Dynamic Anatomy For 3D Artists

Fred Chapman

Creature FX and Rigging Supervisor – Image Engine

Image courtesy of Rengen 3d.

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M&E Customer Luncheon
Tuesday, December 3, noon – 1:30 pm
Venetian B, Level 2

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Introduction

Class summary

I believe improving the realism of animated creatures and characters must first start with a deeper understanding of how they move.

This class will explain some of the principles I follow and observations from several years in the animation and visual effects industry.

Disclaimer

- I’m not a medical professional!
- Real anatomy is of interest only in how it influences what we see on screen
- Wherever possible I will cheat and find the most efficient way to make characters look anatomically real
- It is best to understand the rules before breaking them!
- I’m not deliberately picking on animators, but I do think they have the most to learn about real movement!
- Questions at the end of the class.

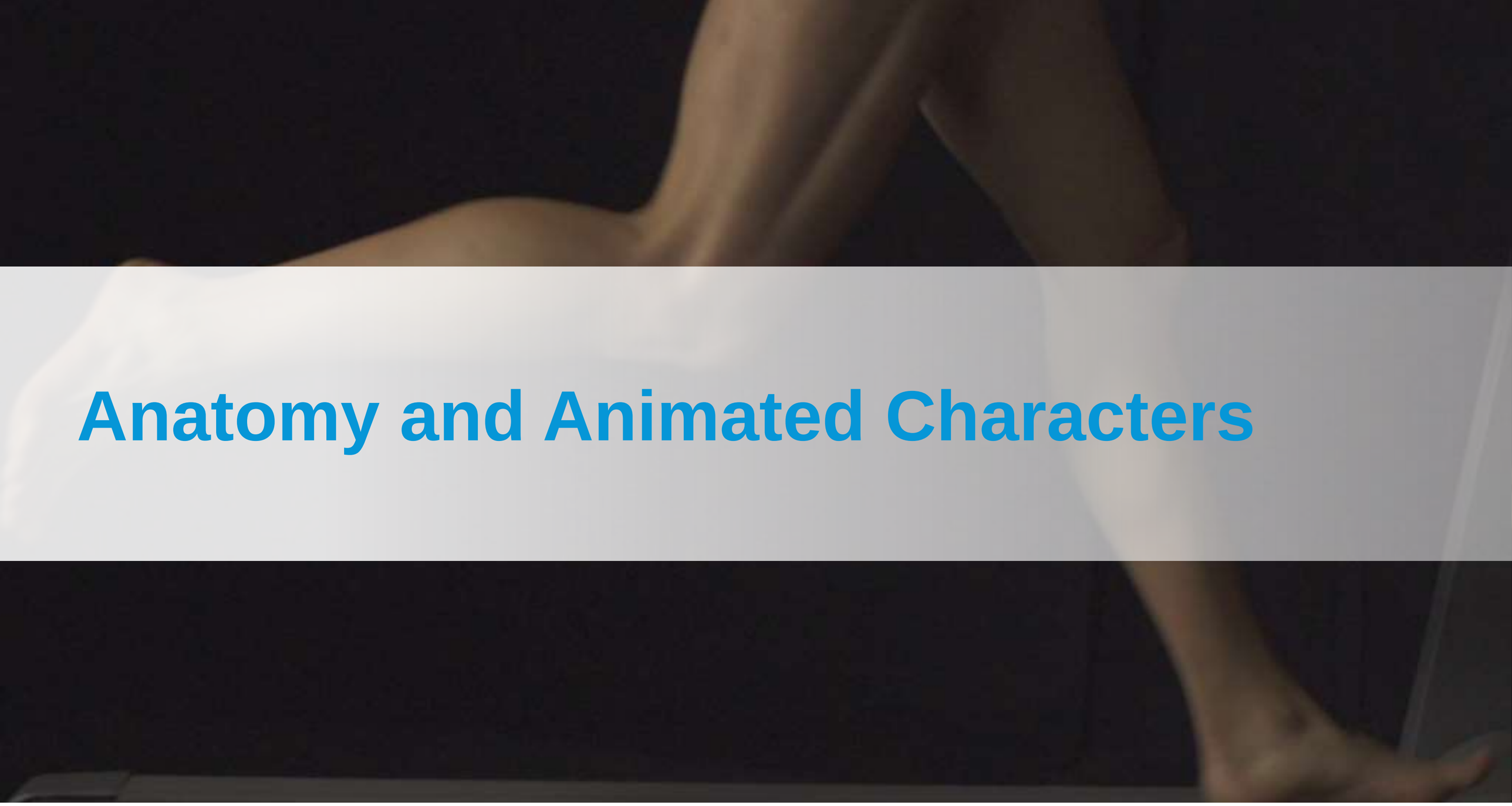
Key learning objectives

At the end of this class, you will be able to:

- Apply a new understanding of anatomy and how it relates to movement
- Describe the forces that act on the body to create movement and distribute weight
- Design characters and build geometry and rigs that are better suited to realistic movement
- Create more realistic animation of creatures and characters

Who am I?

