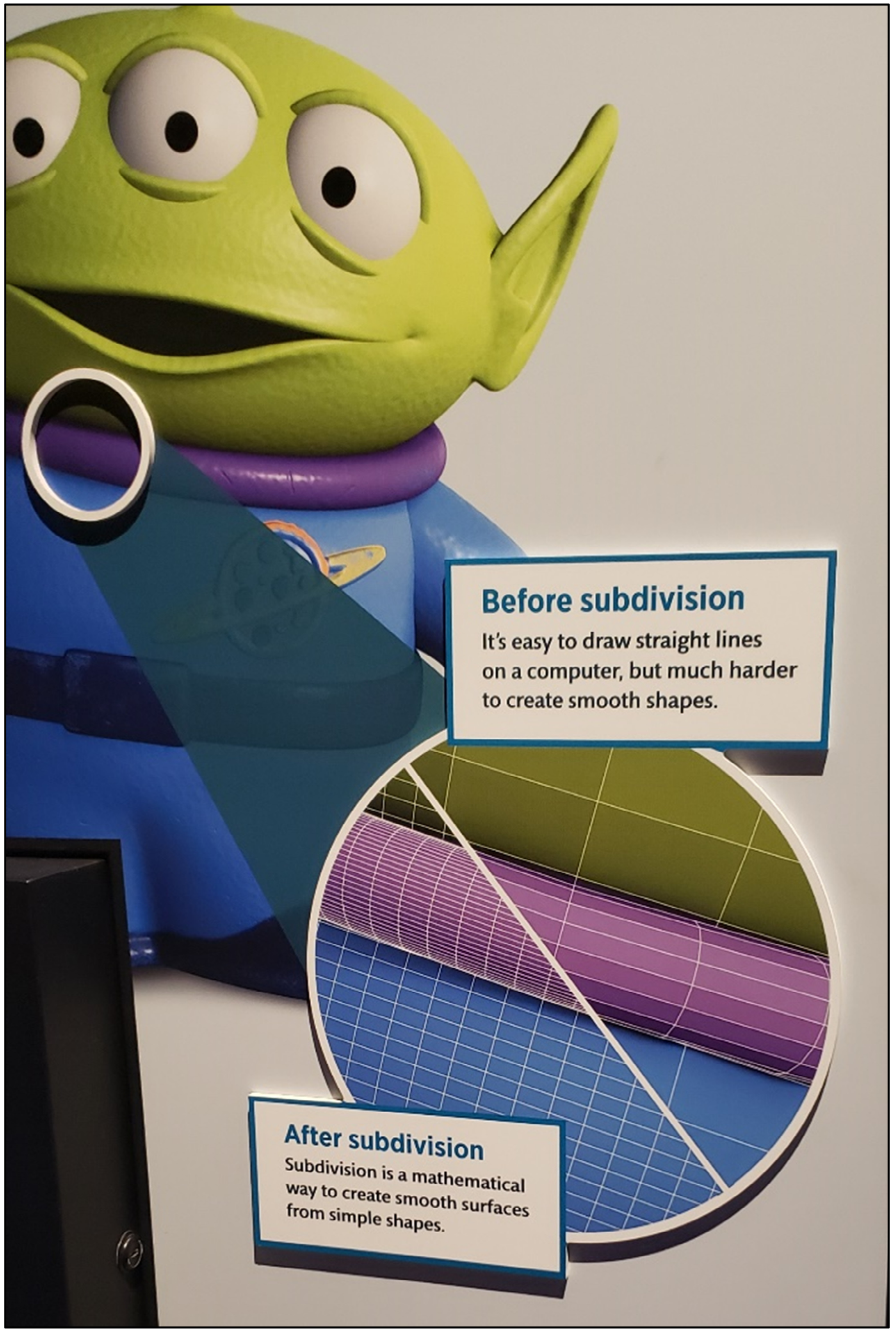
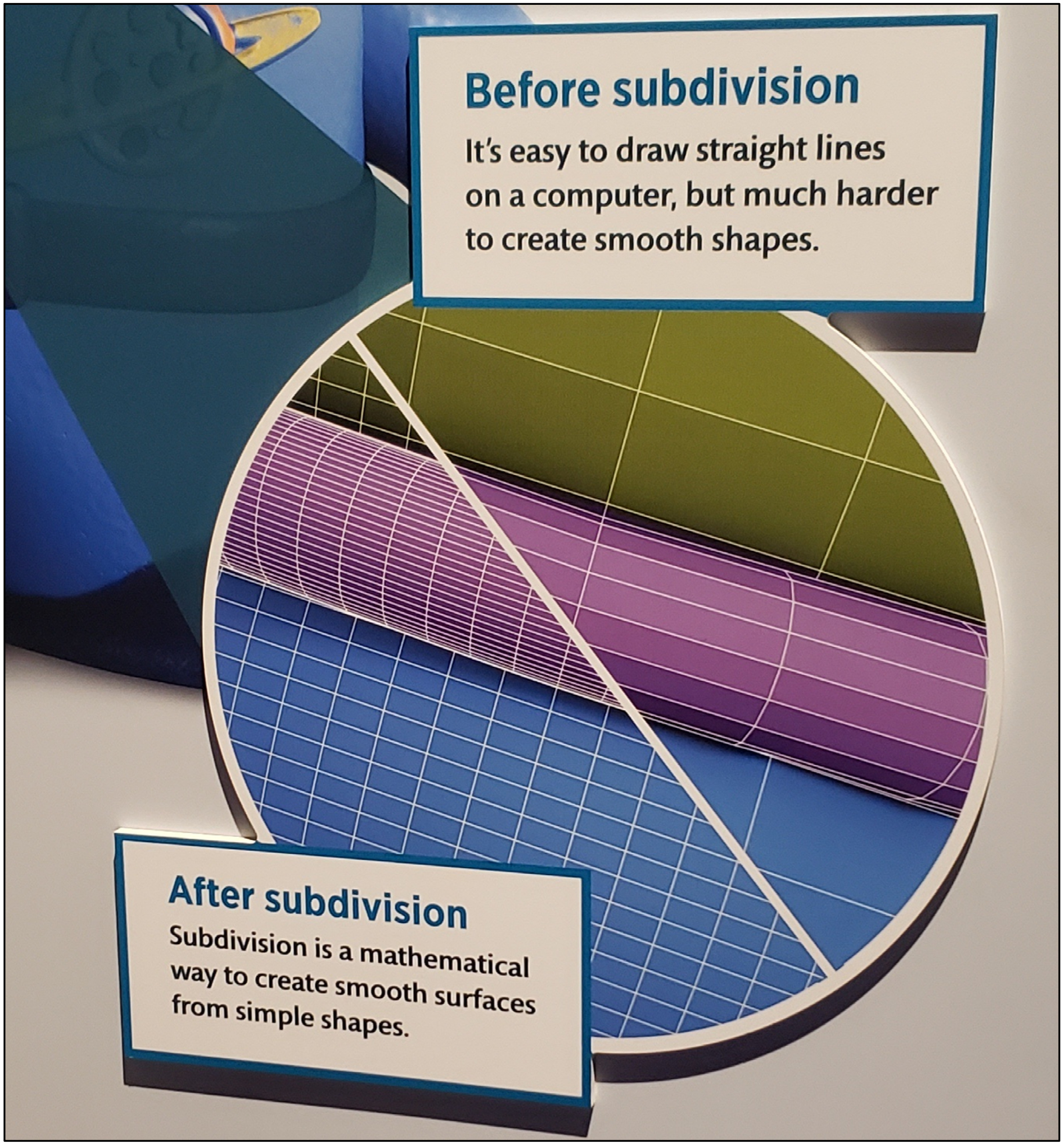
The Science of Pixar
At the Oregon Museum of Science and Industry (OMSI)


