

The Science of Pixar

At the Oregon Museum of Science and Industry (OMSI)

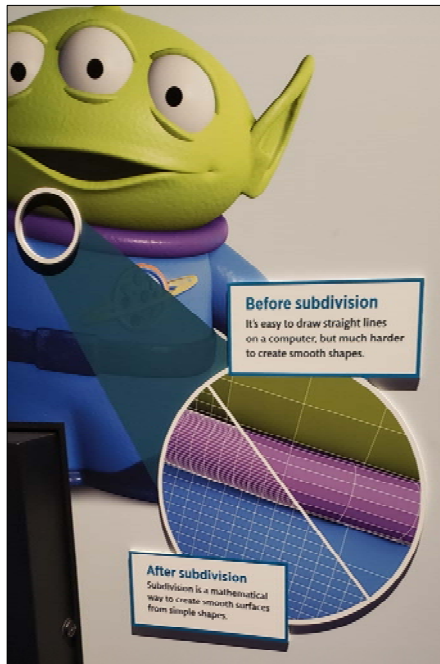
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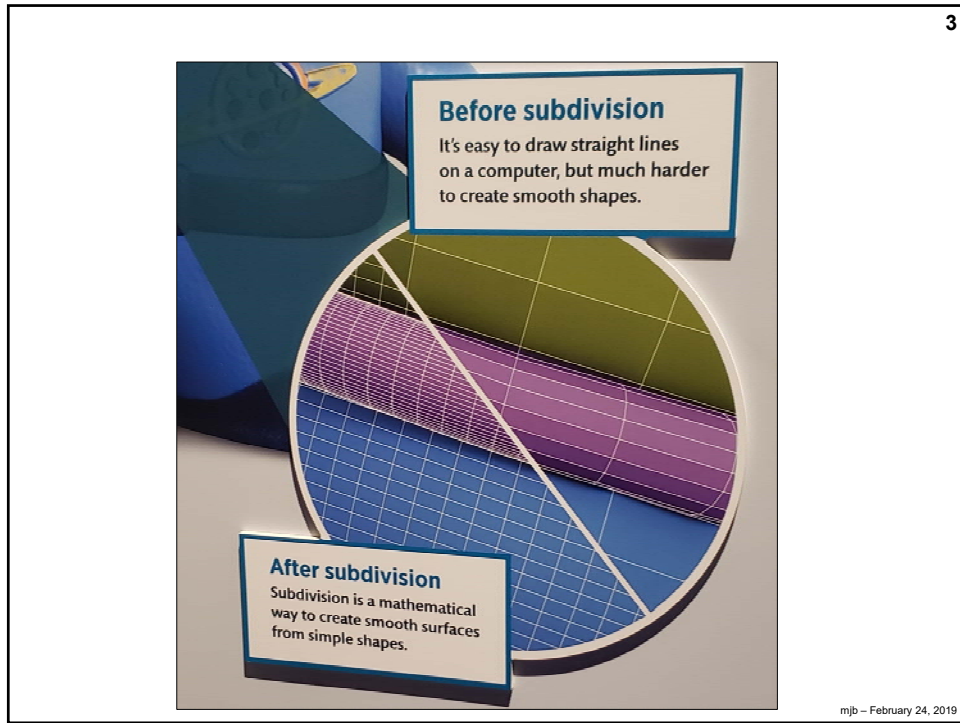
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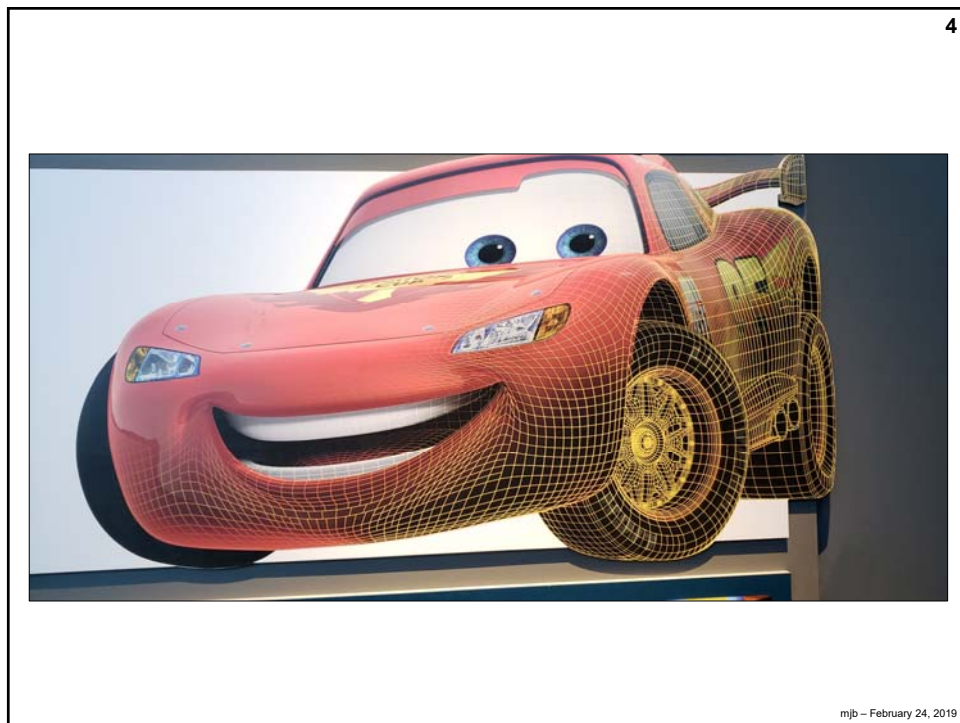