- Over 14 years of animation and VFX experience
- Previously worked on: RIPD, Elysium, The Thing, Battleship, Harry Potter and the Prisoner of Azkabhan, Harry Potter and the Goblet of Fire, Harry Potter and the Half-Blood Prince, Harry Potter and the Deathly Hallows Pt 1, Zero Dark Thirty, White House Down, Terminator Salvation, Twilight: Breaking Dawn Pt 1, The Ruins, Underdog, Aliens Vs Predator…
- Shortlisted in the 2010 VES Awards: Outstanding Animated Character in a Live Action Feature Motion Picture
- Currently working on Ninja Turtles and Chappie
- Raced in 2 Triathlon Age Group World Championships and completed 2 Ironman races
- Studied Ashtanga Yoga for over 10 years including 5 months with a 90 year old guru in India
- Suffered many injuries and worked closely with physiotherapists, coaches and fellow athletes to learn about range of motion, impact, efficiency of movement!

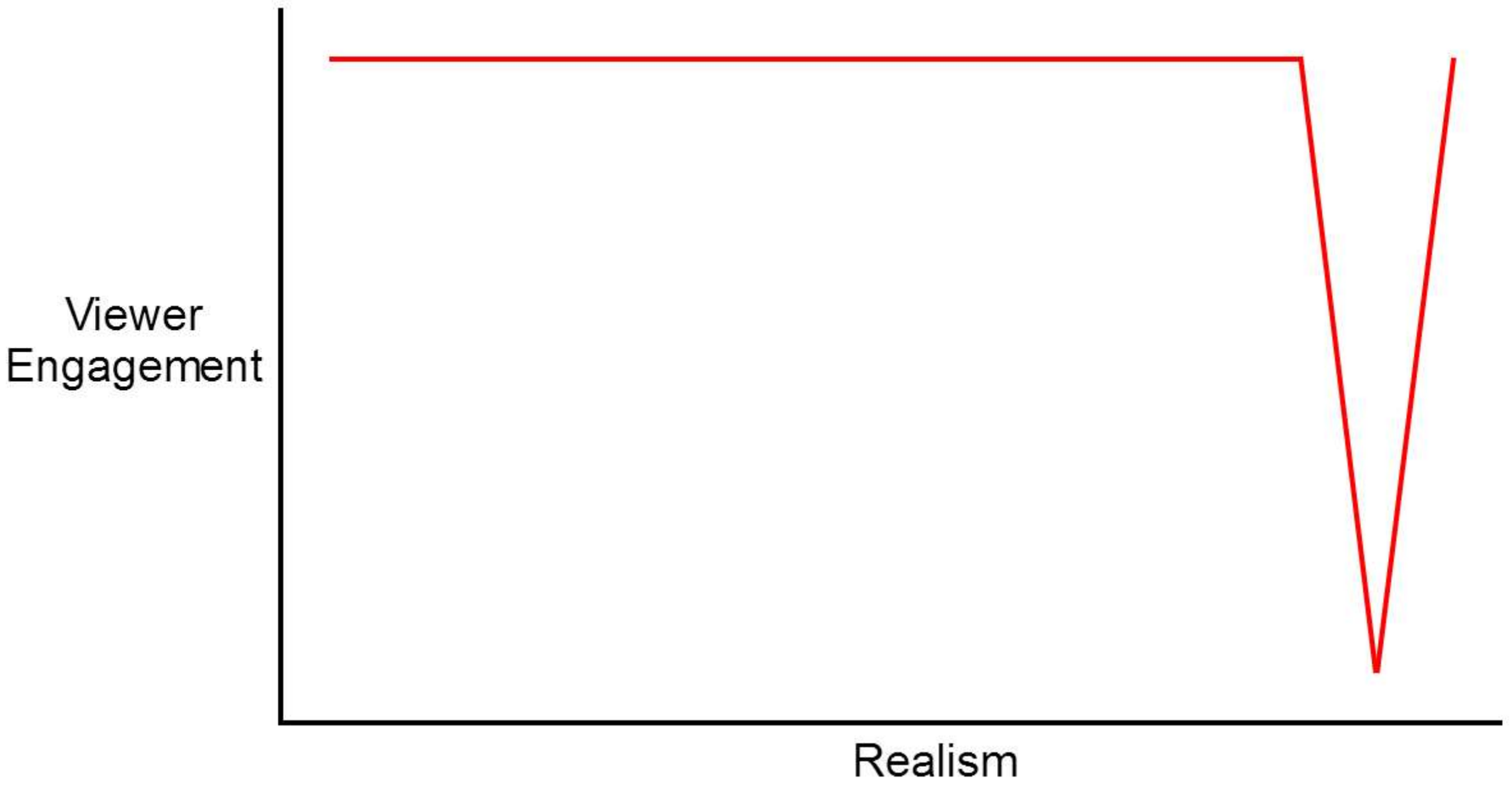


Anatomy and Animated Characters

Is Realism Important?

- Depends on type of movie
- VFX and animation are about fantasy
- Audience engagement

Uncanny Valley



Overcoming Uncanny Valley

- Many movie critics still resistant to VFX
- Most VFX are unnoticeable: set extensions, environments, vehicles, paint outs
- Animated characters hardest to get past uncanny valley
- Good animators need good character designs, models and rigs
- Movement  Anatomy  Physics
- Physics and mechanics of movement are easy, we see them every day!

Why Study Dynamic Anatomy?