Before subdivision
It's easy to draw straight lines on a computer, but much harder to create smooth shapes.
After subdivision
Subdivision is a mathematical way to create smooth surfaces from simple shapes.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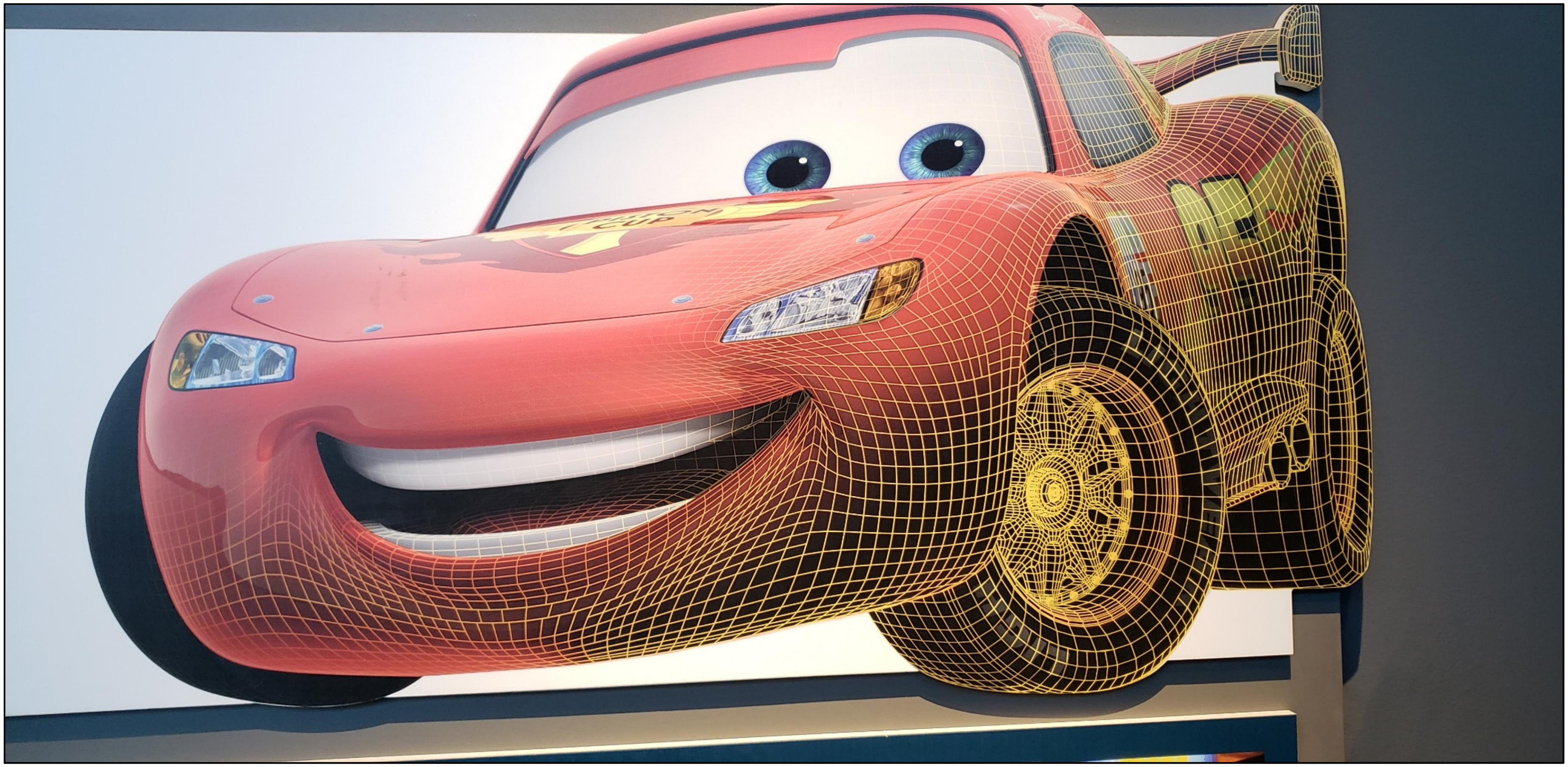
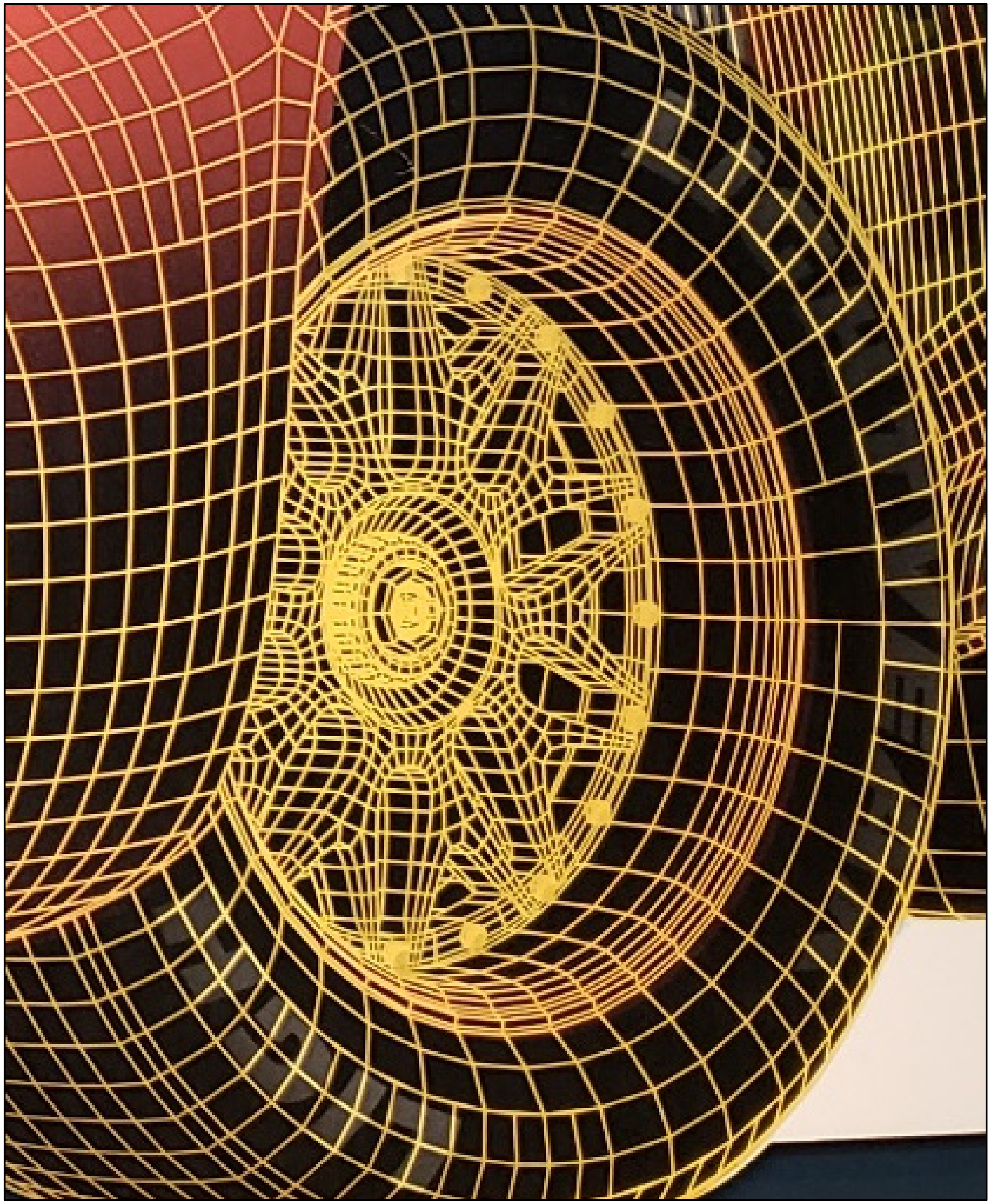
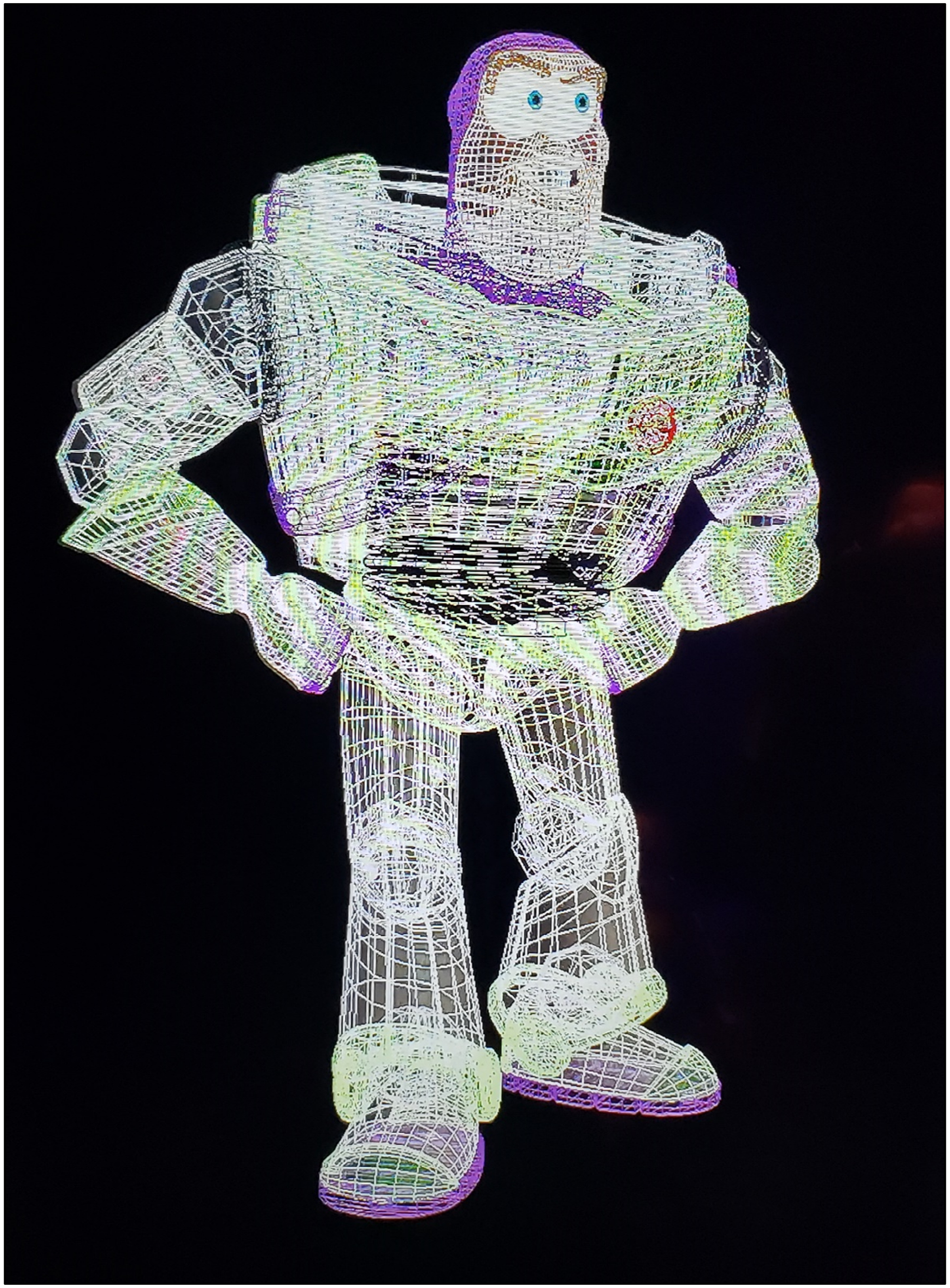
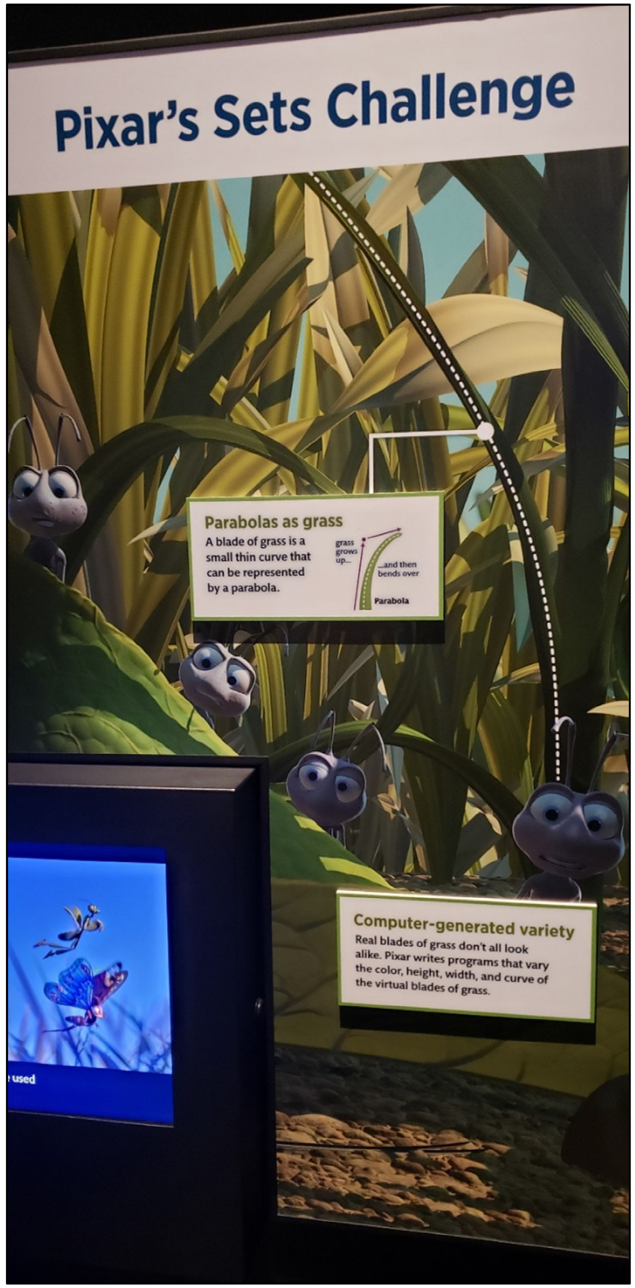
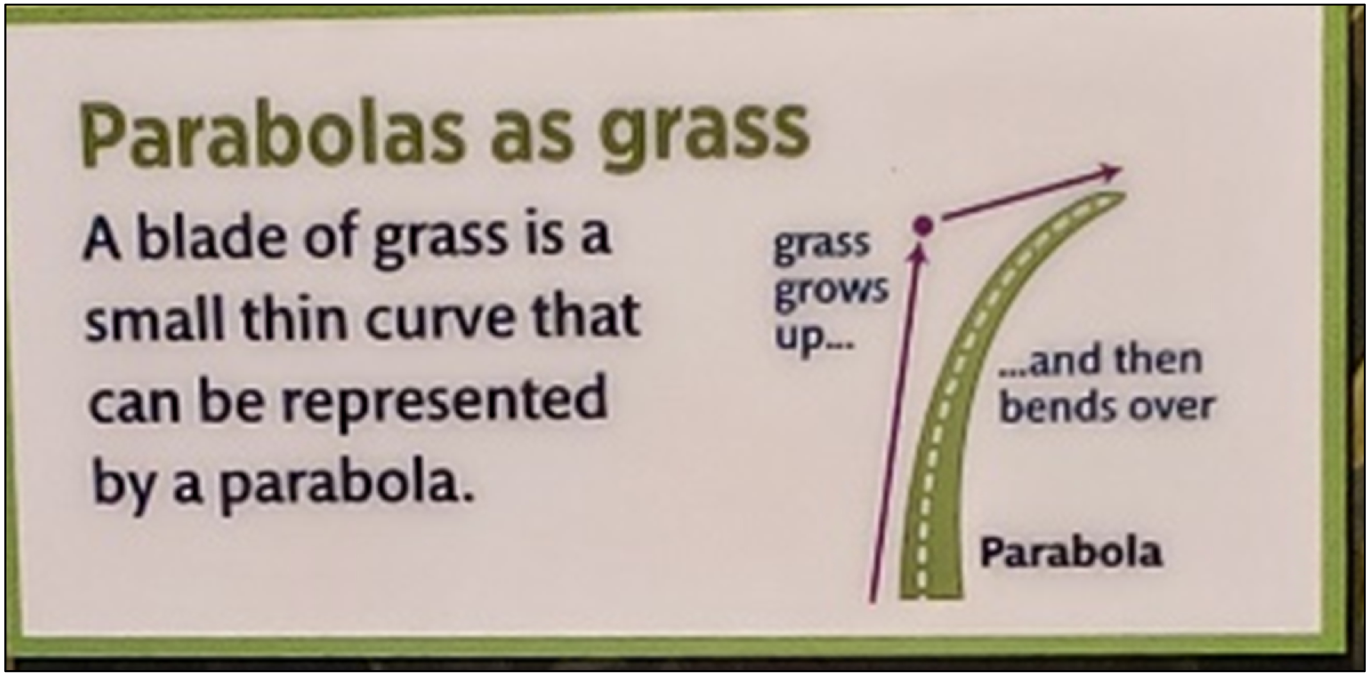