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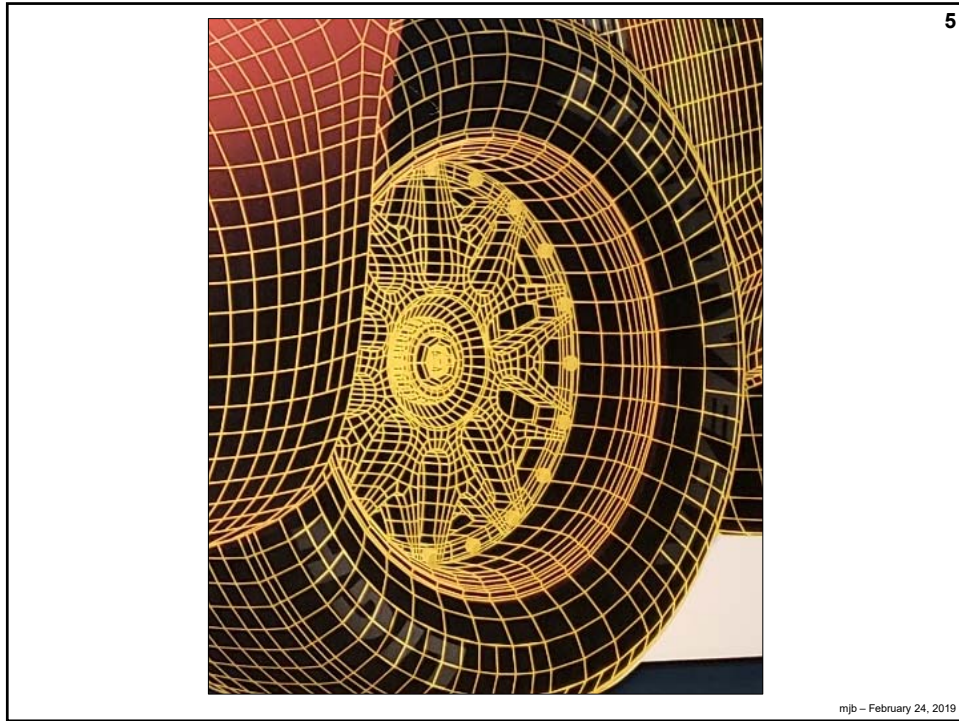
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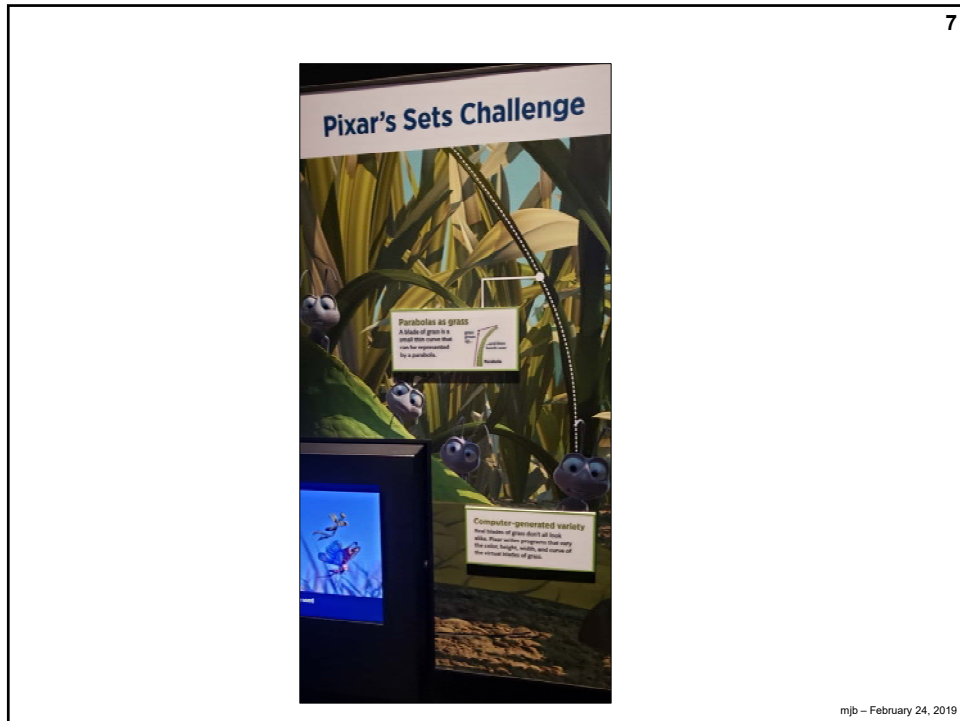
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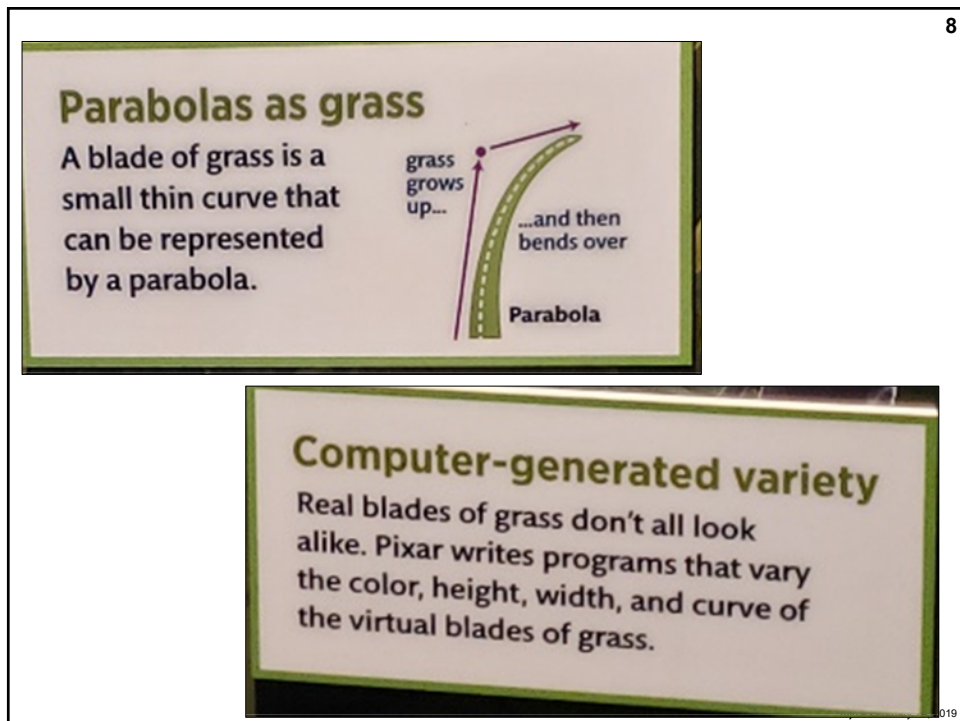
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Surfaces

