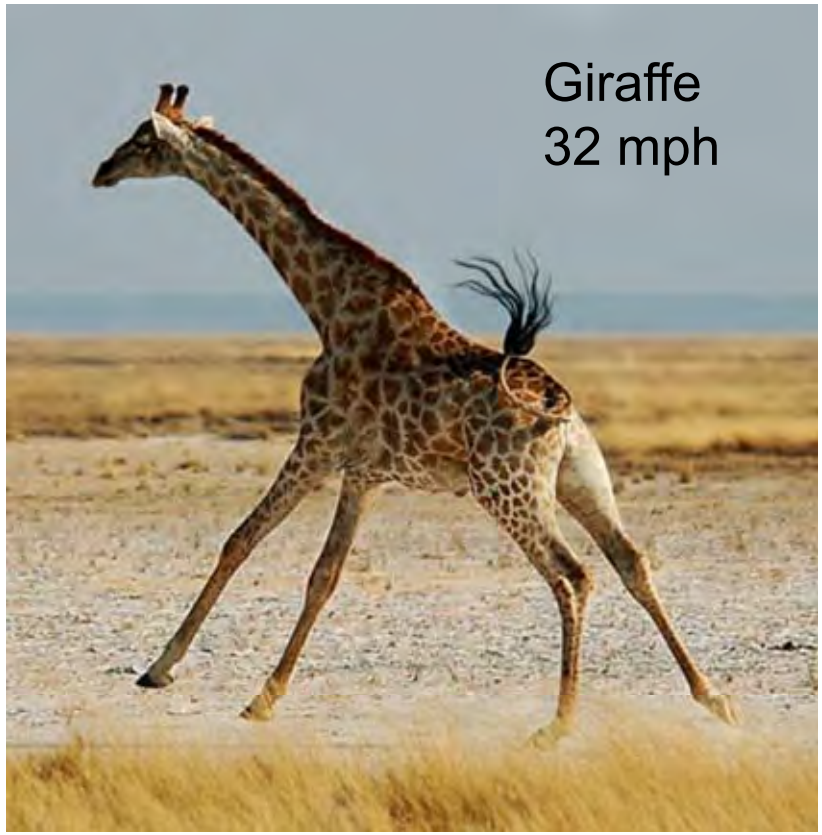


Running Speed

Muscle strength scales as area and stride length scales as height however body weight scales as volume.

Running speed is **independent** of animal size.

Giraffe
32 mph



Zebra 40 mph

Rabbit
35 mph

Most mammals run between 20 to 50 mph, except the very small or large.

Relative Running Speed

Small animals run fast relative to their size (relative running speed).

Rabbit covers a distance equal to its body length in about ½ frame.

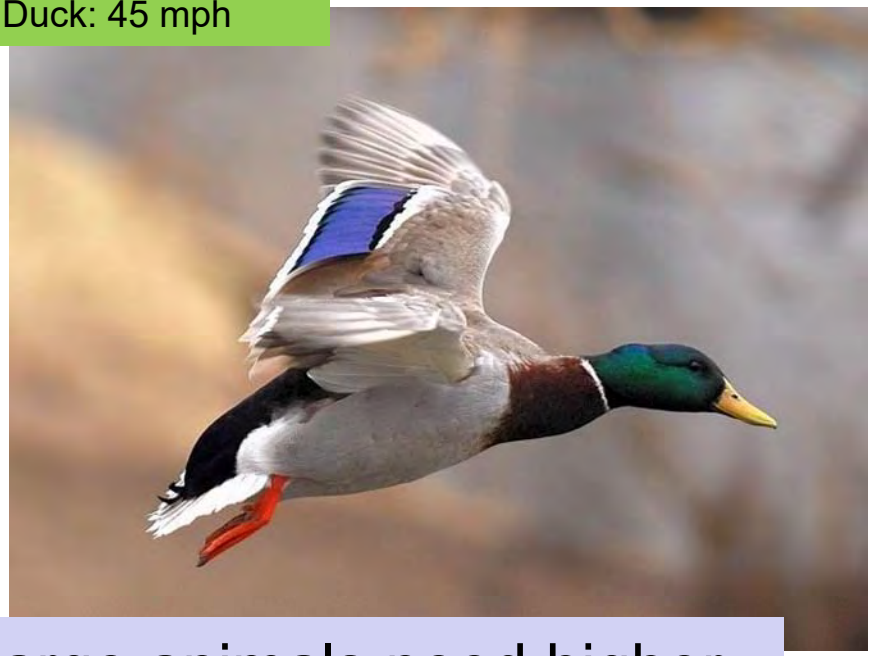
Zebra covers a distance equal to its body length in about 3 frames.

