

The Science of Pixar

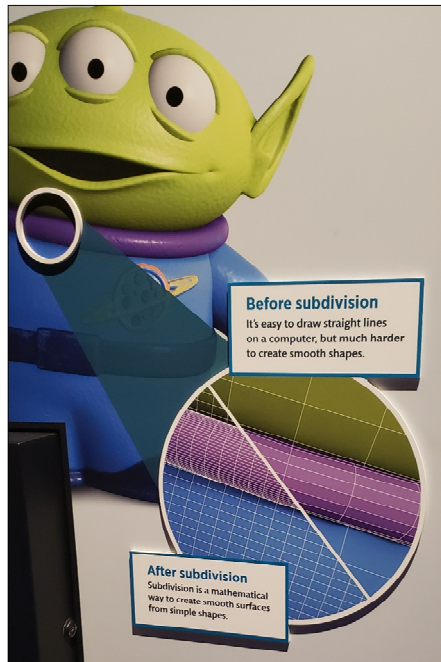
At the Oregon Museum of Science and Industry (OMSI)

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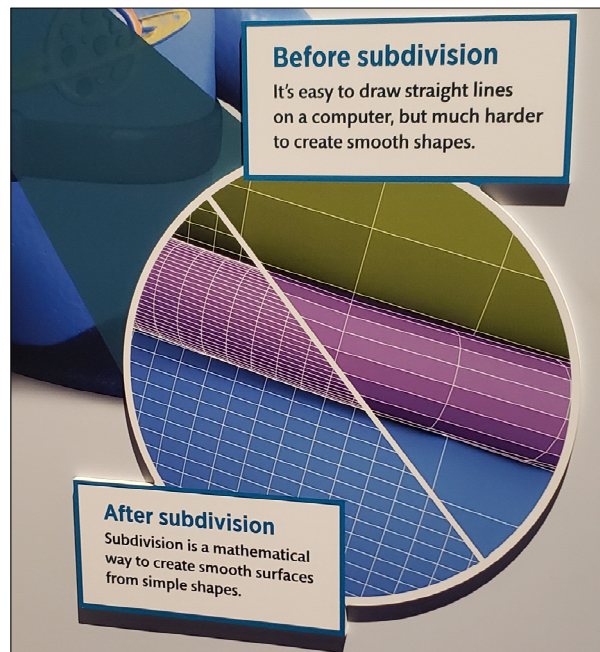
