199: Natural world and CG: modeling

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Computer Graphics: the trinity

- Modeling:

  How do we represent (2D or 3D) objects & environments?

  How do we build these representations?

- Animation:

  How do we represent the way objects move?

  How do we define & control their motion?

- Rendering:

  How do we represent the appearance of objects?

  How do we simulate the image-forming process?

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Animation Timeline

1908: Emile Cohl (1857-1938) France, makes his first film, FANTASMAGORIE, arguably the first animated film.

1911: Winsor McCay (1867-1934) makes his first film, LITTLE NEMO. McCay, already famous for comic strips, used the film in his vaudeville act. His advice on animation:

Any idiot that wants to make a couple of thousand drawings for a hundred feet of film is welcome to join the club.

1928: Walter Disney (1901-1966) working at the Kansas City Slide Company creates Mickey Mouse.

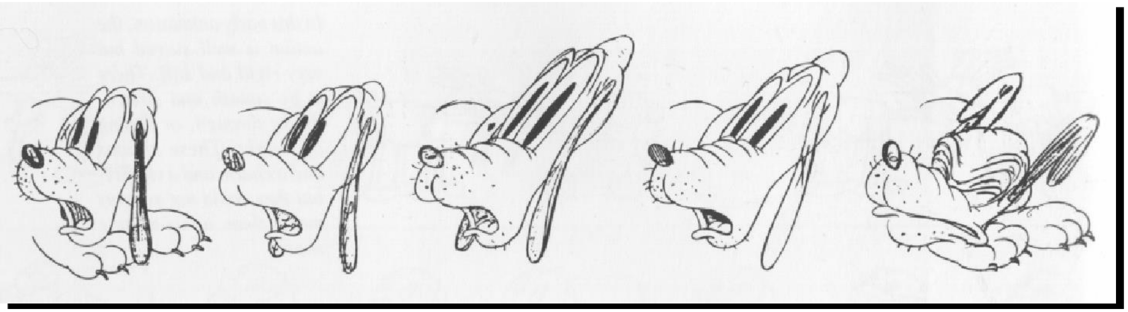
1974: First Computer animated film “Faim” from NFB nominated for an Oscar.

Animation Principles

- Squash and Stretch
- Timing
- Slow-In & Slow-Out
- Arcs
- Anticipation
- Follow-through and Secondary Motion
- Overlapping Action and Asymmetry
- Exaggeration
- Staging
- Appeal
- Straight-Ahead and Pose-to-Pose

Squash and Stretch

- Rigid objects look robotic: deformations make motion natural
- Accounts for physics of deformation
    - Think squishy ball…
    - Communicates to viewer
      what the object is made of,
      how heavy it is, …
    - Usually large deformations conserve volume: if you squash one dimension, stretch in another to keep mass constant
- Also accounts for persistence of vision
    - Fast moving objects leave an elongated streak on our retinas



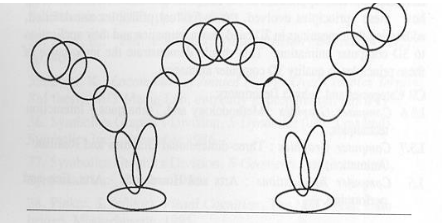


FIGURE 2. Squash & stretch in bouncing ball.

Timing

- Pay careful attention to how long an action takes how many frames
- How something moves - not how it looks - defines its weight and mood to the audience
- Also think dramatically: give the audience time to understand one event before going to the next, but don't bore them