Pixar's Sets Challenge
Parabolas as grass
A blade of grass is a small thin curve that can be represented by a parabola.
grass grows up...
...and then bends over
Parabola
Computer-generated variety
Real blades of grass don't all look alike. Pixar writes programs that vary the color, height, width, and curve of the virtual blades of grass.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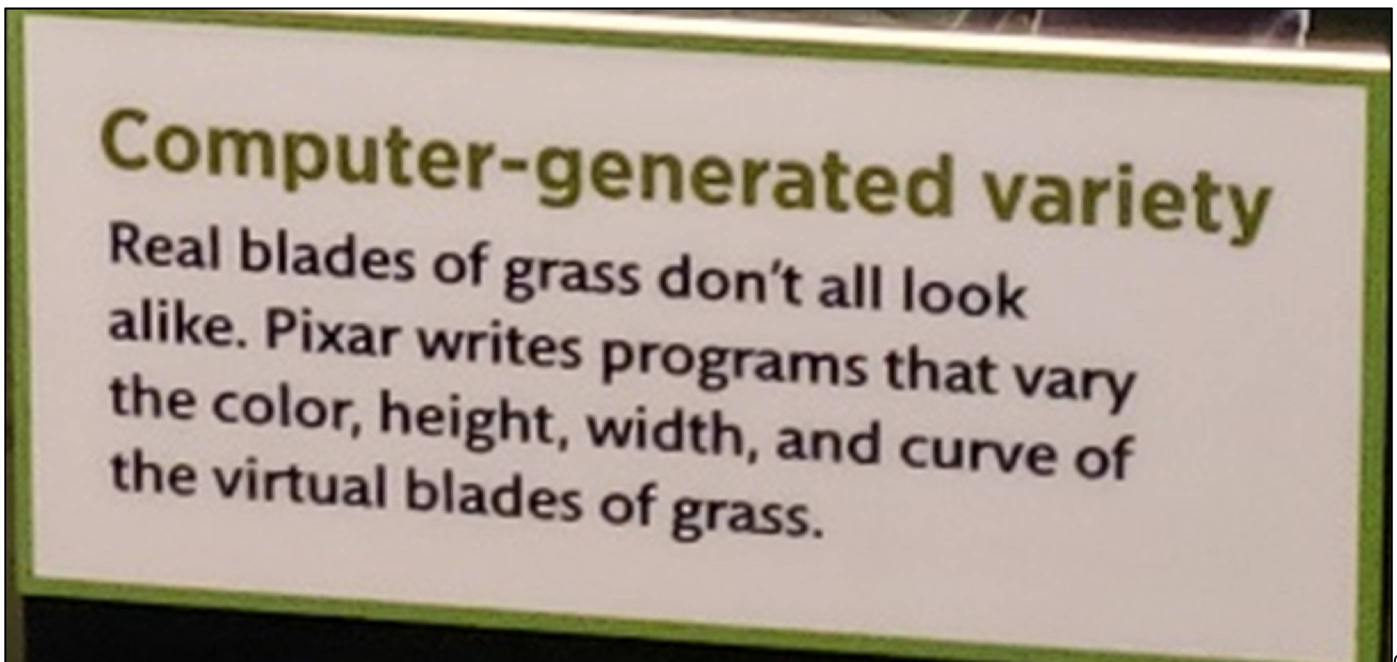
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Surfaces
Surface appearance is controlled separately from shape
The way something looks tells a story. What is it made of? Is it new or old? Well taken care of or neglected? After a virtual 3D model is created, a surfacing artist constructs its appearance 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.
This version of Mater's appearance, in Cars 2, required changes to his geometry and his shaders.
Shaders respond automatically to their environment, such as on Mater's reflective hubcaps.