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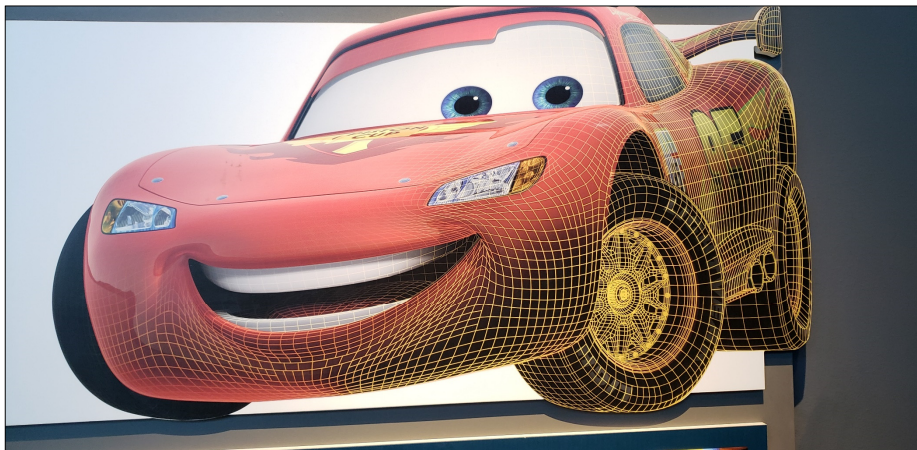
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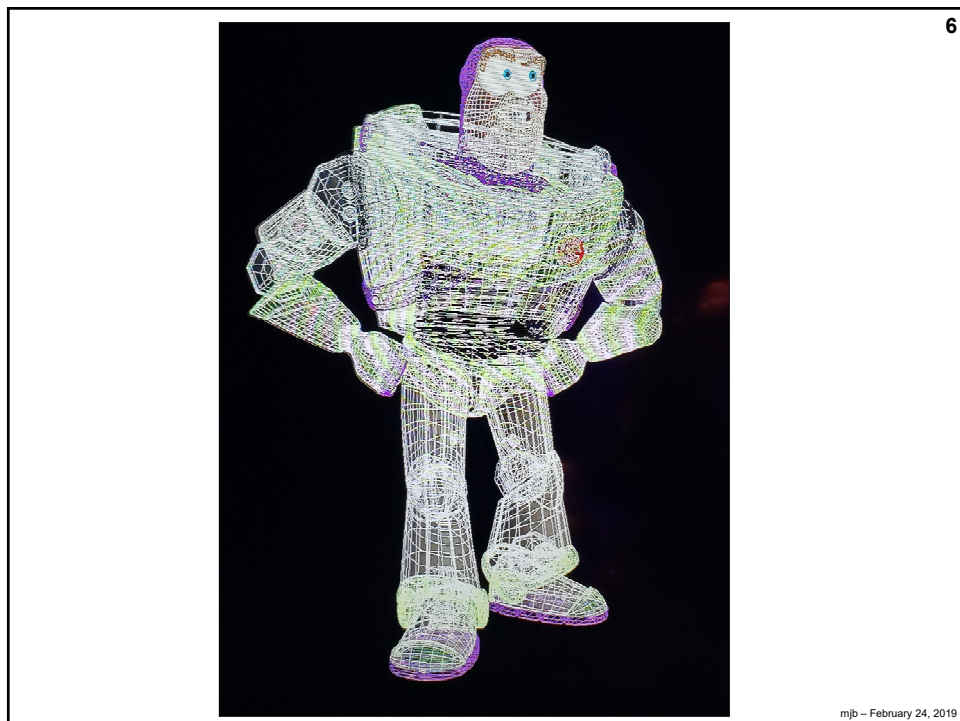
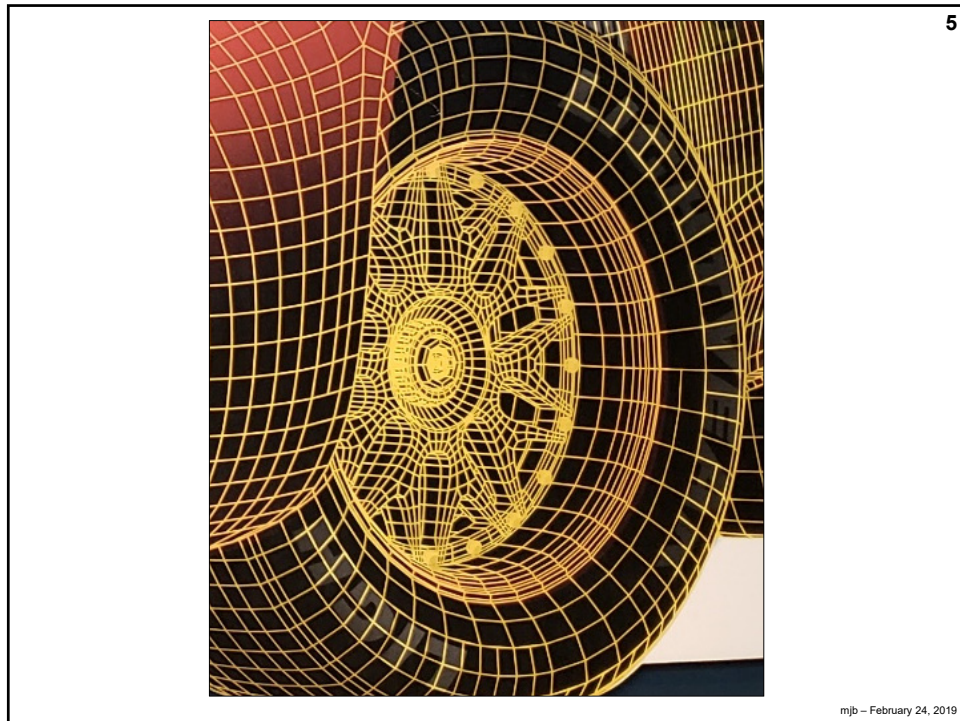


