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The Science of Pixar

At the Oregon Museum of Science and Industry (OMSI)

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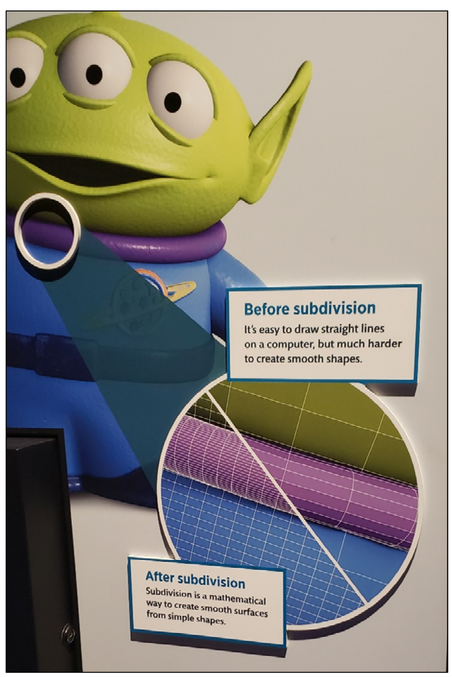

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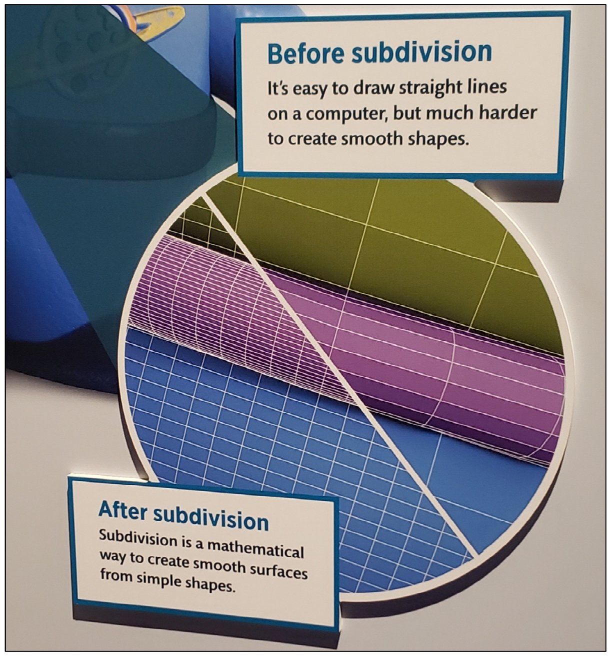

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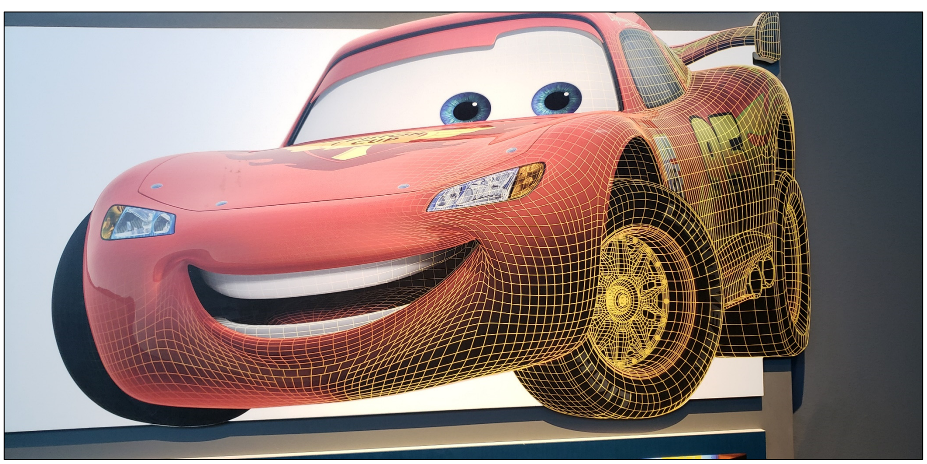