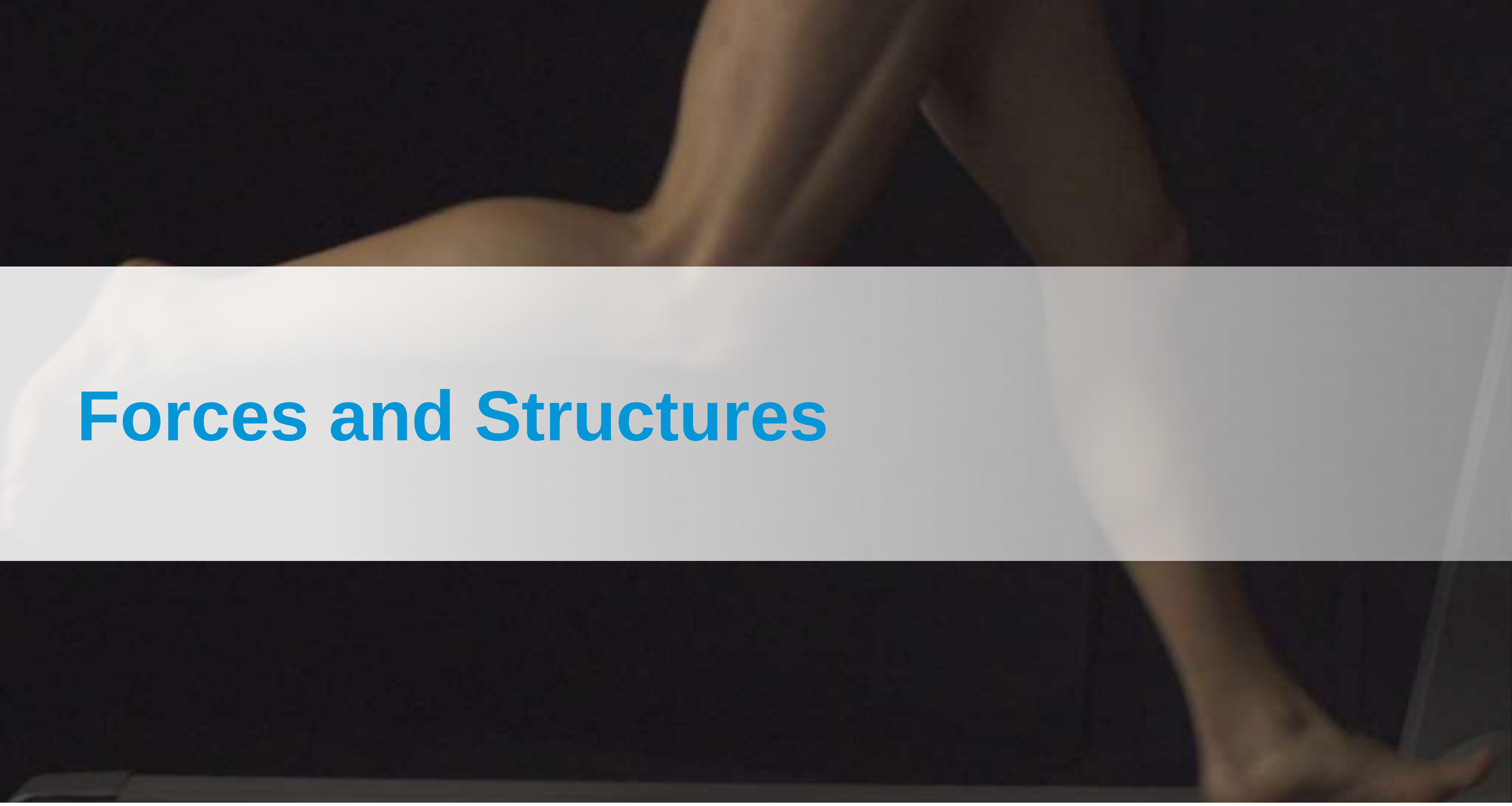
- Animation techniques are traditionally based on silhouette, keyframes, life drawing, etc.
- Most anatomy study is static, on cadavers or from books.
- We create movement. The transition between poses is as important as the poses
- Motion capture is often used because animation isn’t realistic
- Subtle details sell realism
- Increase audience engagement
- Avoid common mistakes

Key Concepts

- Strength / Flexibility
- Form 

Function
- Environment 

Anatomy
- We’re All Lazy!



Forces and Structures

Forces

- Gravity, Momentum, Friction, Drag
- Pulling (contraction)
- Leverage
- ~~Pushing~~

Newton's Third Law of Motion

EVERY ACTION HAS AN EQUAL AND OPPOSITE REACTION

- Every cell in our body is being pulled down by gravity
- In order to stay standing or sitting, every cell must experience an equal force to resist gravity
- To move we must overcome gravity, drag, friction by applying a greater opposing force

Material Properties

SOFT - Disperses force	Fat
	Muscle
	Skin
	Ligaments / Connective Tissue
	Tendons
HARD – Transfers force or breaks	Bone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Active vs Passive Tissue

- Muscle is the only tissue type that changes it's material properties.
- This requires the use of energy
- Our bodies will try to use the minimum amount of energy, so will make use of passive tissue as much as possible