Flying Speed

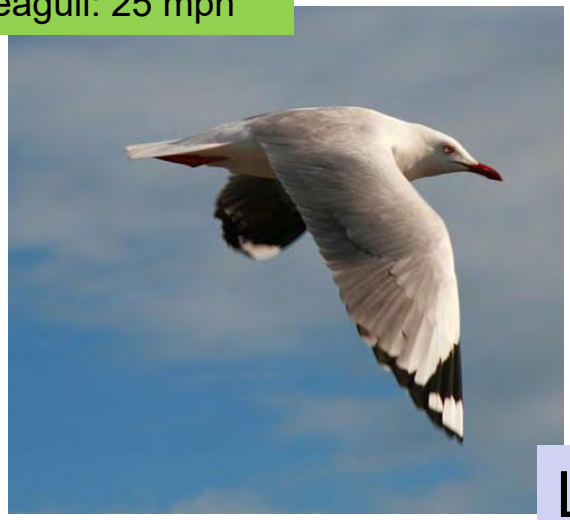
Lift force goes as (area)x(velocity)^2 while weight goes as volume

Flying speed is a physical cue for animal size.

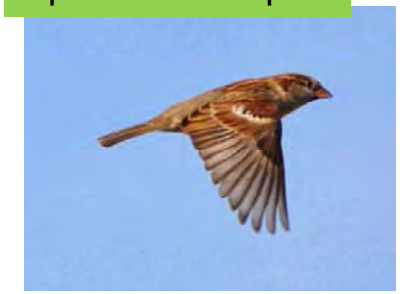
Duck: 45 mph



Seagull: 25 mph



Sparrow: 15 mph



This is for sustained, cruising flight, not sprinting or diving

Large animals need higher speed to generate enough lift to sustain their weight.

Wing Size & Shape

Lift force varies with area and wing shape

Wing size and shape is a physical cue for animal size.

Short, stubby wings provide less lift but are more maneuverable.

Canada Goose: Large, narrow wings

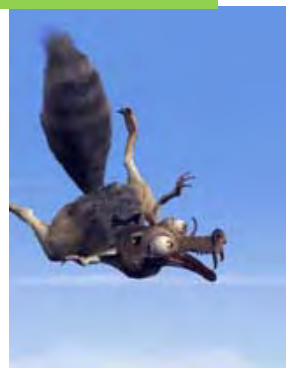
Sparrow: Short, stubby wings

Terminal Velocity

Maximum falling speed (terminal velocity) is a physical cue for size.

Weight goes as volume but force of air resistance goes as (area)x(speed)^2

Squirrel: 25 mph



Cat: 50 mph

Human: 120 mph

Shake Timing

Rotational inertia increases faster than volume but muscle force goes as area

Timing of an animal's shake is a physical cue for size.

http://www.youtube.com/watch?v=vtNS_dVhCwU

When they dry off small animals will shake with a rapid (high frequency) oscillation.

Summary

- Jump height and jump time (time in the air) is similar for all animals.
- Small animals have a short push height, large jump magnification, and short push time.
- Actual running speed is similar for all mammals.
- Small mammals run fast, relative to their size.
- Large birds fly faster than small birds and also need proportionally larger wings.
- Large animals fall faster than small ones.
- Small animals shake faster than large ones.