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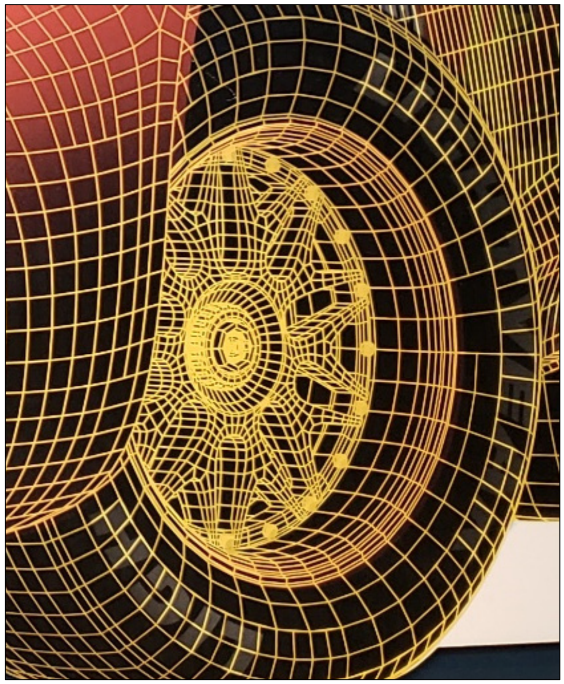

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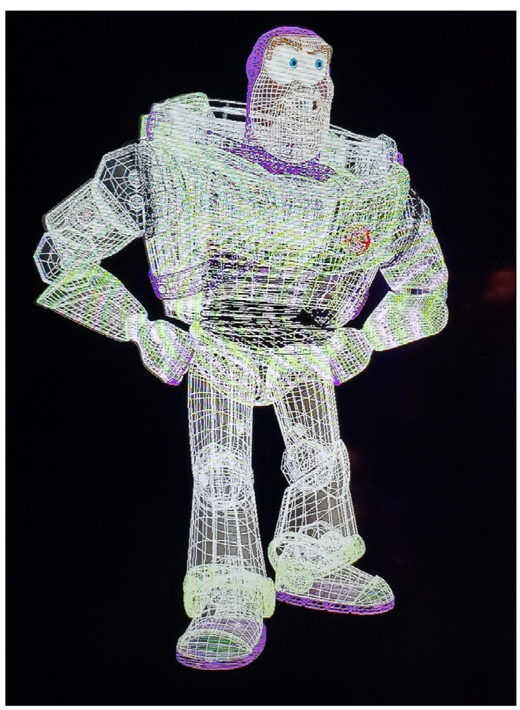

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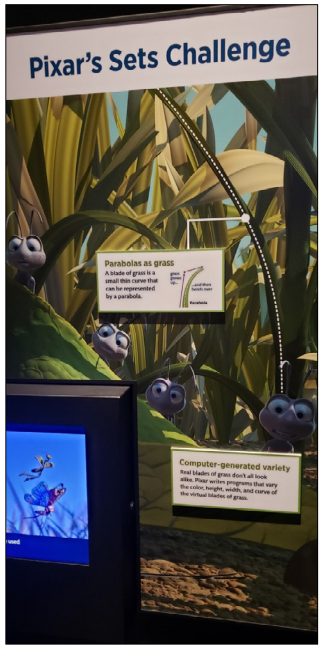
Pixar's Sets Challenge
Parabolas as grass
Computer-generated variety