Muscles

- Long fibres attached at each end
- When relaxed they vibrate most in the middle, furthest from the attachment points
- Use energy to contract and pull ends together
- Contracted muscle will always try to be straight
- Preserve volume by expanding out to the sides

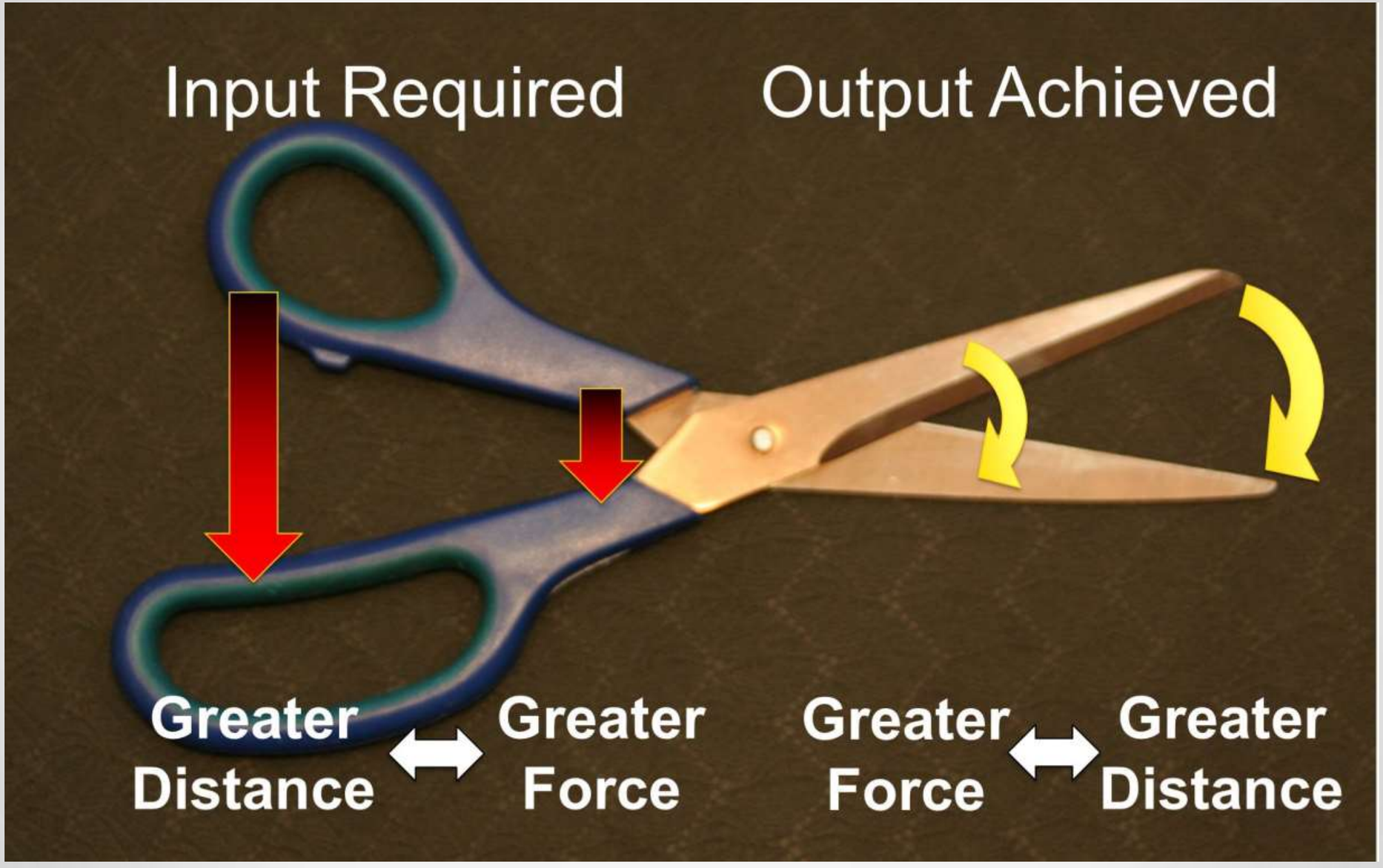
Bones and Joints

- Bones transfer force efficiently and passively
- Joints are combinations of bones that rotate against each other
- In some joints the bone-to-bone contact is more substantial, with greater direct transfer of force
- Some poses of the same joint allow for more or less direct bone to bone force transfer
- Connective tissue holds the bones together and gives some limited cushioning to dissipate impact

Leverage

- Converts between linear force and radial
- The greater the radius from the pivot, the greater the distance moved

Leverage


Input Required
Output Achieved
Greater Distance
Greater Force
Greater Force
Greater Distance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Muscle Attachment to Bone

- The longer the bones, the greater the force is required to lever them
- The further along the bone, away from the joint that the muscle attaches, the greater the force that can be applied but the smaller the range of rotation can be achieved

Strength vs Flexibility

- The structure of different joints favours strength or flexibility
- Hip
  - Weight bearing much of the time
  - Large forces in movement and stability
  - Limited range of motion
- Shoulder
  - Rarely weight bearing
  - More versatile use so larger range of motion required


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Knee and elbow

- Inherent weakness due to lack of close supporting structures
- Are the structures of the knee and elbow biased towards strength or flexibility?
- Limit range of motion to a single axis of rotation
- If the knee were a ball joint, able to rotate in all axes, think how many stabilising muscles would be required to stop it collapsing!