Surface appearance is controlled separately from shape

The way something looks tells a story. What is it made of? Is it new or old? Well taken care of or neglected? After a virtual 3D model is created, a surfacing artist constructs its appearance with computer programs called shaders. Shaders determine the way light scatters off the surface so it looks shiny, transparent, and smooth (like glass) or dull and rough (like rust).



A virtual 3D model of Mater with no shaders.



Mater after the shaders have been applied.



▲ A shader describes how light is scattered and absorbed on Mater's rusty surface.



▲ The roughness of Mater's appearance is determined by the geometry and his shaders.




▲ Shaders respond automatically to their surrounding world as Mater's reflective hood.

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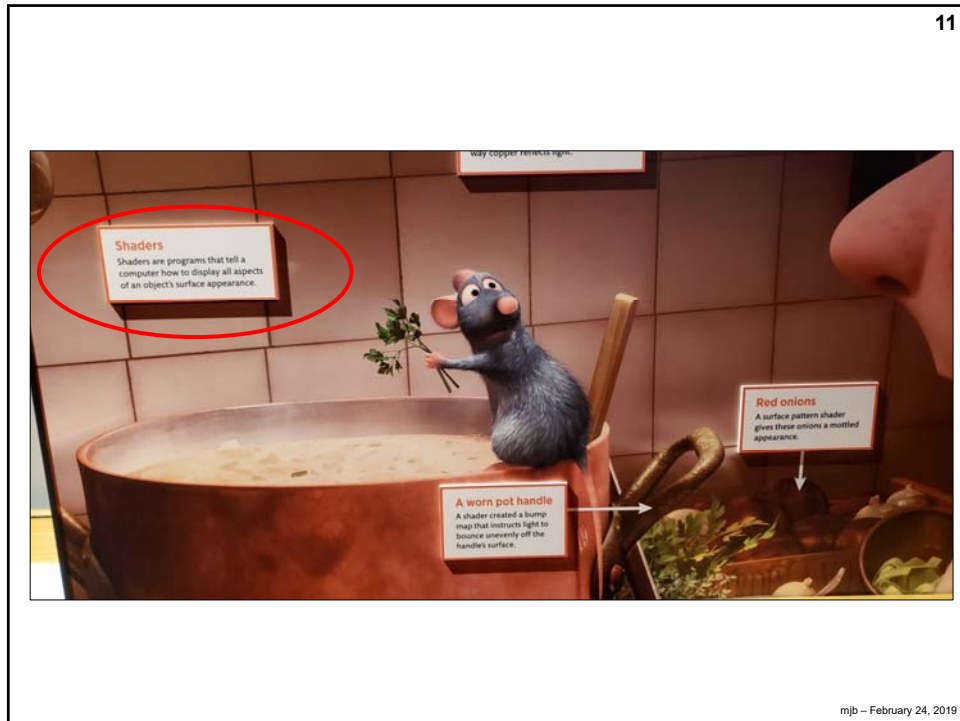
A virtual 3D model of Mater with no shaders.