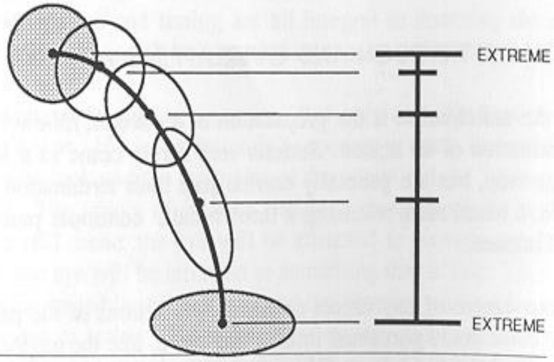
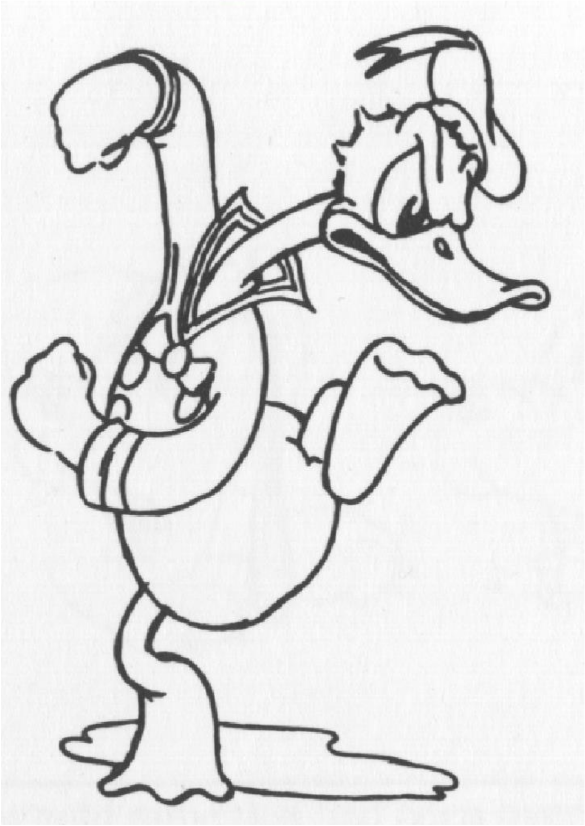


FIGURE 9. Timing chart for ball bounce.

Anticipation

- The preparation before a motion
  - E.g. crouching before jumping, pitcher winding up to throw a ball
- Often physically necessary, and indicates how much effort a character is making
- Also essential for controlling the audience's attention, to make sure they don't miss the action
  - Signals something is about to happen, and where it is going to happen.



Cartoons laws of physics

Cartoon Law I

Any body suspended in space will remain in space until made aware of its situation. Daffy Duck steps off a cliff, expecting further pastureland. He loiters in midair, soliloquizing flippantly, until he chances to look down. At this point, the familiar principle of 32 feet per second per second takes over.

Cartoon Law II

Any body in motion will tend to remain in motion until solid matter intervenes suddenly. Whether shot from a cannon or in hot pursuit on foot, cartoon characters are so absolute in their momentum that only a telephone pole or an outsize boulder retards their forward motion absolutely. Sir Isaac Newton called this sudden termination of motion the stooge's surcease.

…

Cartoon Law Amendment C

Explosive weapons cannot cause fatal injuries. They merely turn characters temporarily black and smoky.

What can be animated?

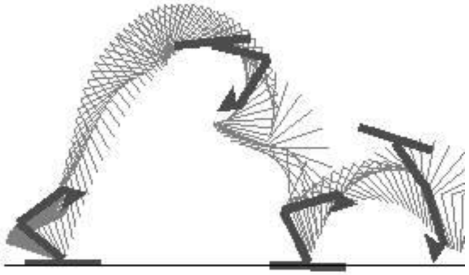
- Lights
- Camera
- Jointed figures
- Deformable objects
- Clothing
- Skin/muscles
- Wind/water/fire/smoke
- Hair
- any variable, Given the right time scale, almost anything…

Elements of CG (animation)

How does one make digital models move?

Keyframing

Physical simulation



Motion capture

Behavior rules

Keyframes

Keyframes, also called extremes, define important poses of a character:

Jump example:

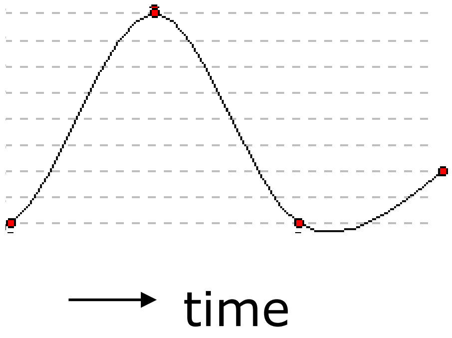
- the start
- the lowest crouch
- the lift-off
- the highest part
- the touch-down
- the lowest follow-through

- Frames in between (“inbetweens”) introduce nothing new to the motion.
- May add additional keyframes to add some interest, better control the interpolated motion.