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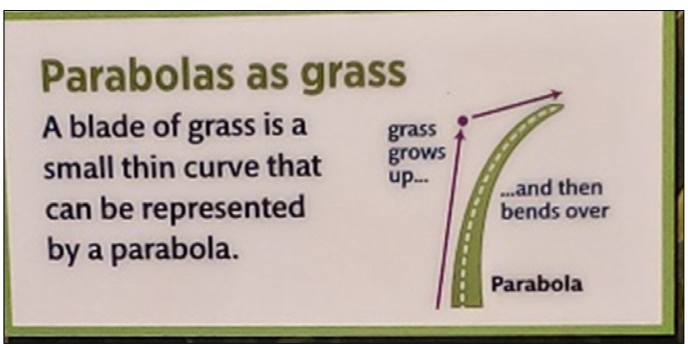
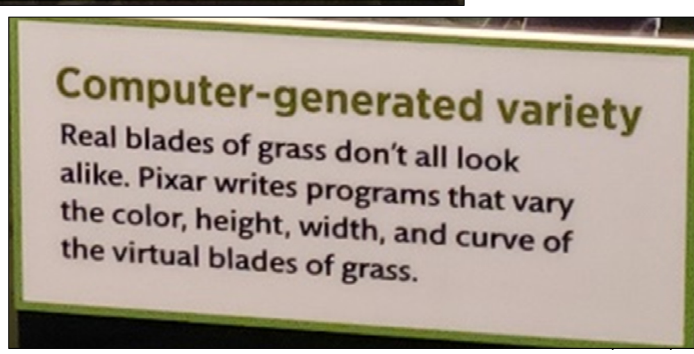

Parabolas as grass
A blade of grass is a
small thin curve that
can be represented
by a parabola.
grass
grows
up...
...and then
bends over
Parabola


Computer-generated variety
Real blades of grass don't all look
alike. Pixar writes programs that vary
the color, height, width, and curve of
the virtual blades of grass.

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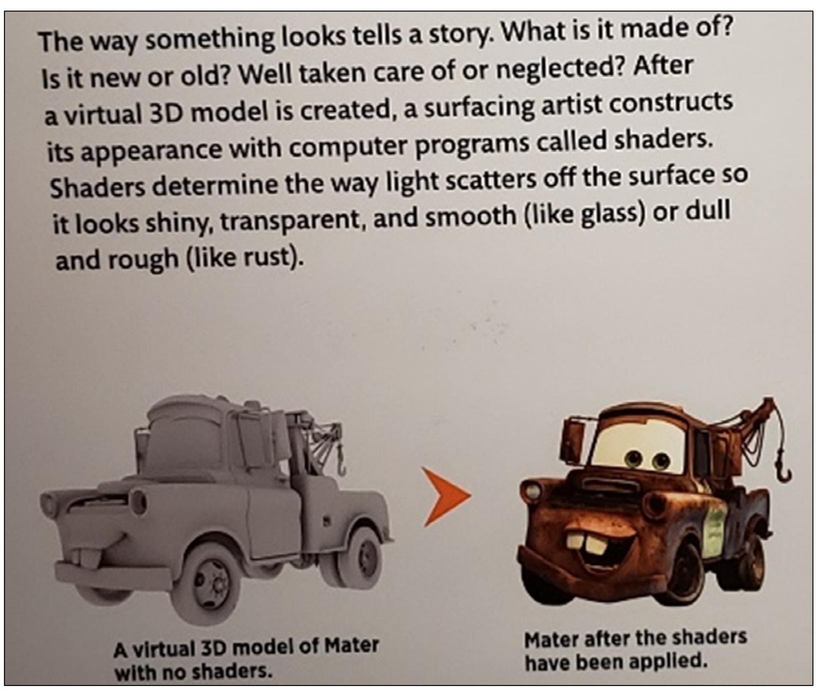