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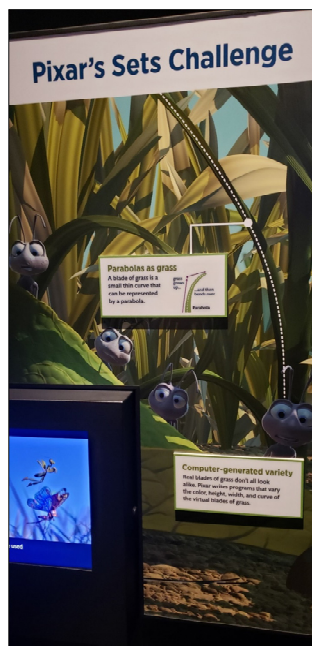
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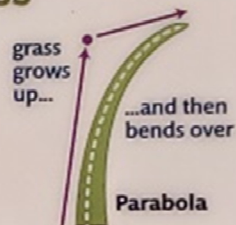


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Parabolas as grass

A blade of grass is a small thin curve that can be represented by a 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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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 reflected and absorbed on Mater's rusty surface.



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




▲ Shaders respond automatically to their environment, such as on Mater's reflective hubcap.


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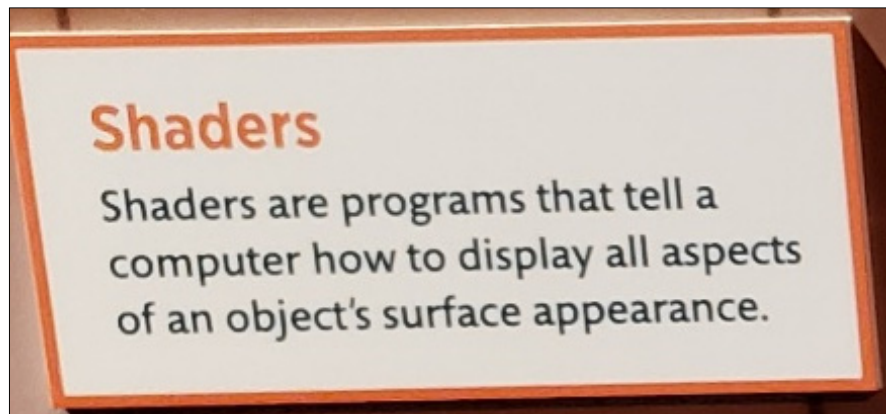
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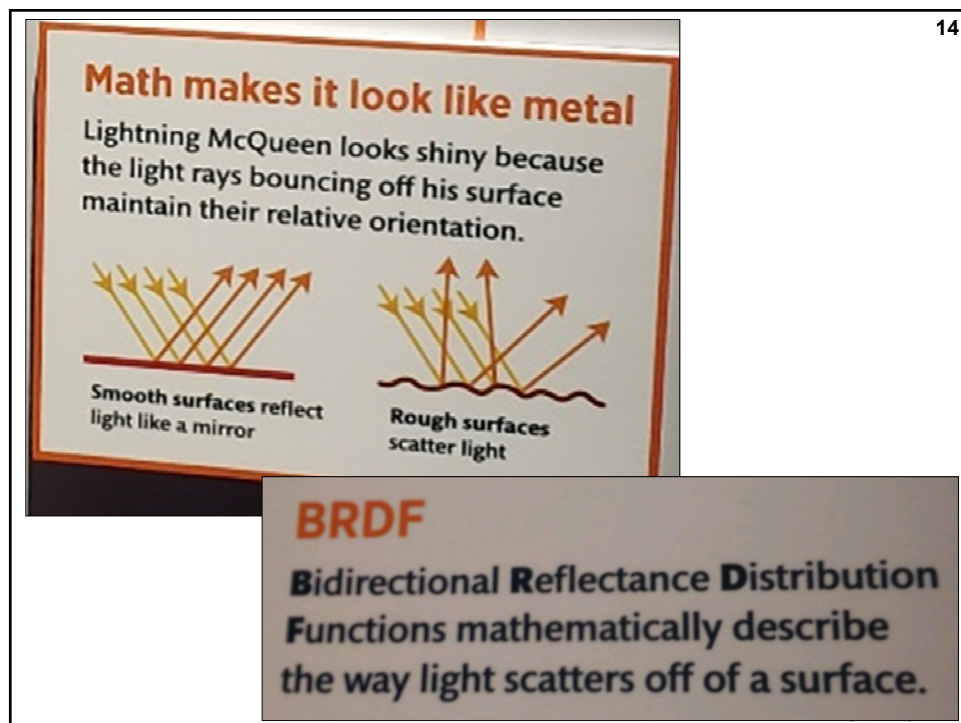
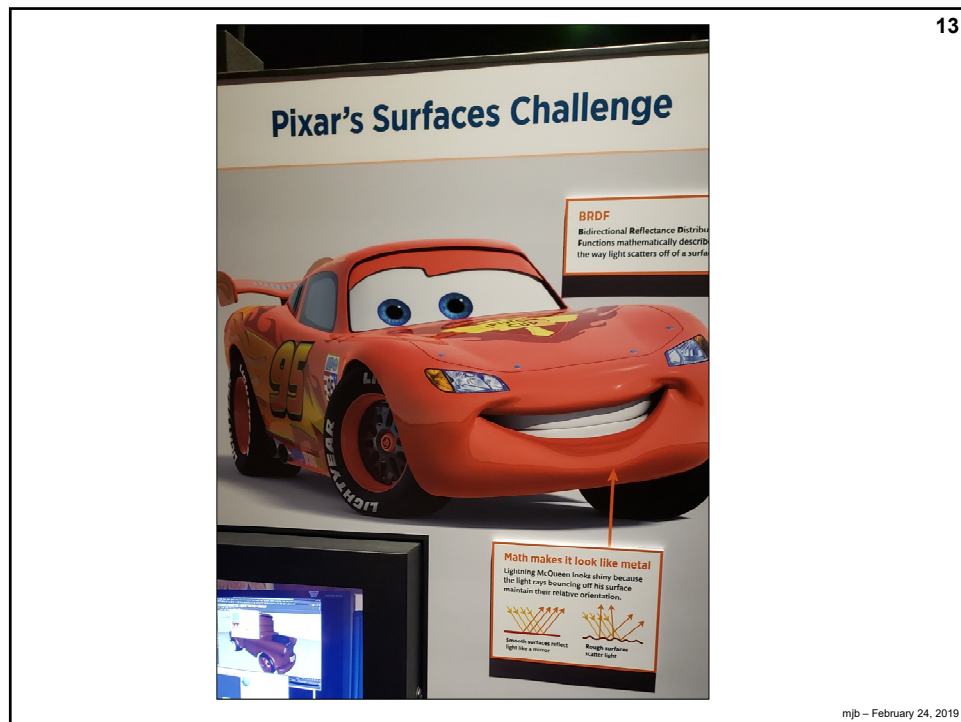


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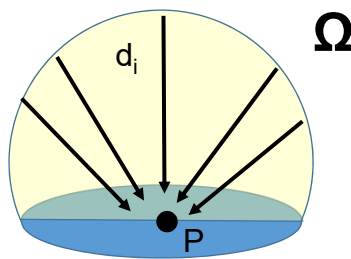
$$L(x, \omega_o) = \int_{\Omega} f(x, \omega_i, \omega_o) L(x, \omega_i) \cos(\theta) d\omega$$