Keyframe Animation

- The task boils down to setting animated variables (e.g. positions, angles, sizes, …) at each frame.
- **Straight-ahead:** set variables in frame 0, then frame 1, frame 2, … forward in time.
- **Pose-to-pose:** set the variables at keyframes, let the computer smoothly interpolate values for frames in between.

How do we interpolate between two values?



Physical Simulation (moovl)

Particles

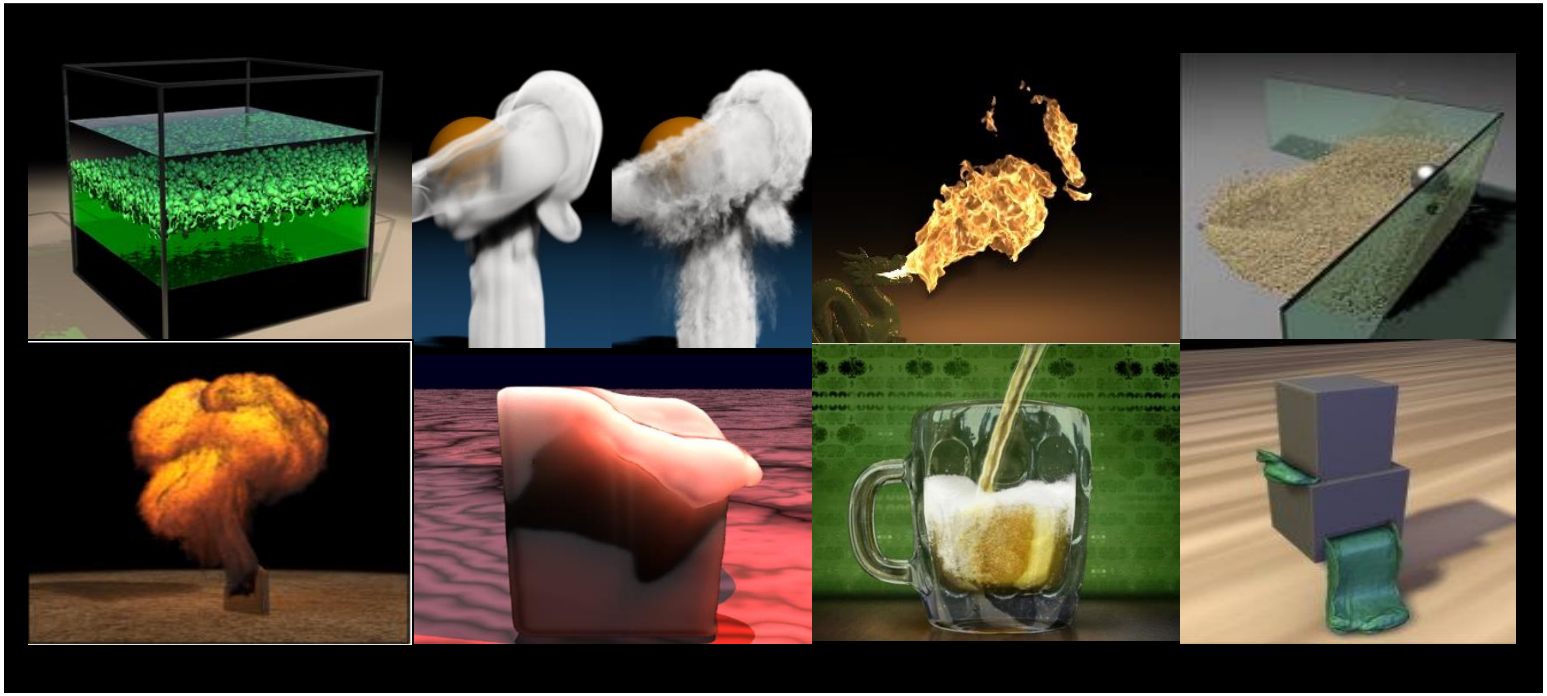
Position	x
Velocity	$v = dx/dt$
Acceleration	$a = dv/dt = d^2x/dt^2$