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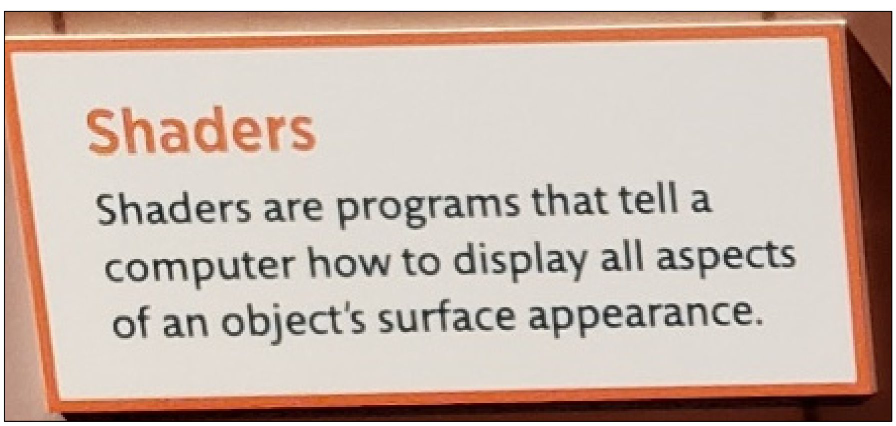
Shaders
Shaders are programs that tell a computer how to display all aspects of an object's surface appearance.
Red onions
A surface pattern shader gives these onions a mottled appearance.
A worn pot handle
A shader created a bump map that instructs light to bounce unevenly off the handle's surface.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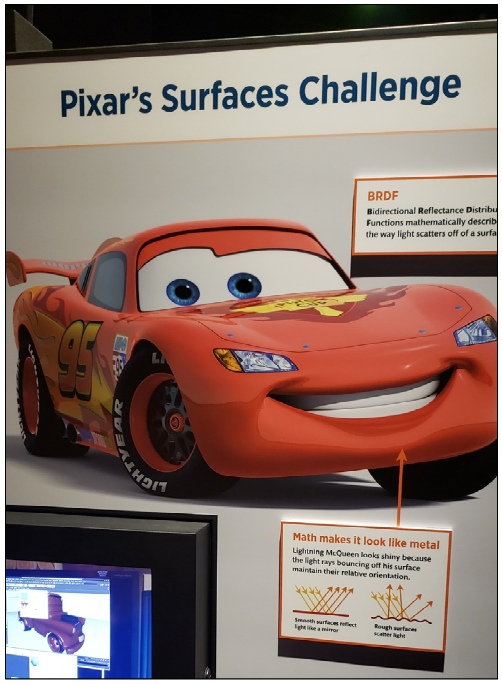

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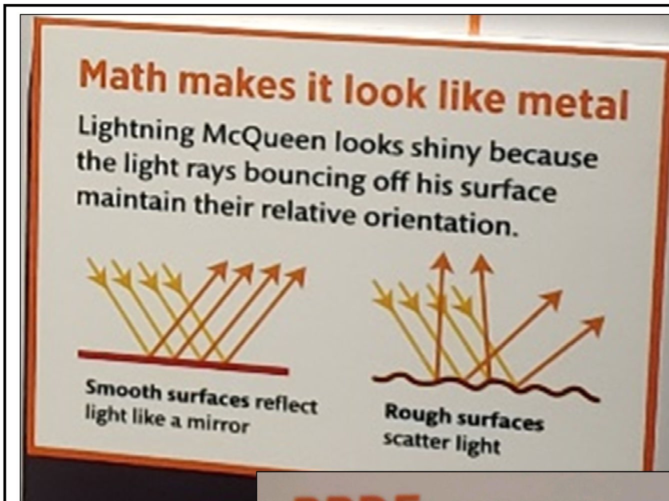

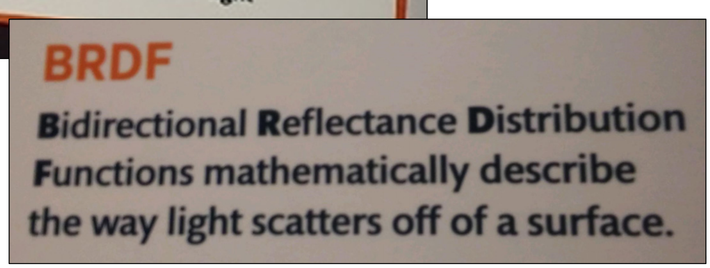

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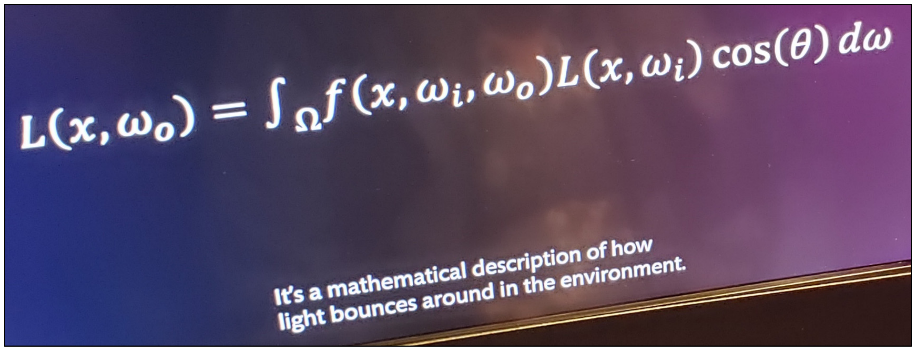