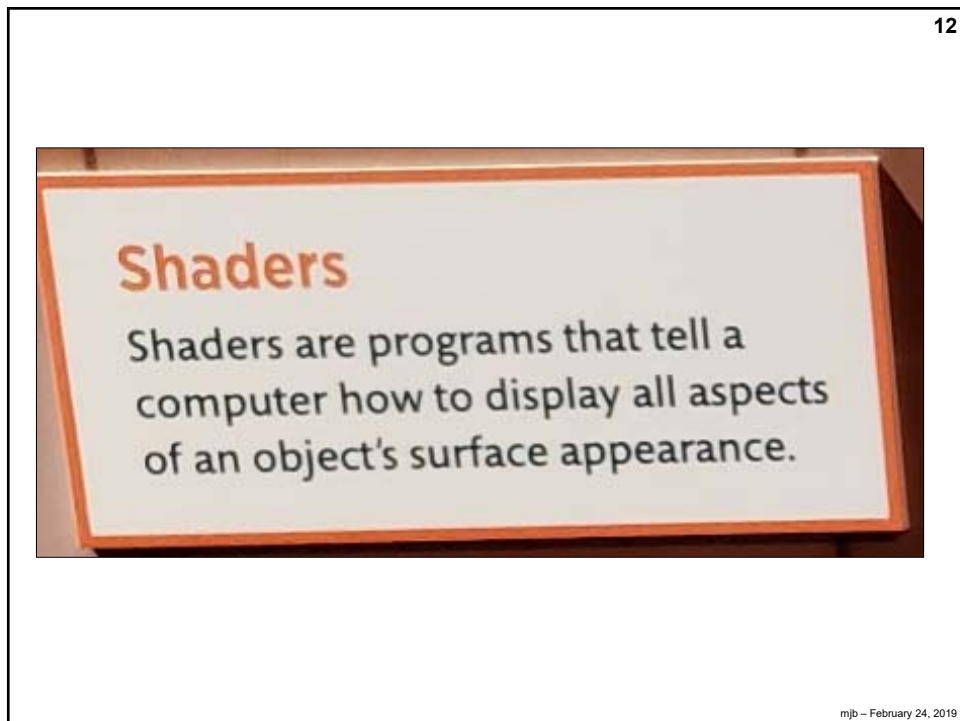
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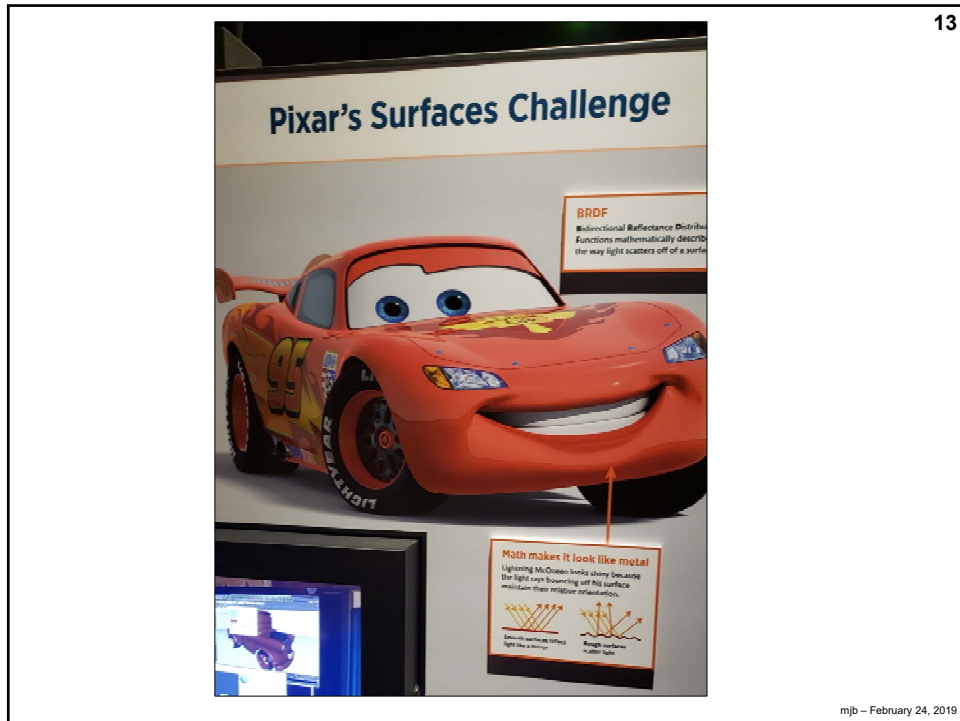
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