Forces

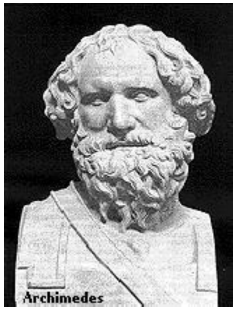
Gravity	$f=mg$
Spring-damper	$f=-kx-cv$

…

Physical Simulation (fluids)



Faces of Fluid Mechanics



Archimedes
(C. 287-212 BC)

Newton
(1642-1727)

Leibniz
(1646-1716)

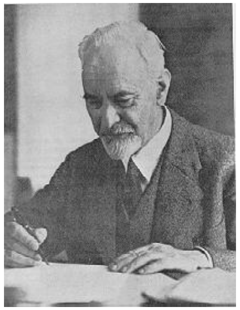
Bernoulli
(1667-1748)

Euler
(1707-1783)

Navier
(1785-1836)

Stokes
(1819-1903)

Reynolds
(1842-1912)



Prandtl
(1875-1953)

Taylor
(1886-1975)

Navier-Stokes Equation

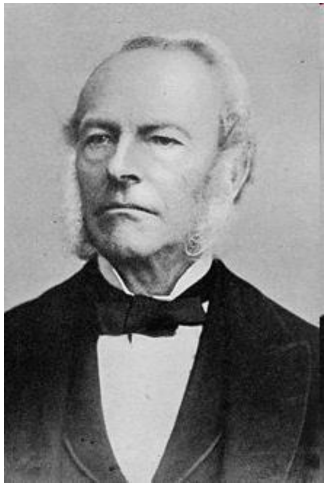
- Incompressibility

$\nabla\cdot\mathbf{v}=0$ **v**: the velocity field

- Momentum equation

$$\overbrace{\rho\Big(\underbrace{\frac{\partial \mathbf{v}}{\partial t}}_{\text{Unsteady acceleration}} + \underbrace{\mathbf{v}\cdot\nabla\mathbf{v}}_{\text{Convective acceleration}}\Big)}^{\text{Inertia (per volume)}} = \overbrace{\underbrace{-\nabla p}_{\text{Pressure gradient}} + \underbrace{\mu\nabla^2\mathbf{v}}_{\text{Viscosity}}}^{\text{Divergence of stress}} + \underbrace{\mathbf{f}}_{\text{Other body forces}}.$$

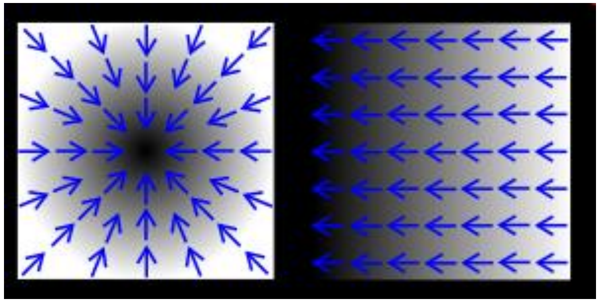
Claude-Louis Navier
(1785~1836)



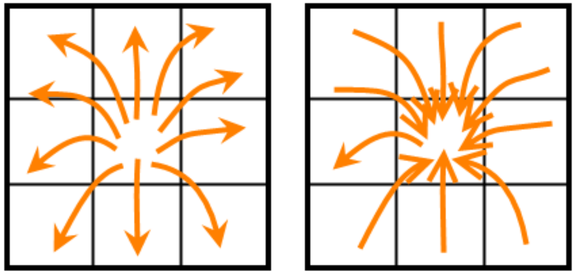
George Gabriel
Stokes
(1819~1903)

Calculus Review/Preview

- Gradient (∇): A vector pointing in the direction of the greatest rate of increment $\nabla u = \left(\frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial u}{\partial z}\right)$



- Divergence ($\nabla \cdot$): Measure how the vectors are converging or diverging at a given location. $\nabla \cdot \boldsymbol{u} = \frac{\partial \boldsymbol{u}}{\partial x} + \frac{\partial \boldsymbol{u}}{\partial y} + \frac{\partial \boldsymbol{u}}{\partial z}$