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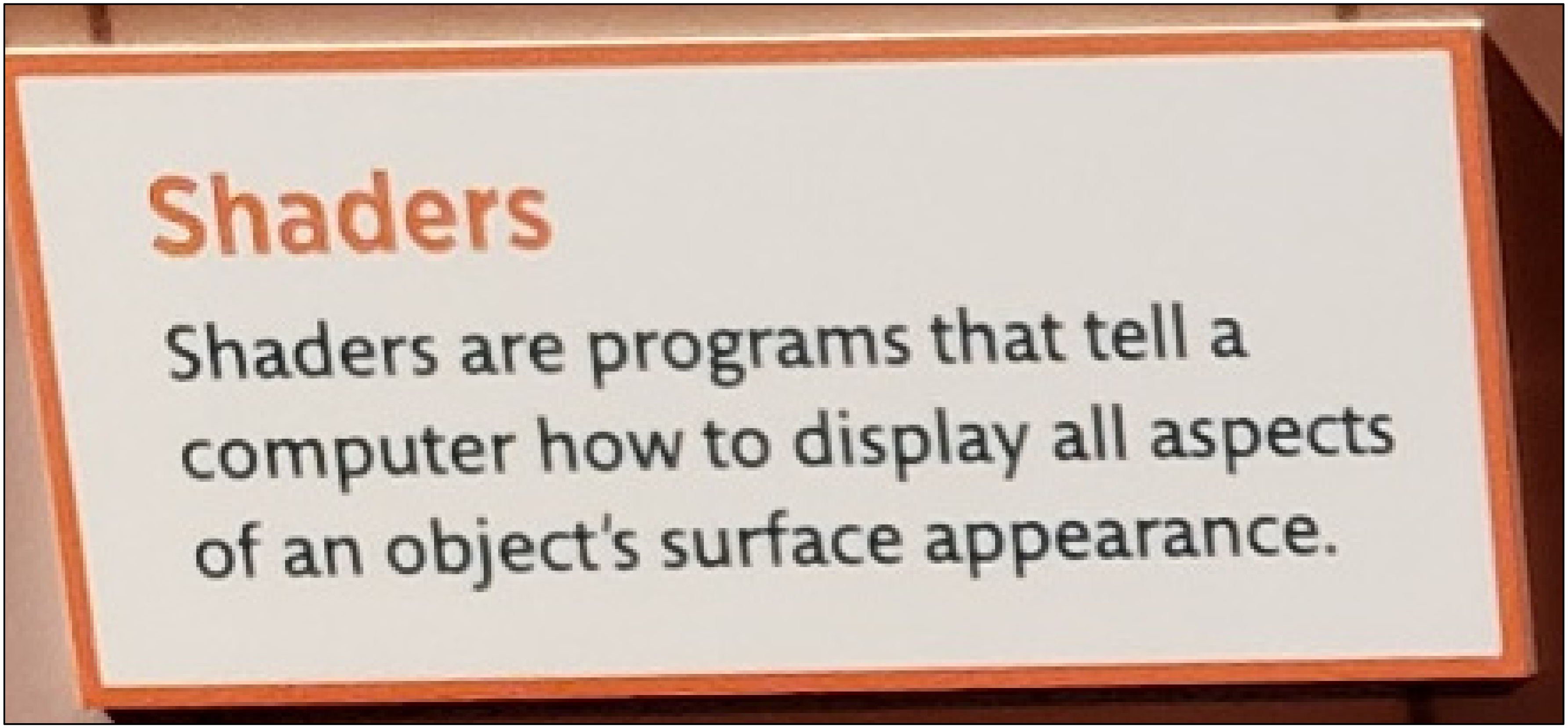
Shaders
Shaders are programs that tell a computer how to display all aspects of an object's surface appearance.
Red onions
A surface pattern shader gives these onions a mottled appearance.
A worn pot handle
A shader created a bump map that instructs light to bounce unevenly off the handle's surface.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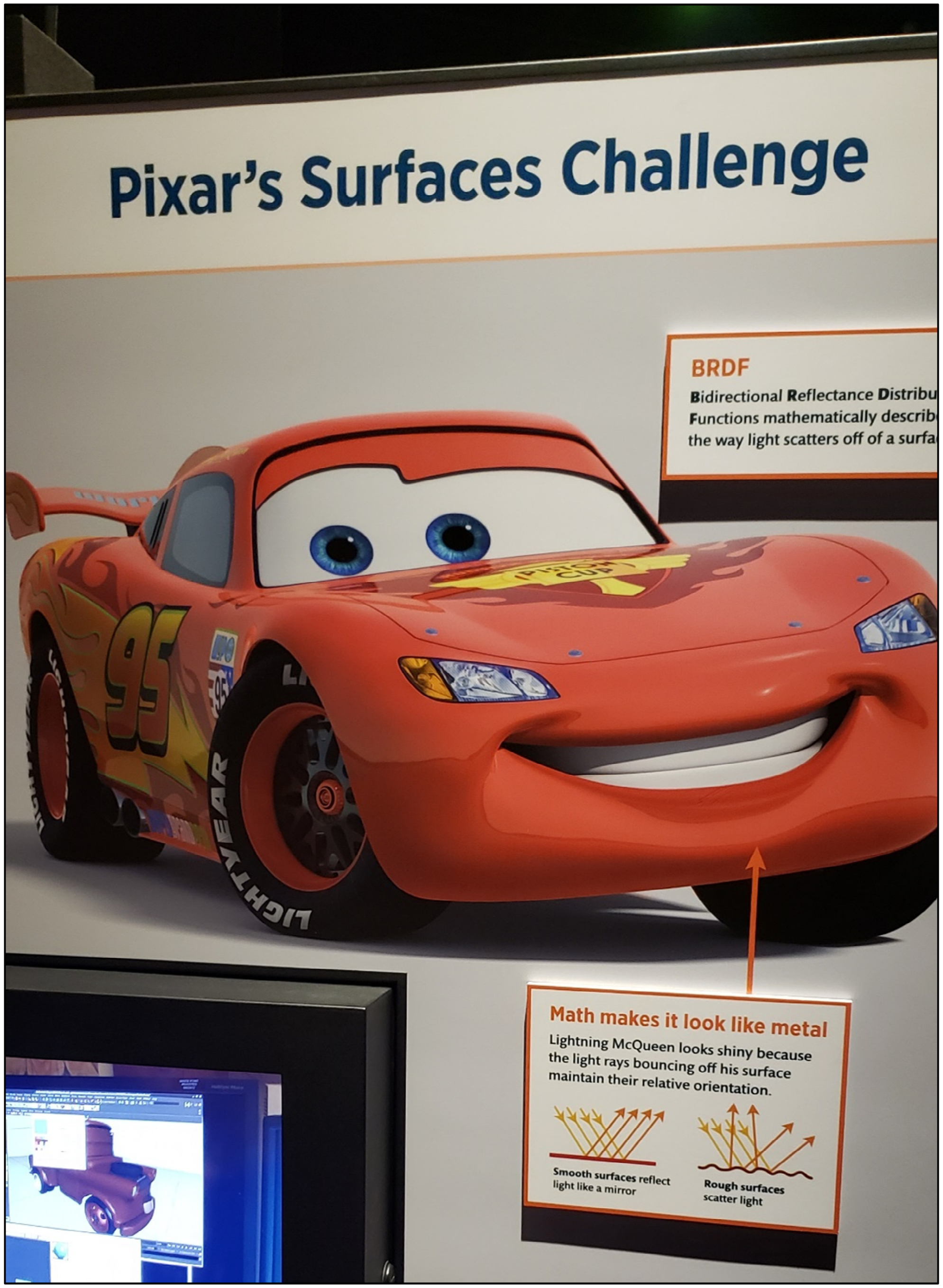
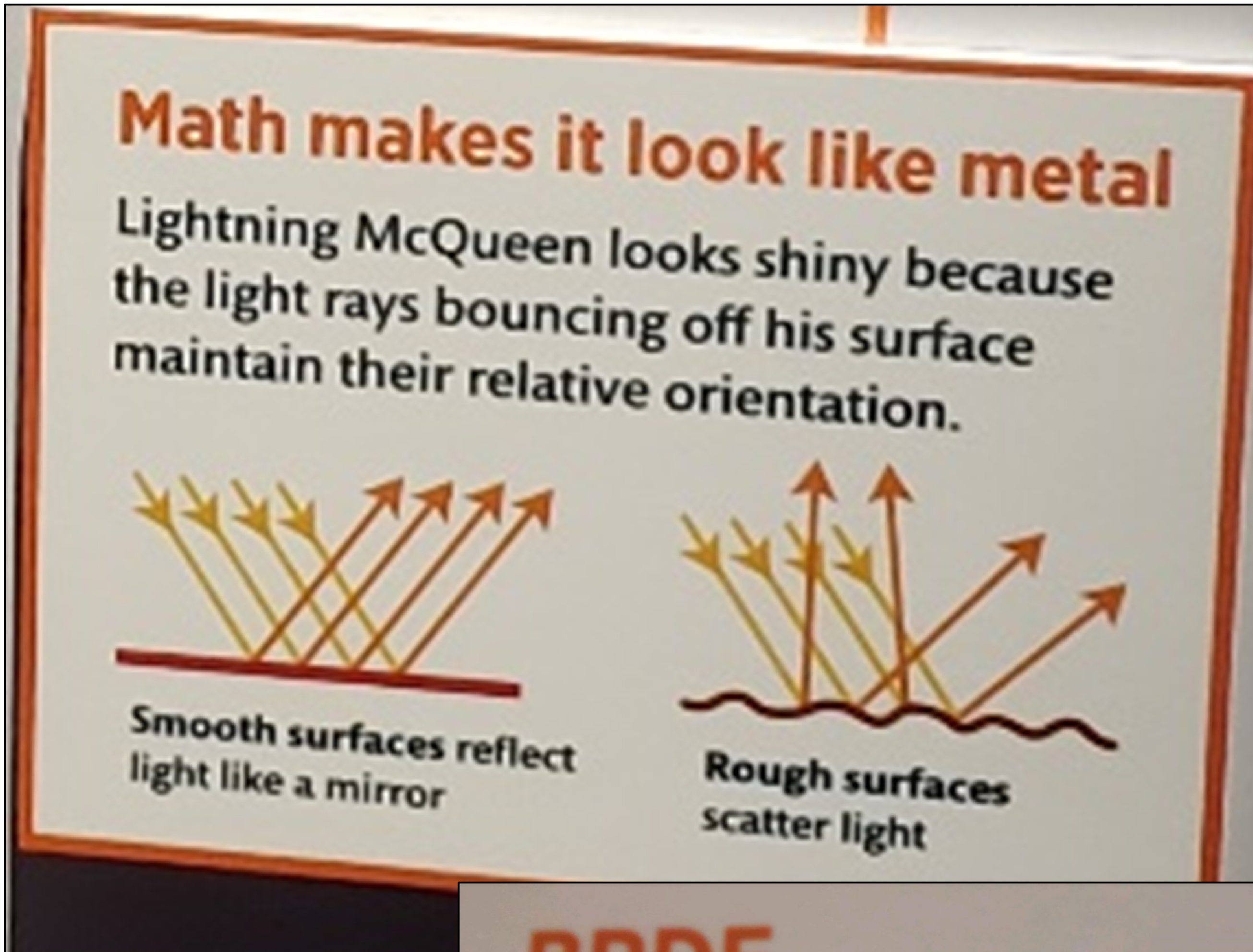