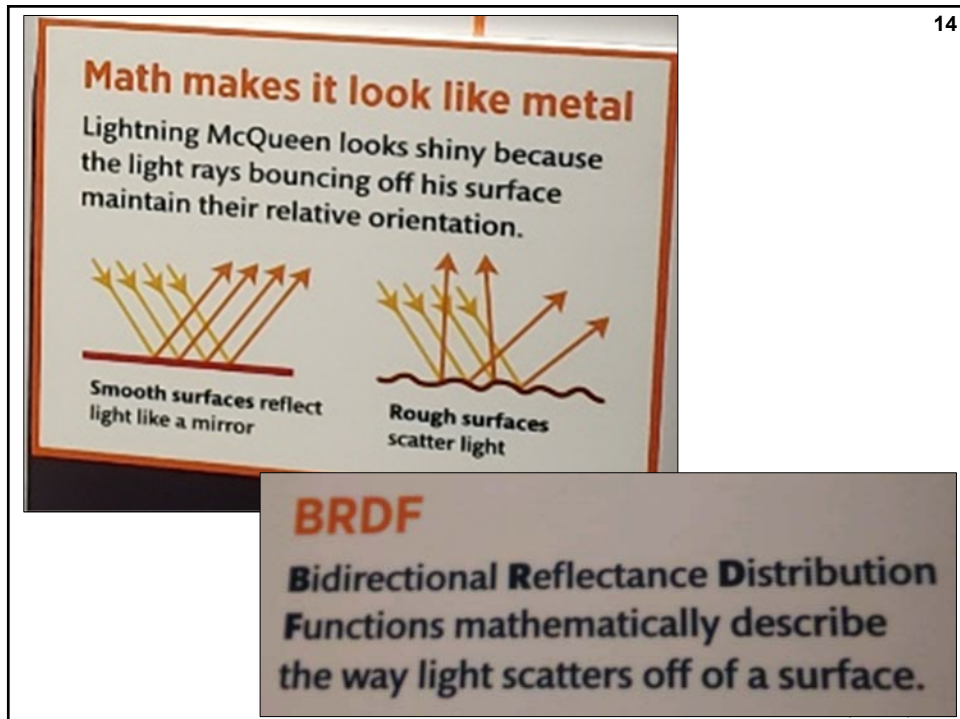
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$$L(x, \omega_o) = \int_{\Omega} f(x, \omega_i, \omega_o) L(x, \omega_i) \cos(\theta) d\omega$$