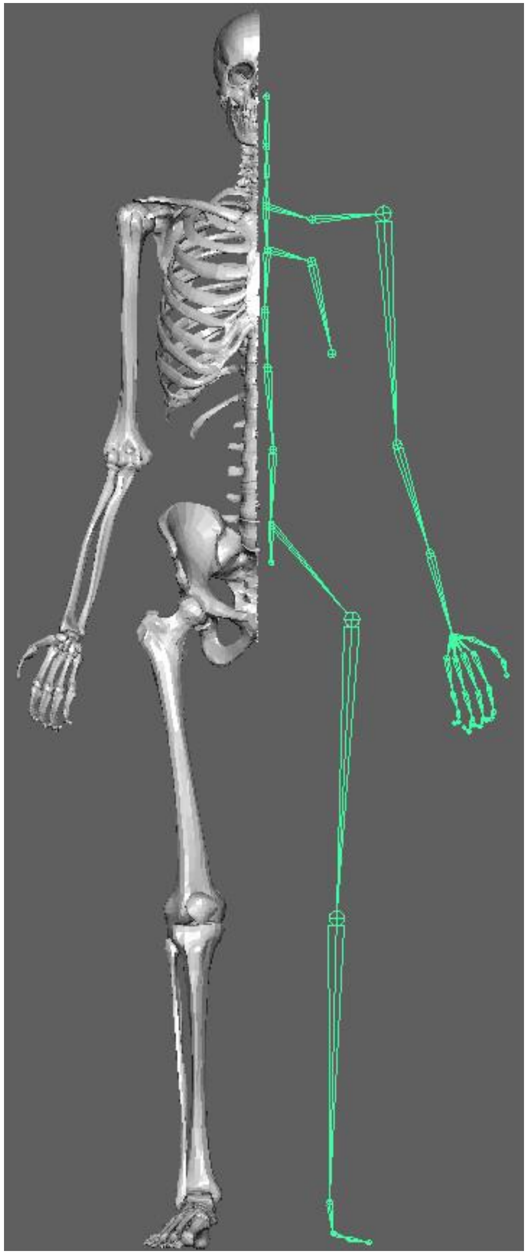


Source, Div(**u**) > 0

Sink, Div(**u**) < 0

- Laplacian (Δ or ∇^2): Divergence of the gradient

$$\nabla^2 u = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}$$



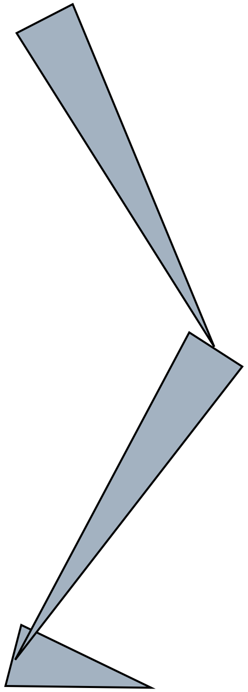
Human Skeleton

- Human bones =206, CG approx. 40.
- Human bones flexible, 6 DOF joints.
- CG bones rigid, 3DOF Kinematics.
- Human bones have connective tissue called ligaments.
- Muscle attached to bone by tendons.

Skeletal control Interfaces

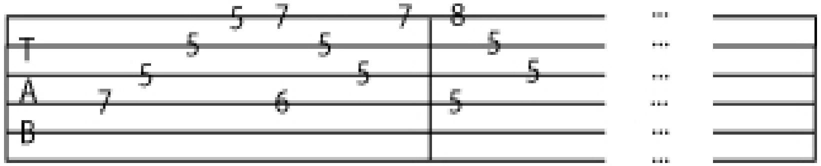
- More DOF = more control (both GOOD & BAD).
- Interfaces that capture the domain of specialized motion makes working with experts easier.
- Complex motion with environmental interaction is best left to physics and motion capture.
- Even simple abstractions of the human form are rooted in understanding the underlying anatomy.
- An anatomic model could establish a ground truth for realistic character animation.