Pixar's Surfaces Challenge
BRDF
Bidirectional Reflectance Distribu
Functions mathematically describ
the way light scatters off of a surfa
Math makes it look like metal
Lightning McQueen looks shiny because the light rays bouncing off his surface maintain their relative orientation.
Smooth surfaces reflect light like a mirror
Rough surfaces scatter light
95
LIGHTYEAR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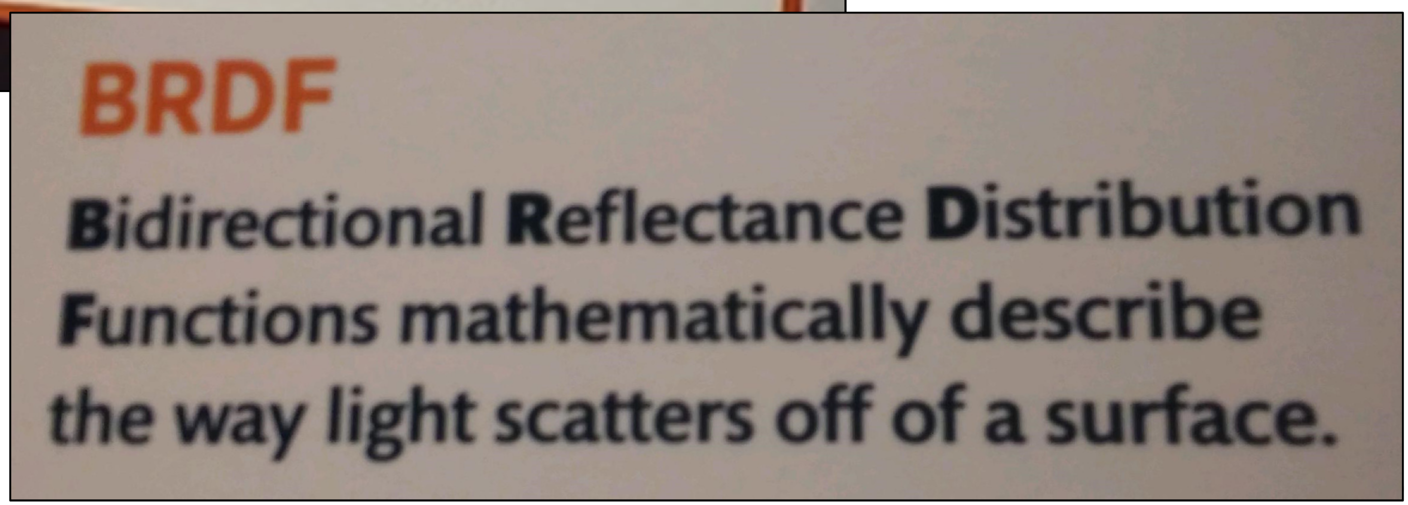
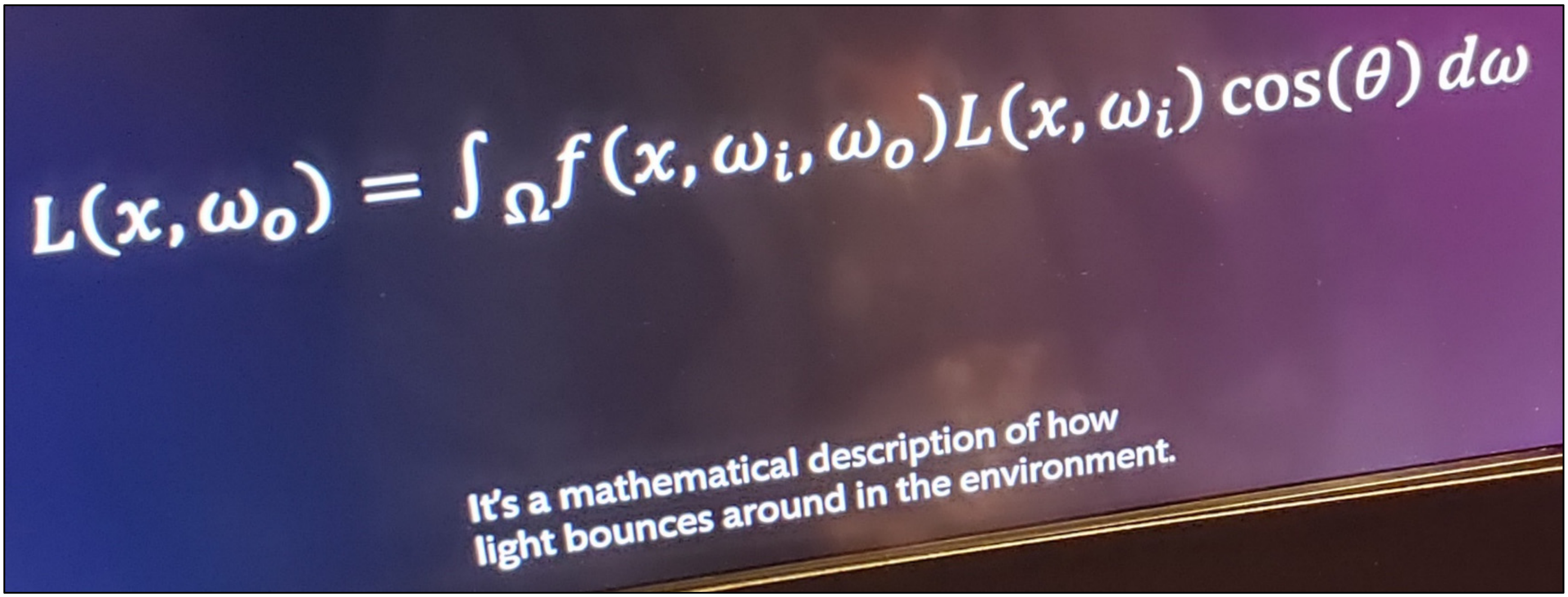
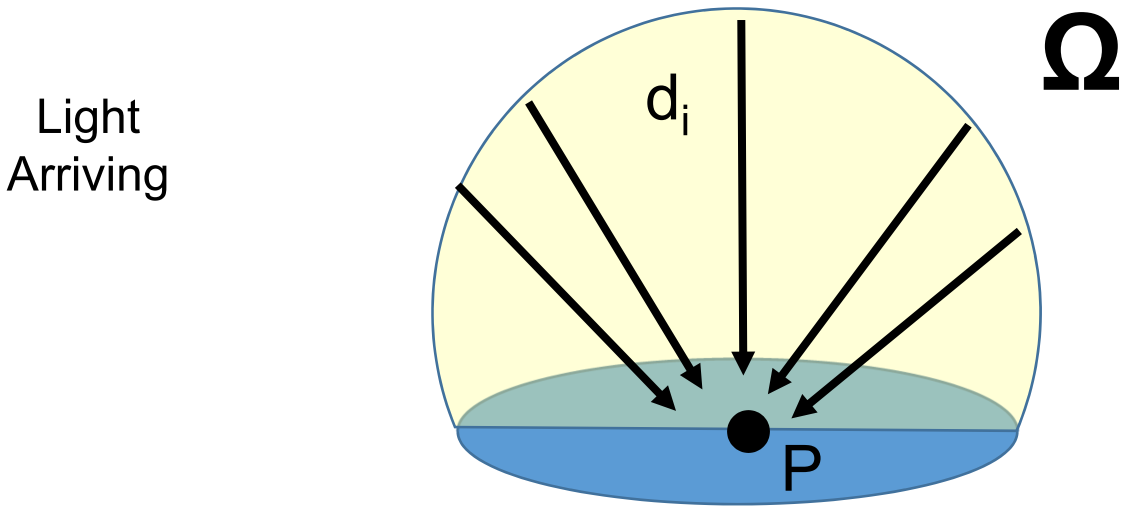
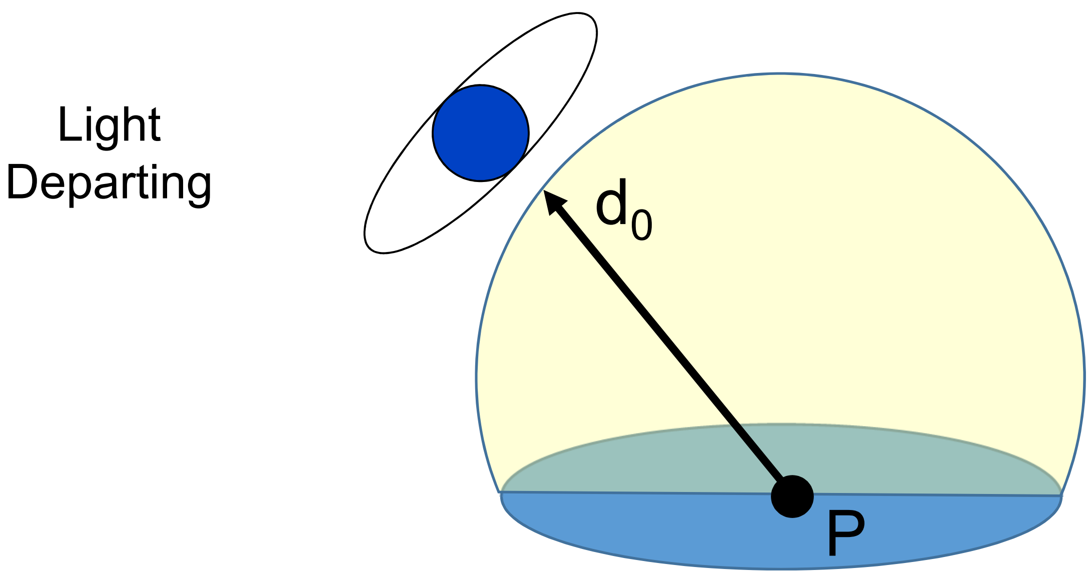