Opposing muscles

- Every movement is from a muscle contraction
- There must be an opposing muscle contraction to create the opposite movement
- Opposing muscles do not need to be the same strength
- How can I tense a muscle without creating movement?


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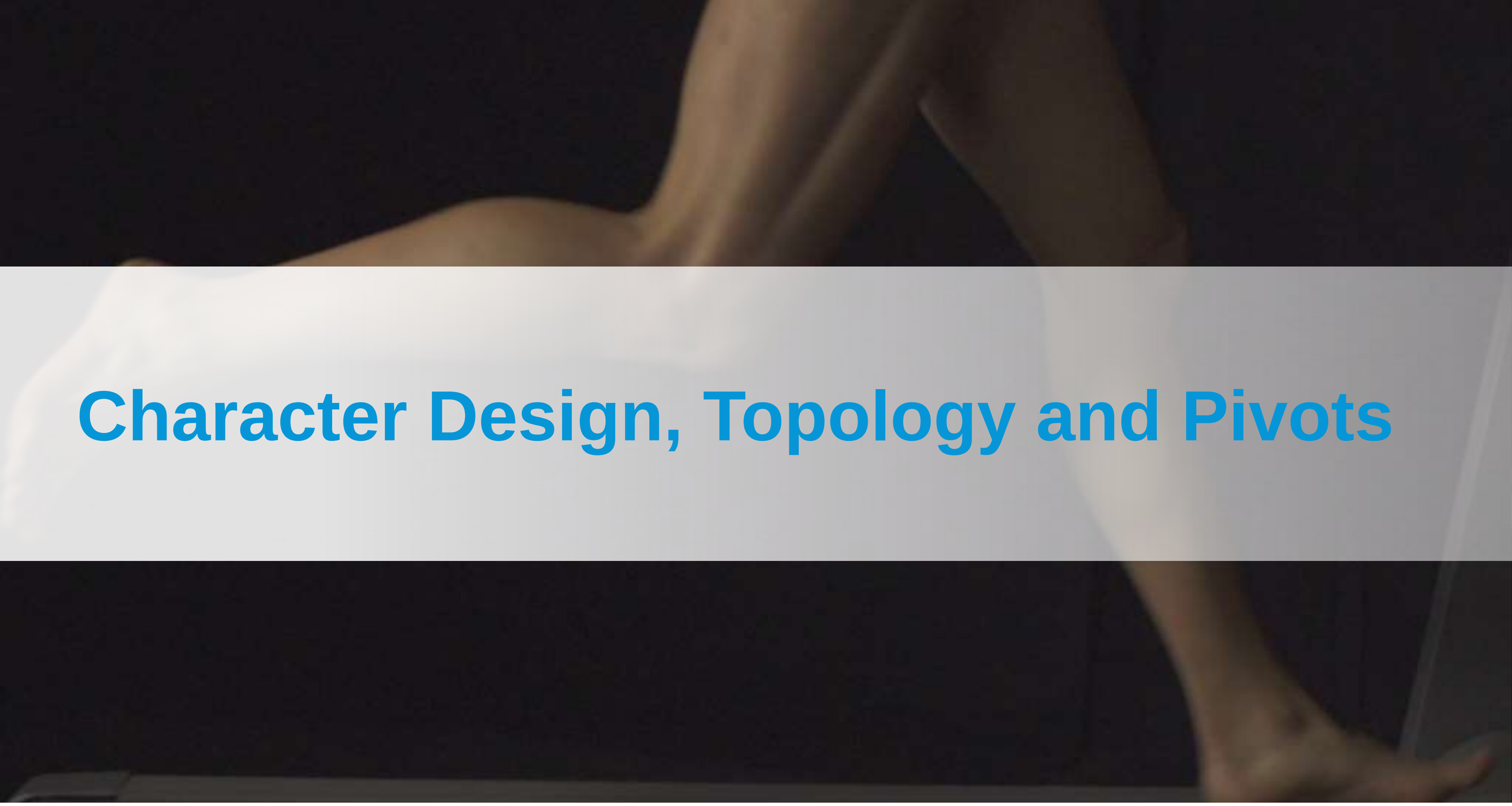

Character Design, Topology and Pivots

Standing with Bent Legs

- Think of a large animal that stands at rest with more than a 10 degree bend in it’s knees
- Check reference images to confirm if you are correct
- Do a Google image search for “creature design” and see how many designed creatures follow reality.

How Animals Stand

- All animals (including humans) are lazy – We will use minimal energy to stand
- The majority of force to resist gravity in any rest pose is transmitted through passive tissue. Mostly bone
- Heavier animals = more force to resist gravity = bones lock into a straight line = less ability to absorb shocks = less extreme movement. Elephants don’t jump!