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The Rendering Equation

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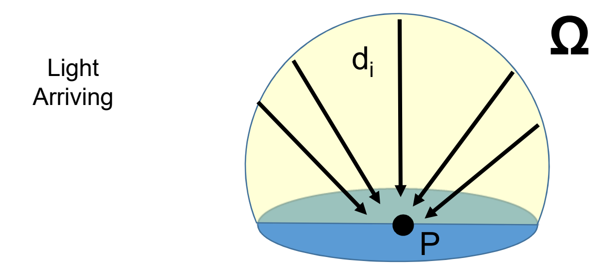
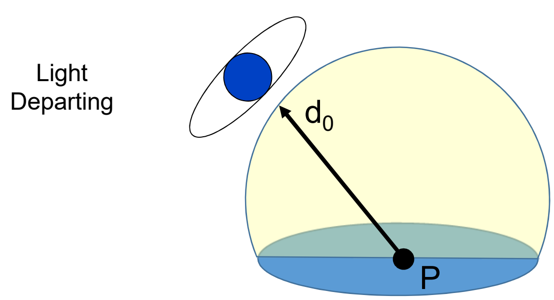


$$L(P, d_0, \lambda) = E(P, d_0, \lambda) + \int_\Omega L(P, d_i, \lambda) f(\lambda, d_i, d_0)(d_i \cdot \hat{n}) d\Omega$$



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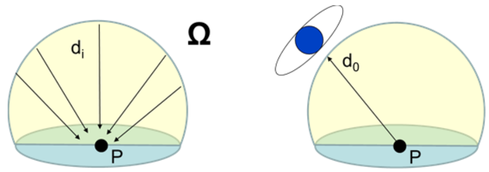

$$B(x, d_0, \lambda) = E(P, d_0, \lambda) + \int_{\Omega} B(x, d_i, \lambda) f(x, \lambda, d_i, d_0)(d_i \cdot \hat{n}) d\Omega$$

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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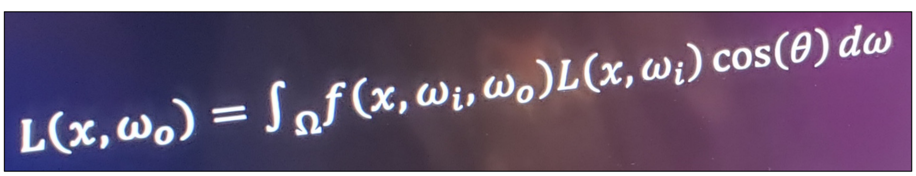

$$L(x, d_0, \lambda) = E(P, d_0, \lambda) + \int_{\Omega} L(x, d_i, \lambda) f(x, \lambda, d_i, d_0)(d_i \cdot \hat{n}) d\Omega$$