Kinematics (Maya)



Handrix

How do we get from this:



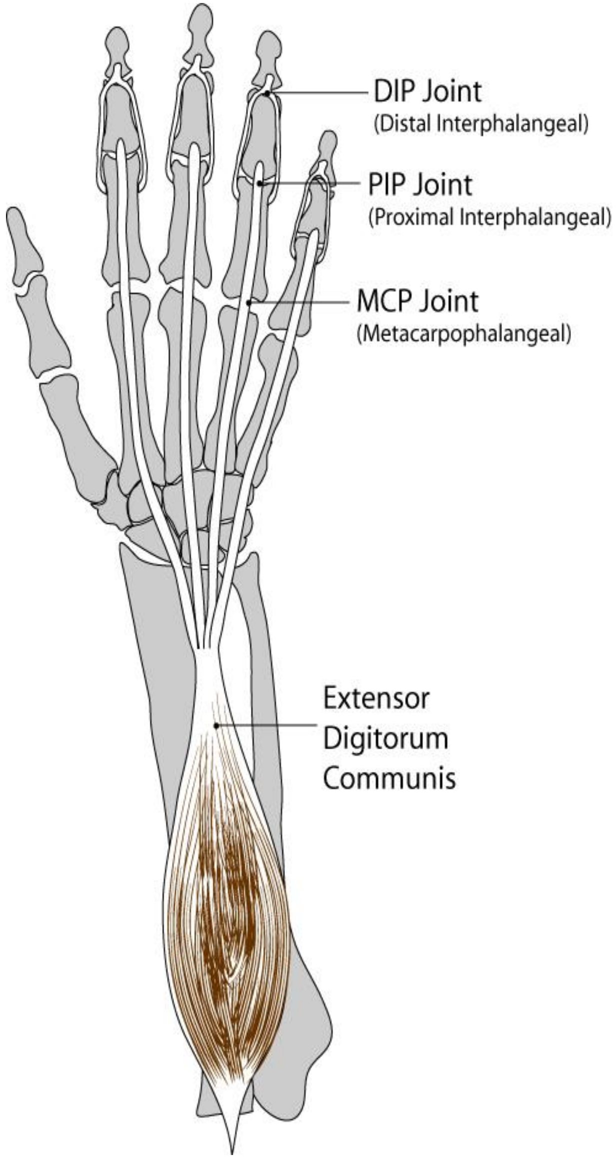
To this:

A Bit of Anatomy

- Why are fingers interdependent?
  - “One to many” muscle insertion sites
  - Close proximity of tendons
  - Neurological constraints

- A clear anatomical understanding is still being developed.

- We can interpolate observed data kNN.

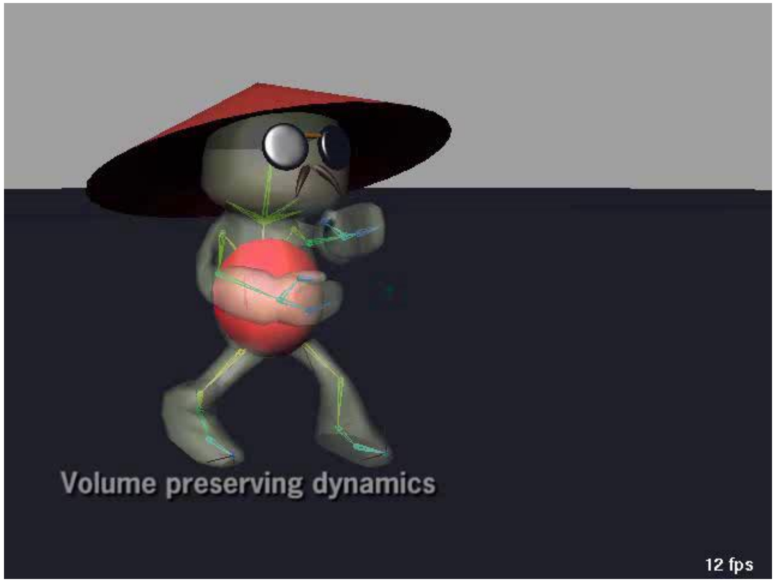


Motion Capture

- Easy to capture real motion data.

How do we adapt and reuse it?