BRDF
Bidirectional Reflectance Distribution Functions mathematically describe the way light scatters off of a surface.


$L(x, \omega_o) = \int_\Omega f(x, \omega_i, \omega_o) L(x, \omega_i) \cos(\theta)\, d\omega$
It's a mathematical description of how
light bounces around in the environment.

The Rendering Equation



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



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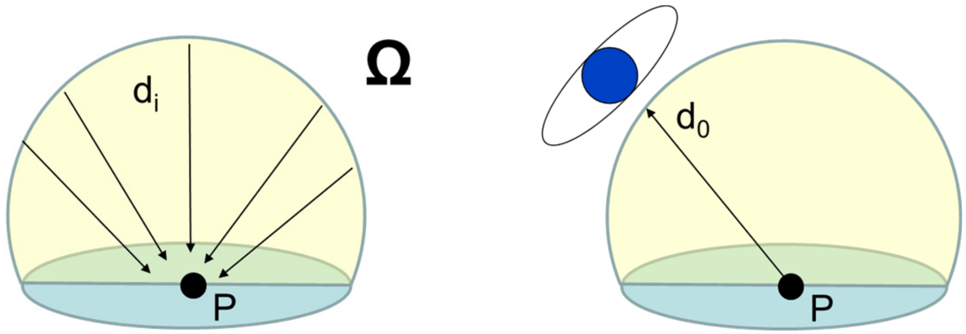

$$B(x, d_0, \lambda) = E(P, d_0, \lambda) + \int_{\Omega} B(x, d_i, \lambda) f(x, \lambda, d_i, d_0)(d_i \cdot \hat{n}) d\Omega$$

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."