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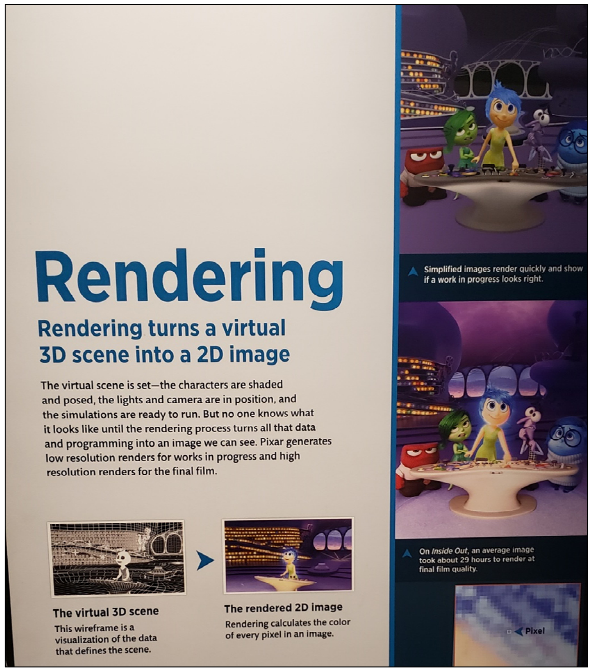
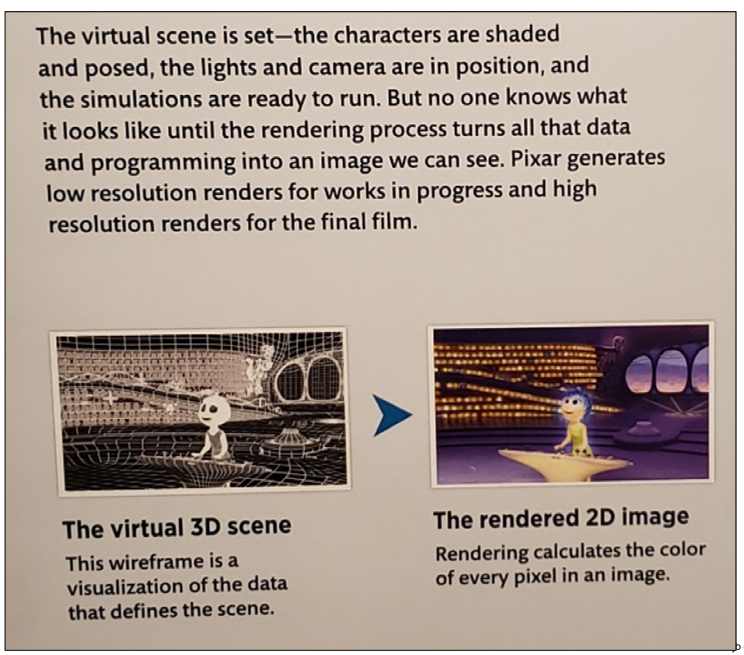


Rendering
Rendering turns a virtual 3D scene into a 2D image
The virtual scene is set—the characters are shaded and posed, the lights and camera are in position, and the simulations are ready to run. But no one knows what it looks like until the rendering process turns all that data and programming into 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 image took about 29 hours to render at final film quality.
Pixel



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Pixar's Animation Challenge
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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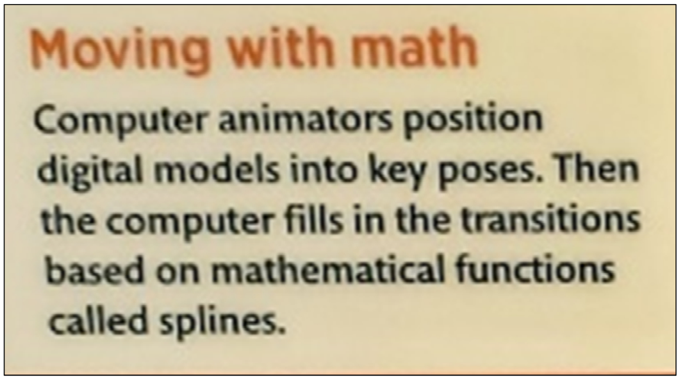