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

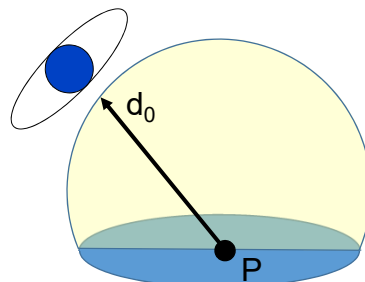
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The Rendering Equation

Light
Arriving

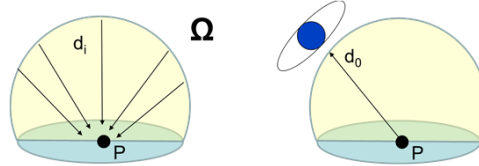
$$L(P, d_o, \lambda) = E(P, d_o, \lambda) + \int_{\Omega} L(P, d_i, \lambda) f(\lambda, d_i, d_o) (d_i \cdot \hat{n}) d\Omega$$

Light
Departing

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The Rendering Equation

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

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Rendering

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

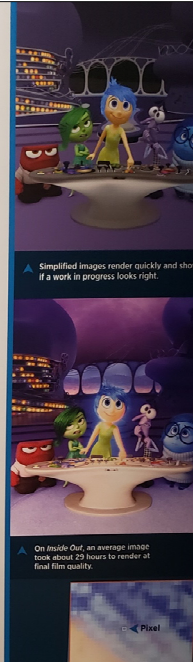
The virtual scene is set—the characters are shaded and posed, the lights and camera are in position, and the simulations are ready to run. But no one knows what it looks like until the rendering process turns all that data and programming into an image we can see. Pixar generates low resolution renders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



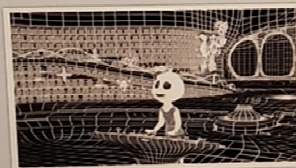
▲ Simplified images render quickly and show if a work in progress looks right.

▲ On *Inside Out*, an average image took about 29 hours to render at final film quality.

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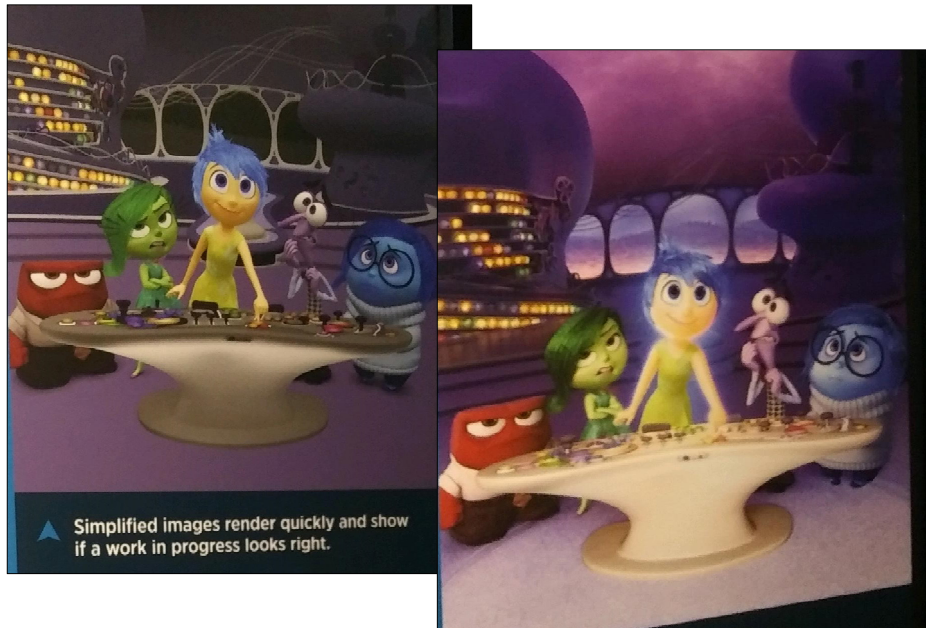
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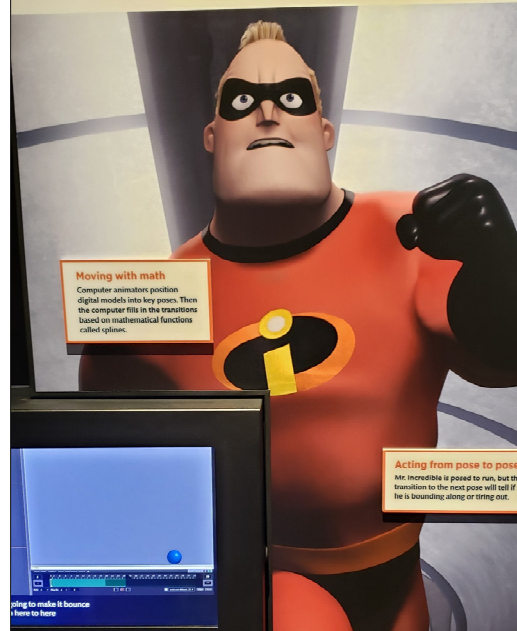
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Pixar's Animation Challenge