Creature design

- Design your creatures so they have energetically neutral means of resisting gravity in a rest pose.
- Make sure they have the means to propel themselves forward with well placed muscles and appropriate range of motion
- Follow the principle of strength vs flexibility by limiting range of motion on joints that require strength and vice versa. Form follows function

Skin Properties

- Skin has some small amount of elasticity
- Skin loses elasticity with age, wrinkles become permanent
- Wrinkles occur perpendicular to the skin compression
- Cleaner geometry deformation when topology follows skin compression. Reduces shearing of faces


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Skin Tension

- Langer’s Lines / Kraissl’s Lines
- Orientation of collagen fibres / direction of resting skin tension
- Closely follows direction of the top layer of muscle fibres
- Useful starting point for geometry edge flow

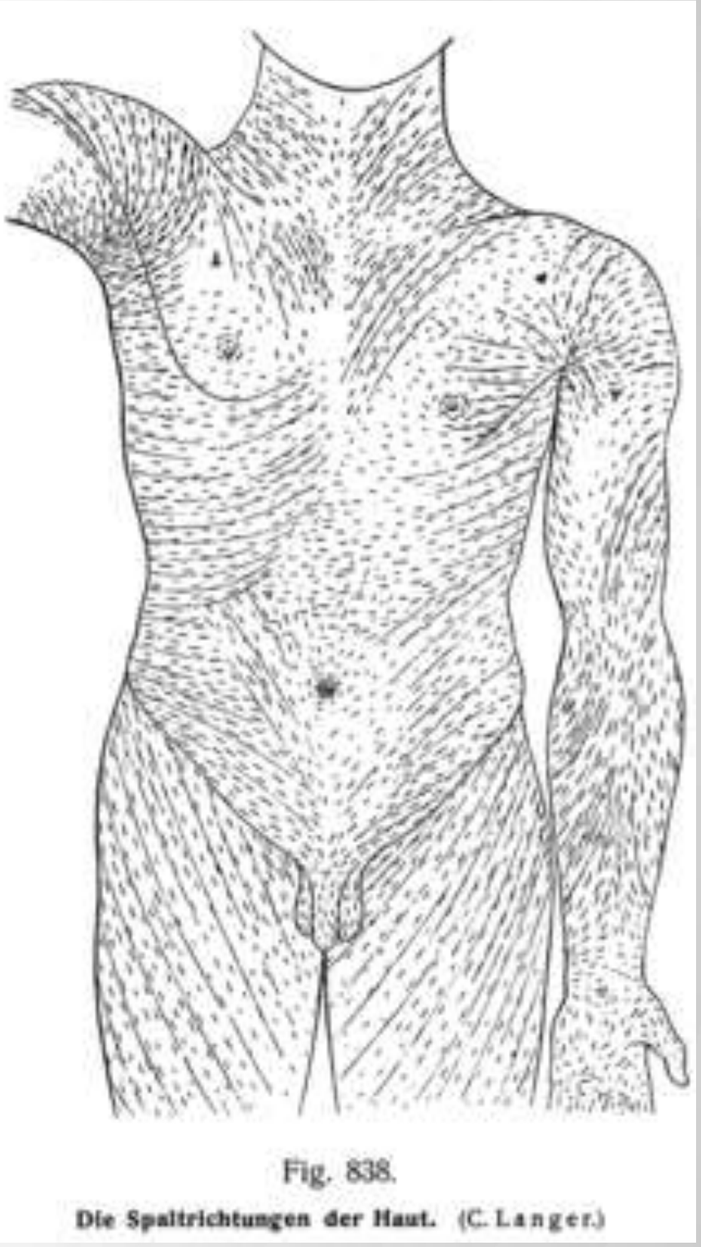
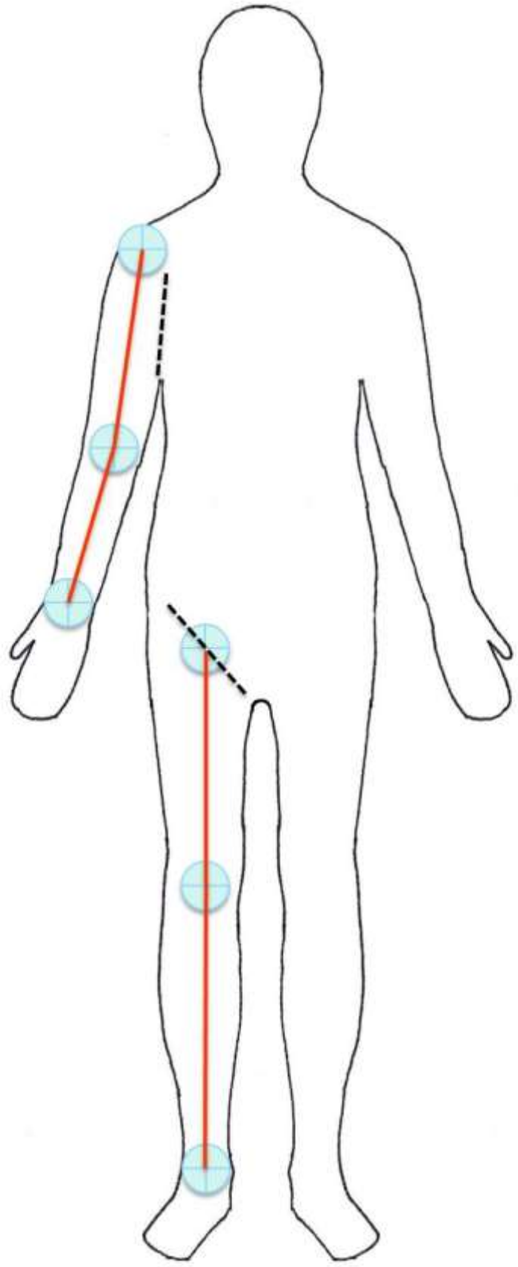


Fig. 838.