Dynamics & Motion Capture



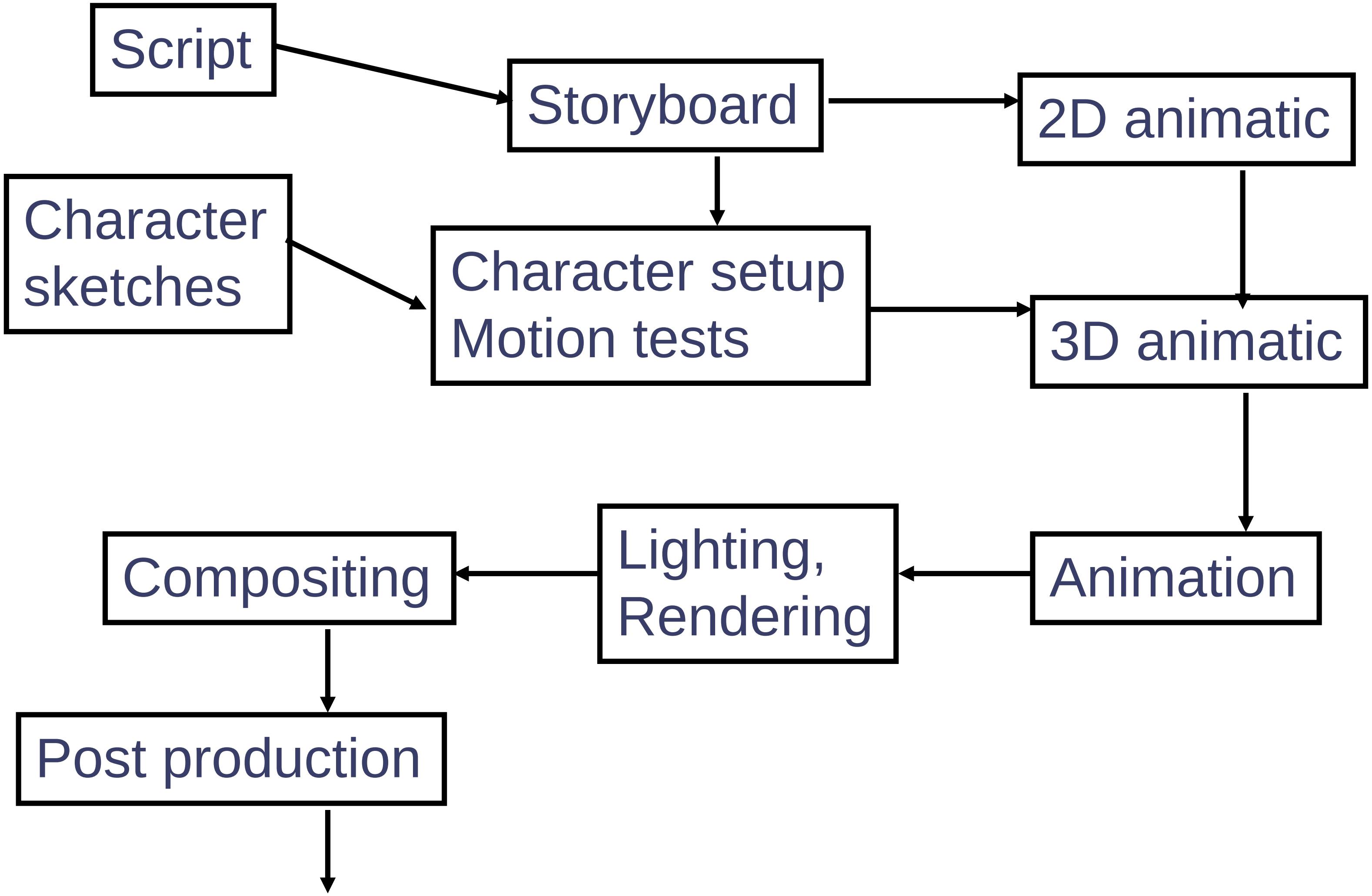
anatomic skinning

kinematic motion editing

Layers upon Layers

- Skeletal.
- Muscle.
- Skin and underlying tissue.
- Hair, nails, blemishes.
- Clothes and accessories.