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Moving with math

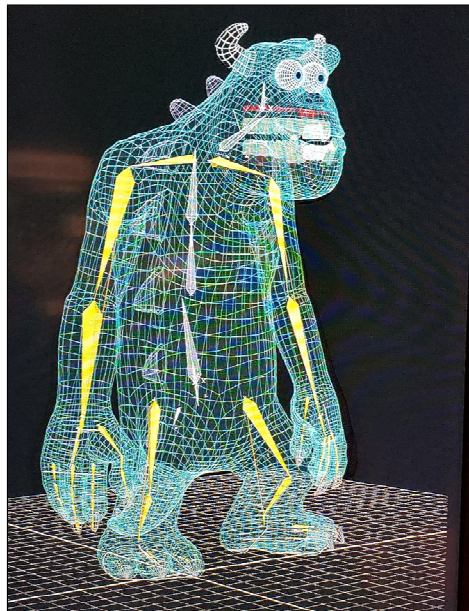
Computer animators position digital models into key poses. Then the computer fills in the transitions based on mathematical functions called splines.

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's Frozen before the simulated elements were included.

The same frame with the simulations added.

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

Continued advances in technology allow simulations, such as fire, to become more realistic.

Moving all the hairs on Anna's body is a 100-million-hair task accomplished by a computer program.

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



The same frame with the simulations added.

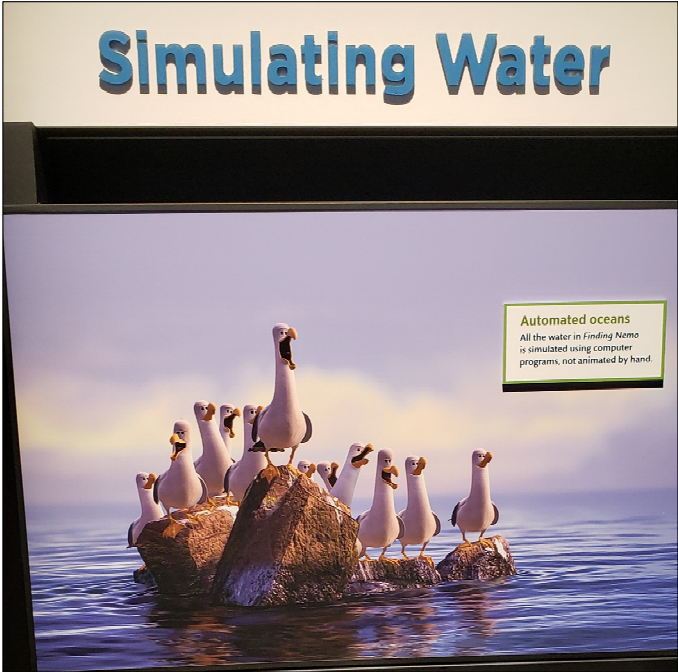
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Simulating Water



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

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