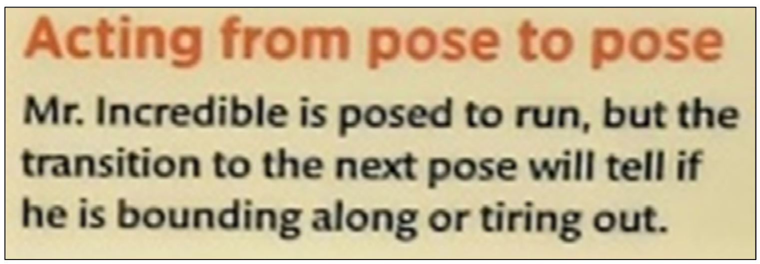

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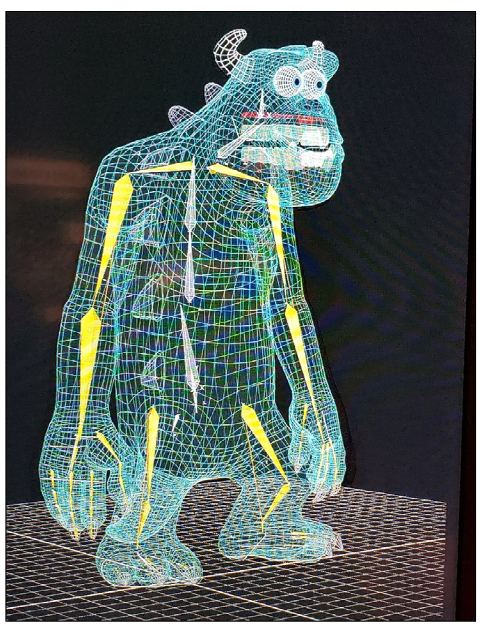

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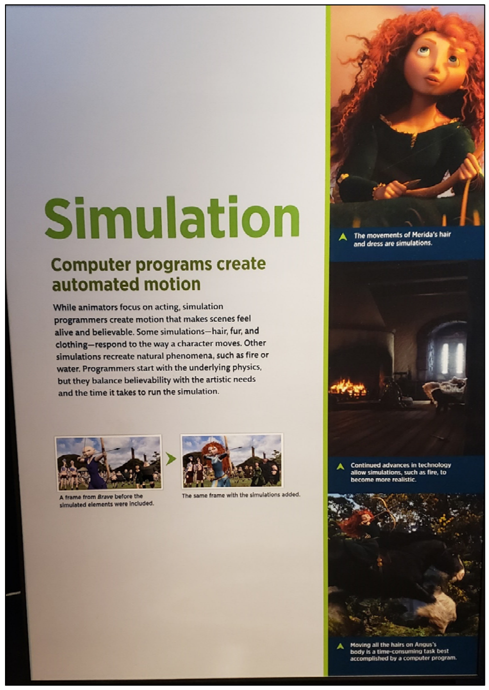

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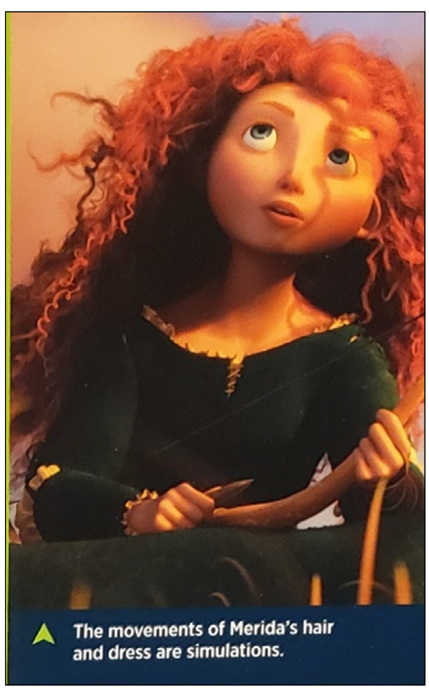

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While animators focus on acting, simulation programmers create motion that makes scenes feel alive and believable. Some simulations—hair, fur, and clothing—respond to the way a character moves. Other simulations recreate natural phenomena, such as 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 *Brave* before the simulated elements were included.

The same frame with the simulations added.