Production pipeline



Script

Storyboard

2D animatic

Character sketches

Character setup
Motion tests

3D animatic

Animation

Lighting,
Rendering

Compositing

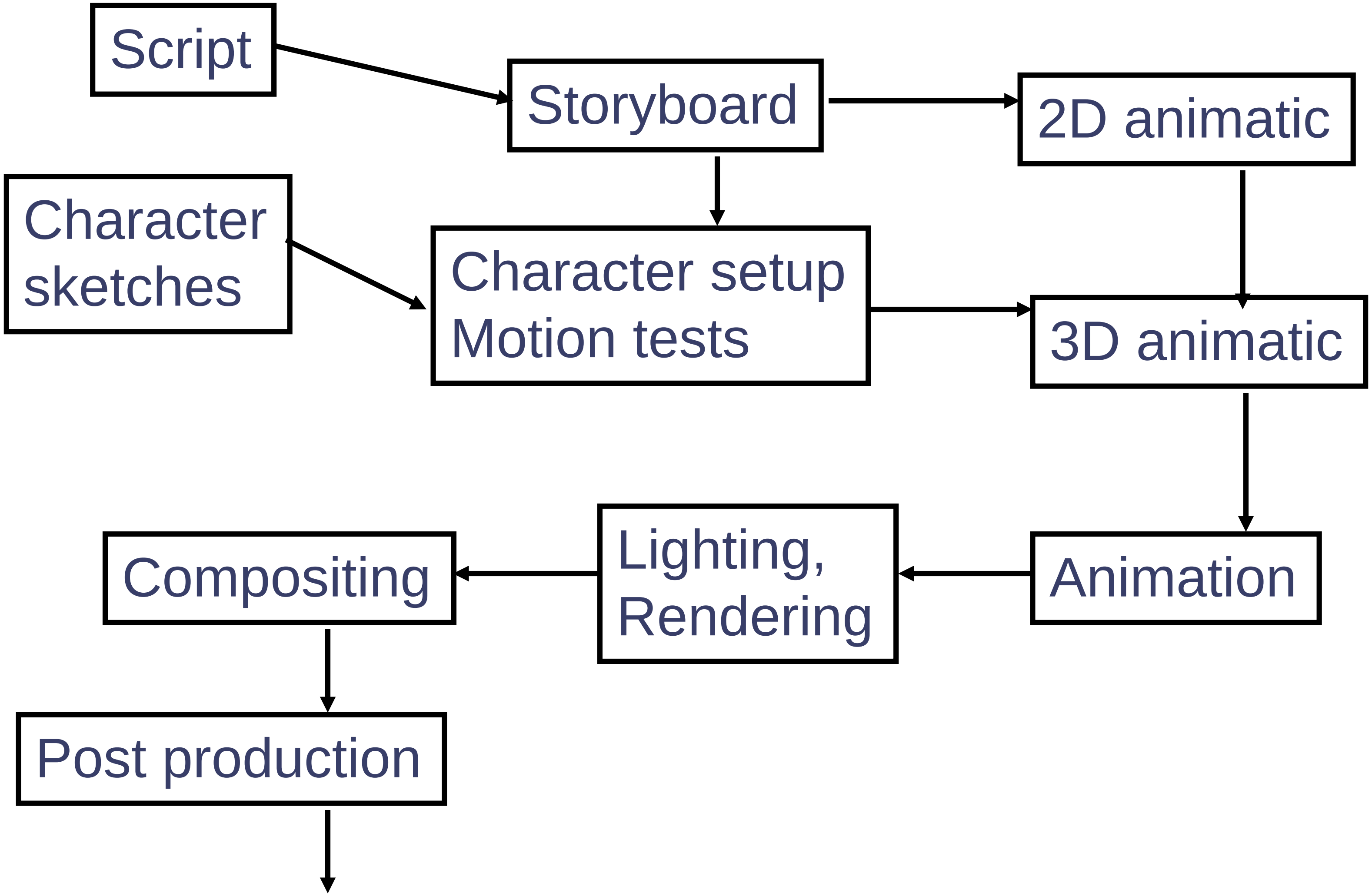
Post production

Character Sketches

2D animatic (storyreel)

Character setup, motion tests

Putting it back together



Script

Storyboard

2D animatic

Character sketches

Character setup
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3D animatic

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Lighting,
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Next: Rendering