It's a mathematical description of how light bounces around in the environment.

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The Rendering Equation 16

Light Arriving

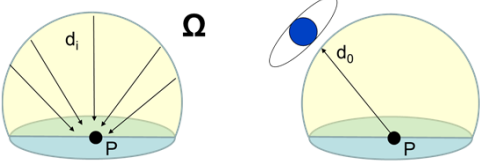
$$L(P, d_o, \lambda) = E(P, d_o, \lambda) + \int_{\Omega} L(P, d_i, \lambda) f(\lambda, d_i, d_o) (d_i \cdot \hat{n}) d\Omega$$

Light Departing

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The Rendering Equation 17



$$B(x, d_0, \lambda) = E(P, d_0, \lambda) + \int_{\Omega} B(x, d_i, \lambda) f(x, \lambda, d_i, d_0) (d_i \cdot \hat{n}) d\Omega$$

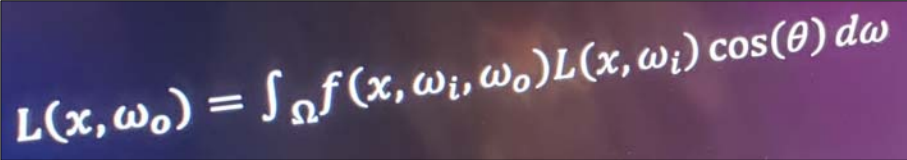
In plain language, this is a simultaneous-equation energy balance:

“The light shining from the point P is the reflection of the incoming light directed to the point P from all of the other points in the scene.”

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$$L(x, \omega_0) = \int_{\Omega} f(x, \omega_i, \omega_0) L(x, \omega_i) \cos(\theta) d\omega$$

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Rendering

Rendering turns a virtual 3D scene into a 2D image

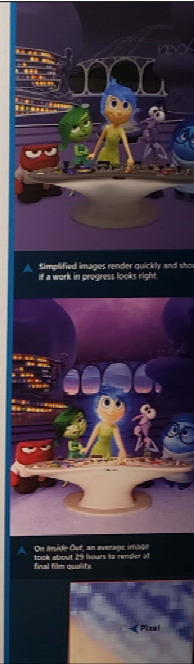
The virtual scene is set—the characters are shaded and posed, the lights and camera are in position, and the simulations are ready to run. But no one knows what it looks like until the rendering process turns all that data and programming into an image we can see. Pixar generates low resolution renders for works in progress and high resolution renders for the final film.



The virtual 3D scene
This wireframe is a visualization of the data that defines the scene.



The rendered 2D image
Rendering calculates the color of every pixel in an image.



▲ Simplified images render quickly and show if a work in progress looks right.