Die Spaltrichtungen der Haut. (C. Langer.)

Pivot Points

- Spine
  - Central in the body at the hips and neck.
  - Follows same distance from back of torso
- Hip
  - Centre of mass of thigh
  - Single plane if movement with knee and ankle
  - Sits on diagonal groin crease

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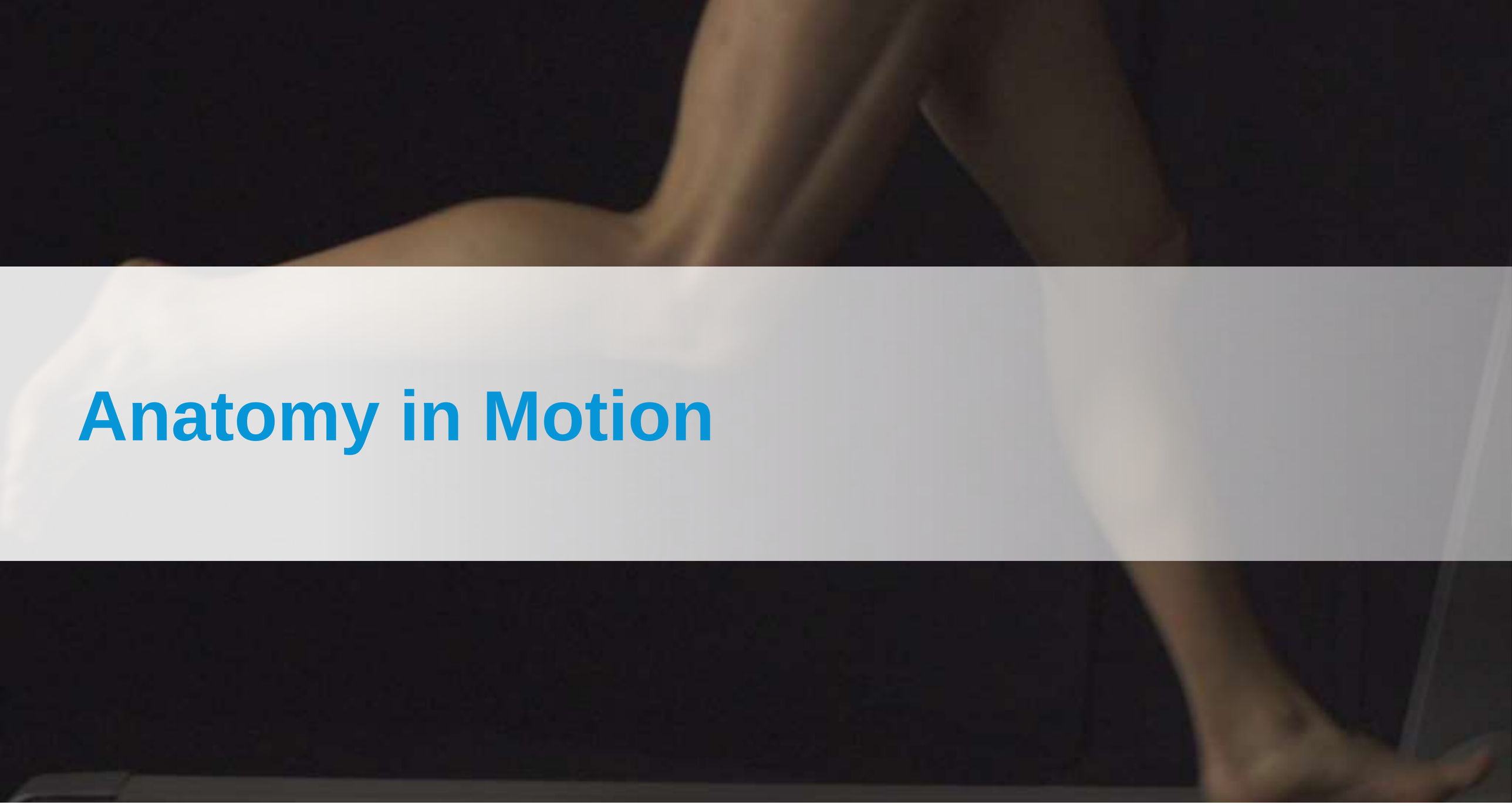
Double Pivots

- Shoulder
  - Arms hang vertically at the side so pivot must be wider than the chest
  - Bone same distance from outer skin at shoulder than at elbow
  - Top of crease at shoulder and pectoral muscle to rear of rotator cuff
  - Shoulder blade pivots around clavicle, offsetting shoulder pivot and extending range of motion
- Knee
  - Single oval shaped pivot
  - Can be approximated with a double pivot although a single pivot with a translate is more anatomically accurate



Anatomy in Motion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Absorbing impact