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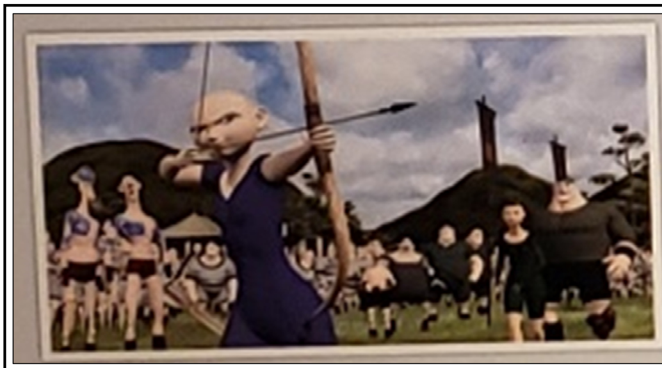
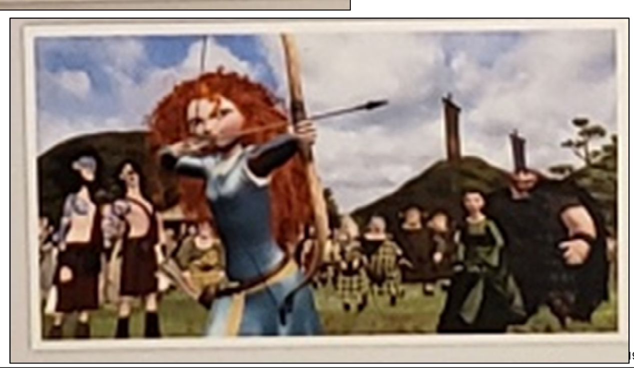
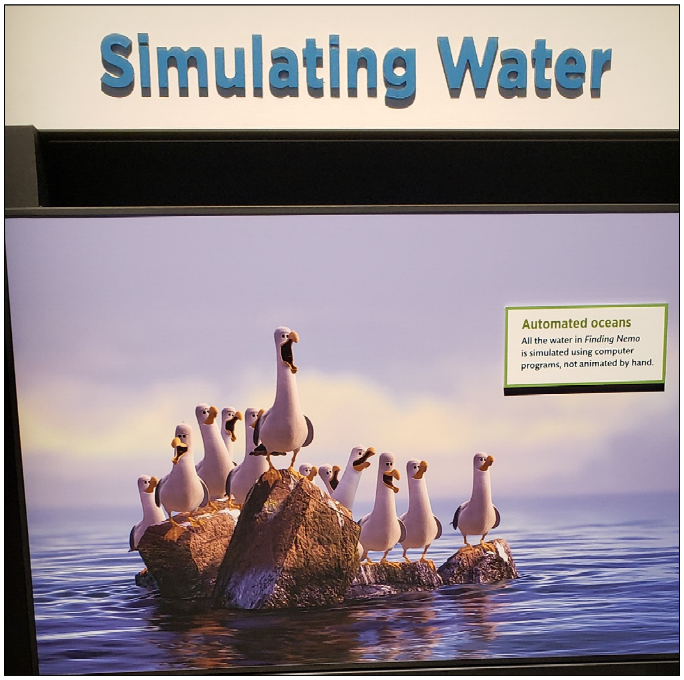
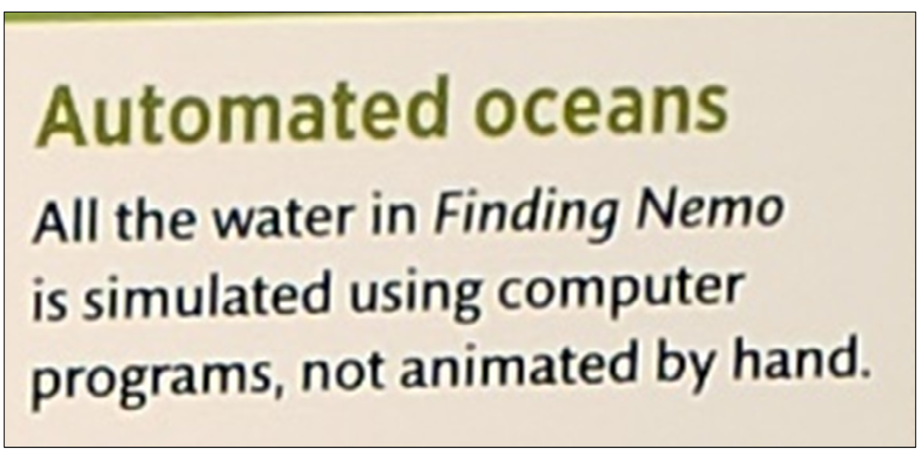





Simulating Water
Automated oceans
All the water in Finding Nemo
is simulated using computer
programs, not animated by hand.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