▲ On *Inside Out*, an average shot took about 23 hours to render at final film quality.

← Pixel

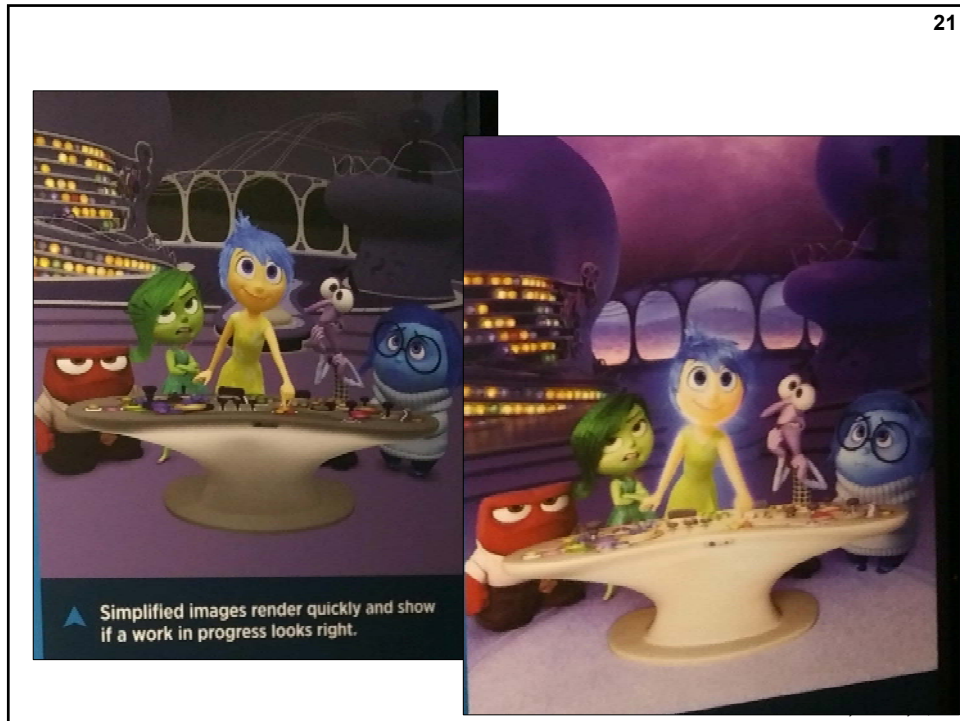
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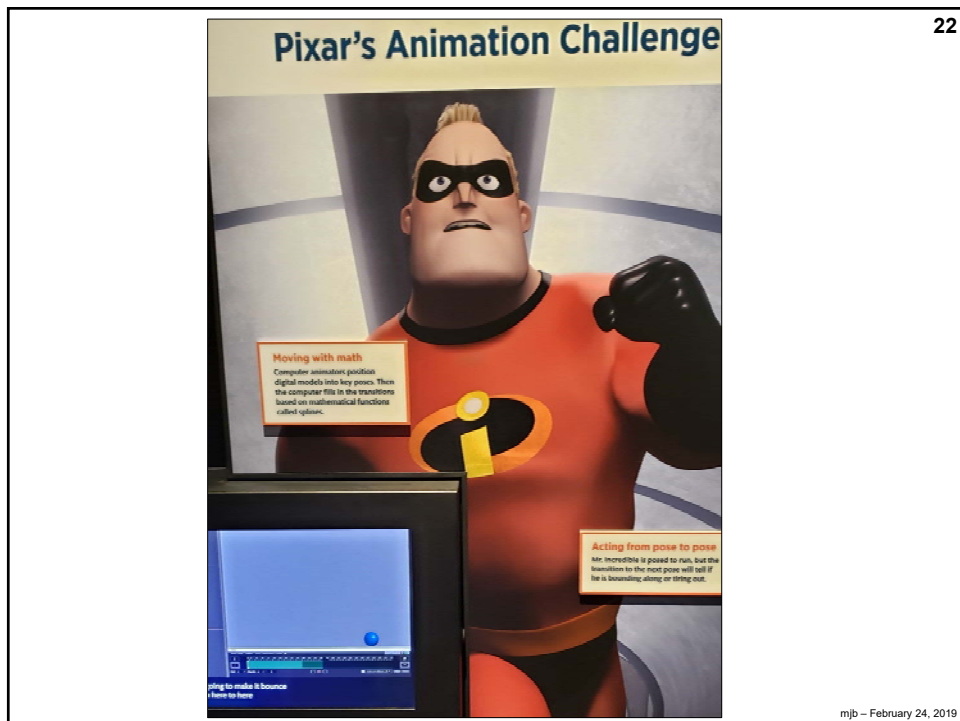
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Moving with math

Computer animators position digital models into key poses. Then the computer fills in the transitions based on mathematical functions called splines.