- Decelerate to reduce shock
- Bend joints with tensed muscles to act as a spring
- Land on forefoot to prevent shock transfer from heel to leg bones

Walk Cycle vs Run Cycle

WALK	RUN
Always at least one leg on the ground	One or no legs contacting ground
Gentle transfer of weight between legs	Spring and catch
Lower momentum	Higher momentum
Lower impact	Higher impact
Weight transfer in front	Weight transfer towards COG
Foot stationary in space at contact	Foot travelling backwards at contact
Heel absorbs impact	Foot absorbs impact
Knee locked straight	Knee bent

Heel vs Toe/Mid Foot Strike

Heel	Toe
Shock transferred up leg	Impact decelerated in foot
Higher strain on anterior tibialis	Higher strain on calf muscles
Decelerating action against momentum	Force goes with momentum
Often found with lower cadence	Associated with higher foot turnover

Avoid common mistakes

- Google video search for “run cycle”
- How many animated run cycles feature heal strikes and weight transfer in front of the centre of gravity with no associated impact?
- How can it look realistic if the forces we are subconsciously expecting to see are not transferred or dissipated throughout the body?

Analyse Reality to Recreate Reality

- Don’t assume you know how things move based on memory
- Check reference material
- Film yourself or your colleagues
- When you see work that doesn’t look right, learn lessons by figuring out why.


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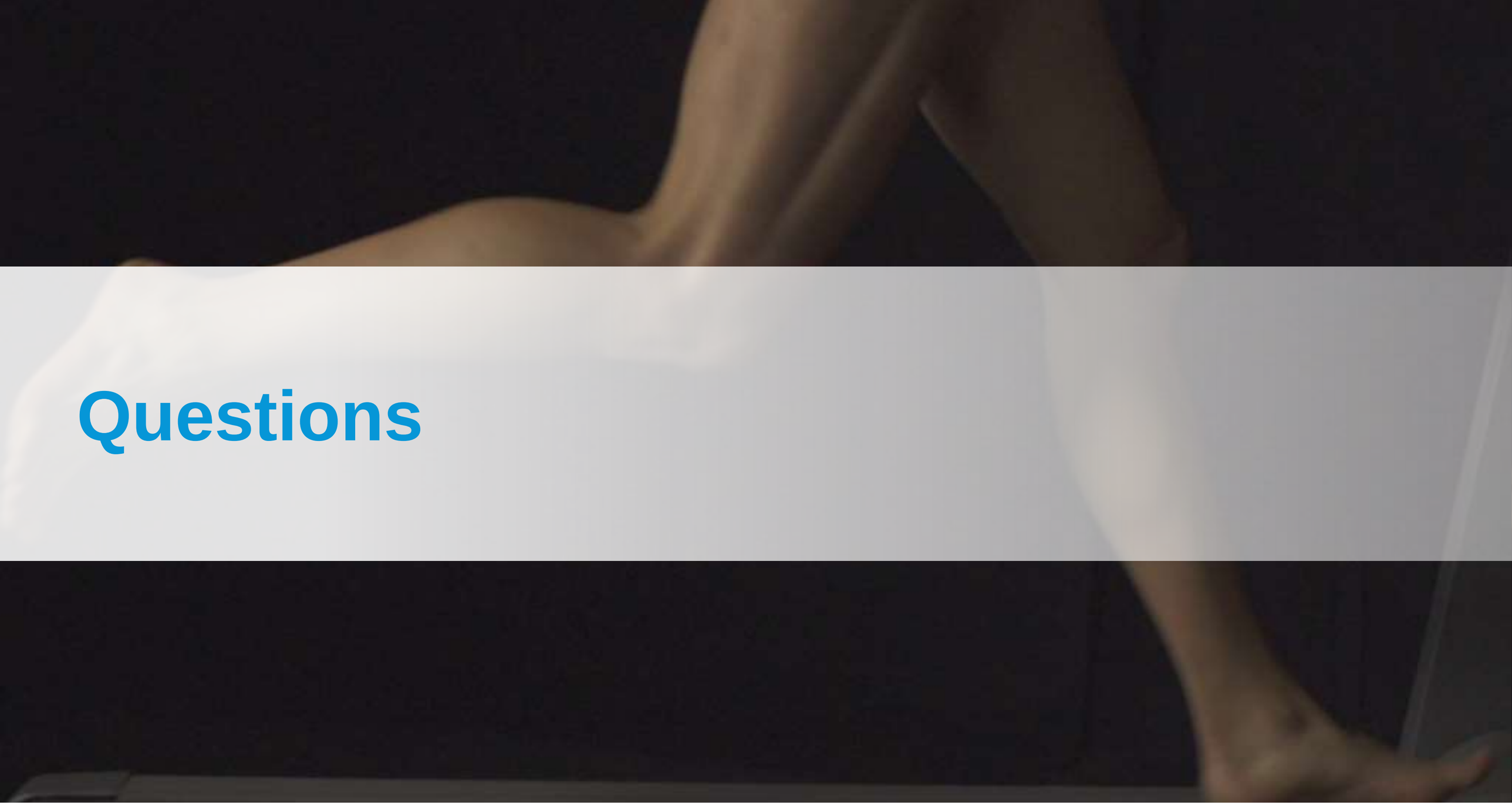

Questions

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