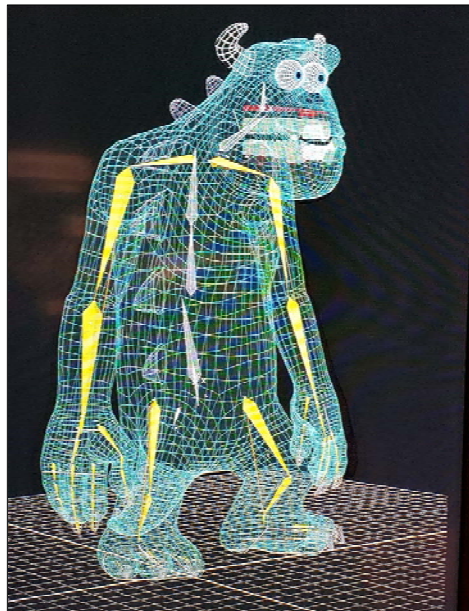
Acting from pose to pose

Mr. Incredible is posed to run, but the transition to the next pose will tell if he is bounding along or tiring out.

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Simulation

Computer programs create automated motion


While animators focus on acting, simulation programmers create motion that makes scenes feel alive and believable. Some simulations—hair, fur, and clothing—respond to the way a character moves. Other simulations recreate natural phenomena, such as fire or water. Programmers start with the underlying physics, but they balance believability with the artistic needs and the time it takes to run the simulation.

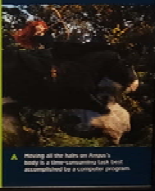
A frame from Disney before the simulation was added. The same frame with the simulation added.



▲ The movements of Merida's hair and dress are simulations.



▲ Continued advances in landscape simulation, such as fire, for example, were crucial.




▲ Having all the hairs on Merida's head in a 3D environment took 100 computers and 5 computer programs.

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▲ The movements of Merida's hair and dress are simulations.

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A frame from *Brave* before the simulated elements were included.

The same frame with the simulations added.

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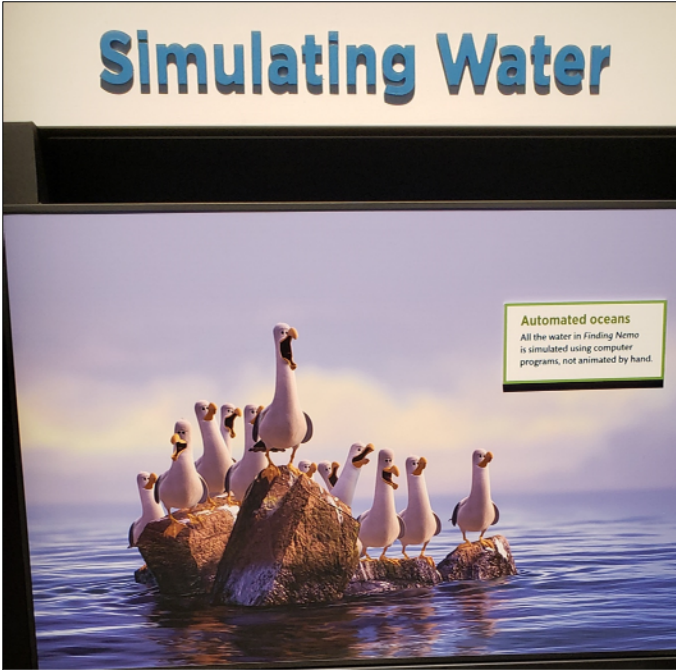


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Simulating Water



Automated oceans
All the water in *Finding Nemo* is simulated using computer programs, not animated by hand.

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