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

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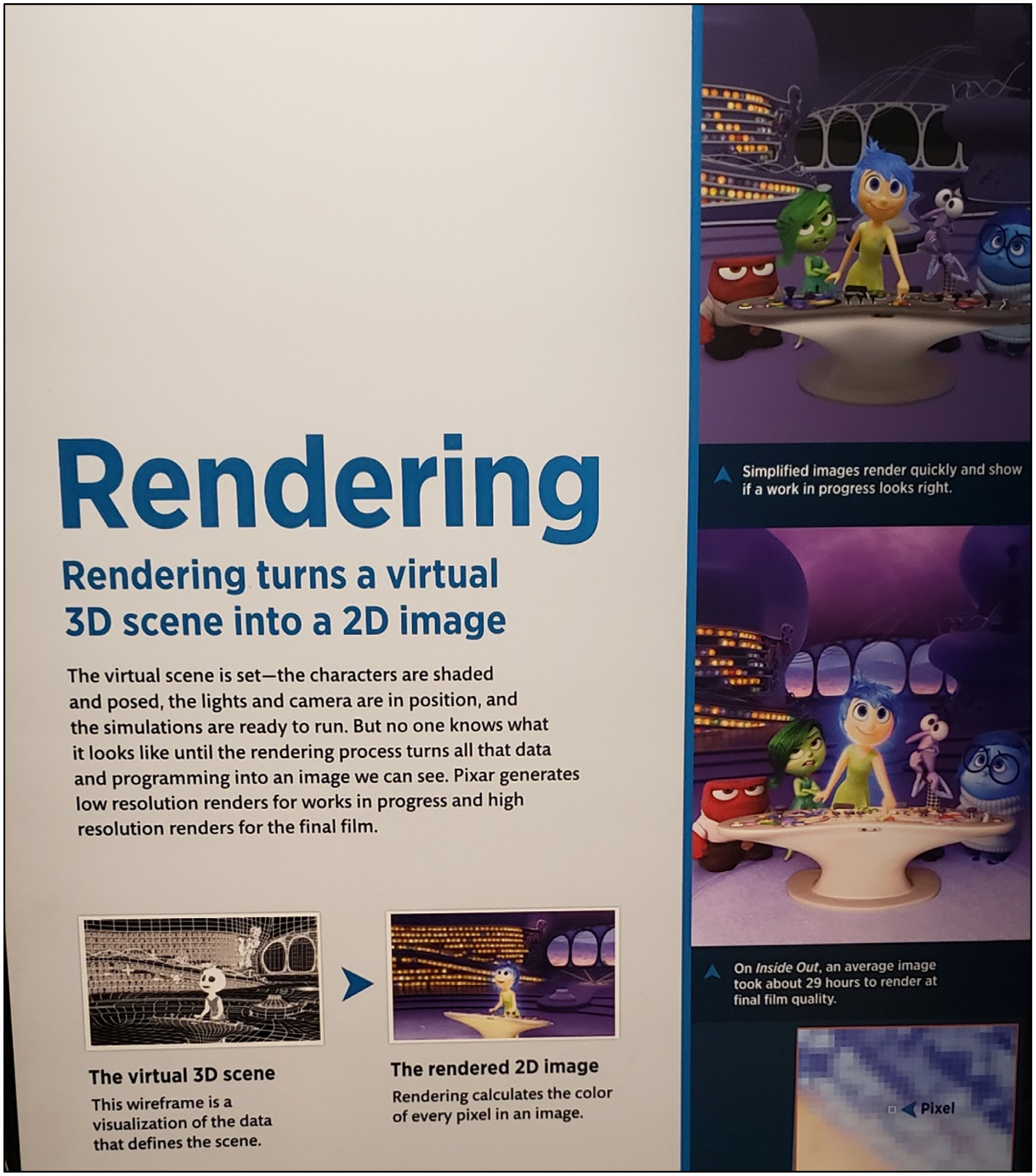
Rendering
Rendering turns a virtual 3D scene into a 2D image
The virtual scene is set—the characters are shaded and posed, the lights and camera are in position, and the simulations are ready to run. But no one knows what it looks like until the rendering process turns all that data and programming into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

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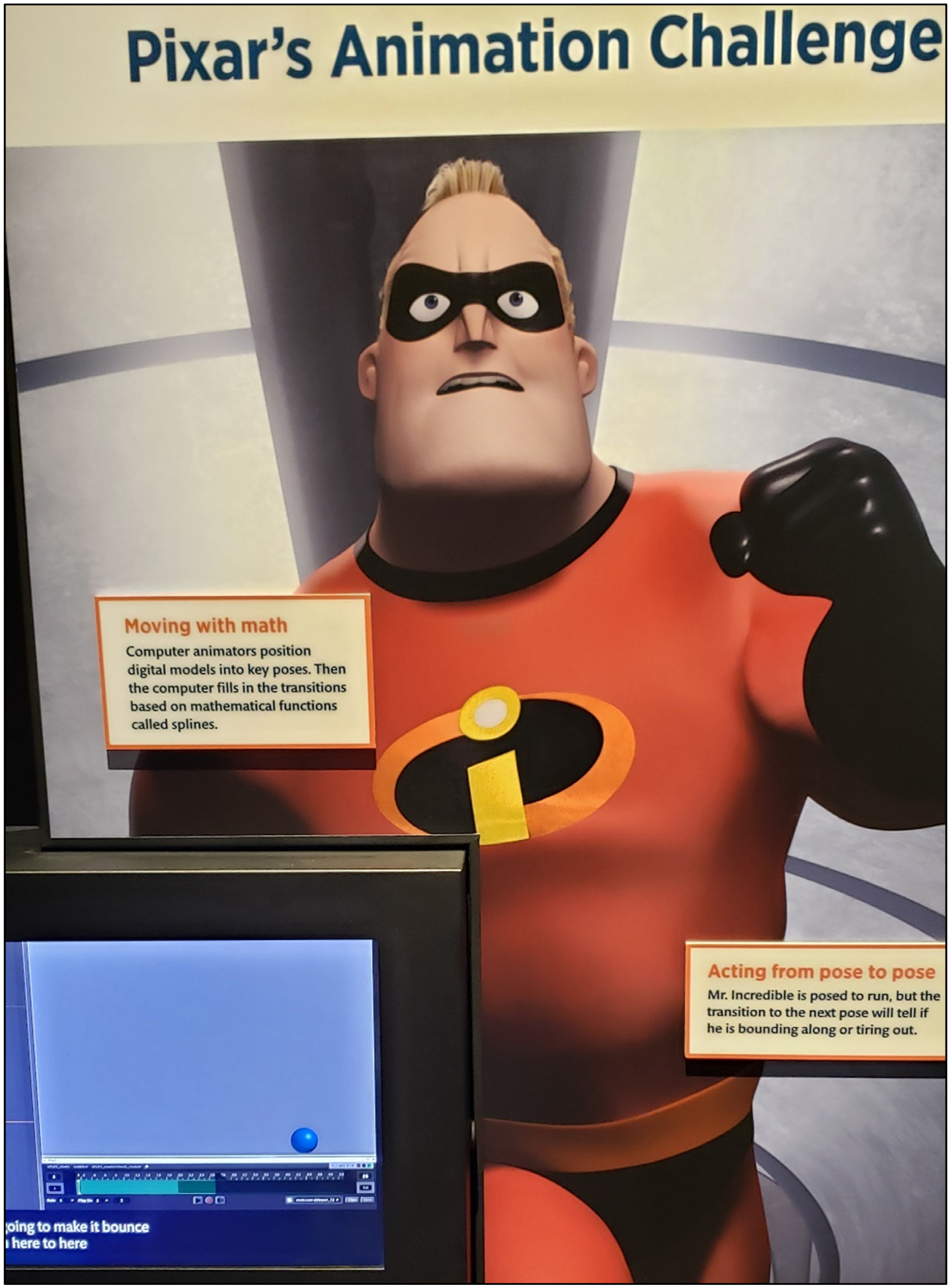
Pixar's Animation Challenge
Moving with math
Computer animators position digital models into key poses. Then the computer fills in the transitions based on mathematical functions called splines.
Acting from pose to pose
Mr. Incredible is posed to run, but the transition to the next pose will tell if he is bounding along or tiring out.
oing to make it bounce
here to here

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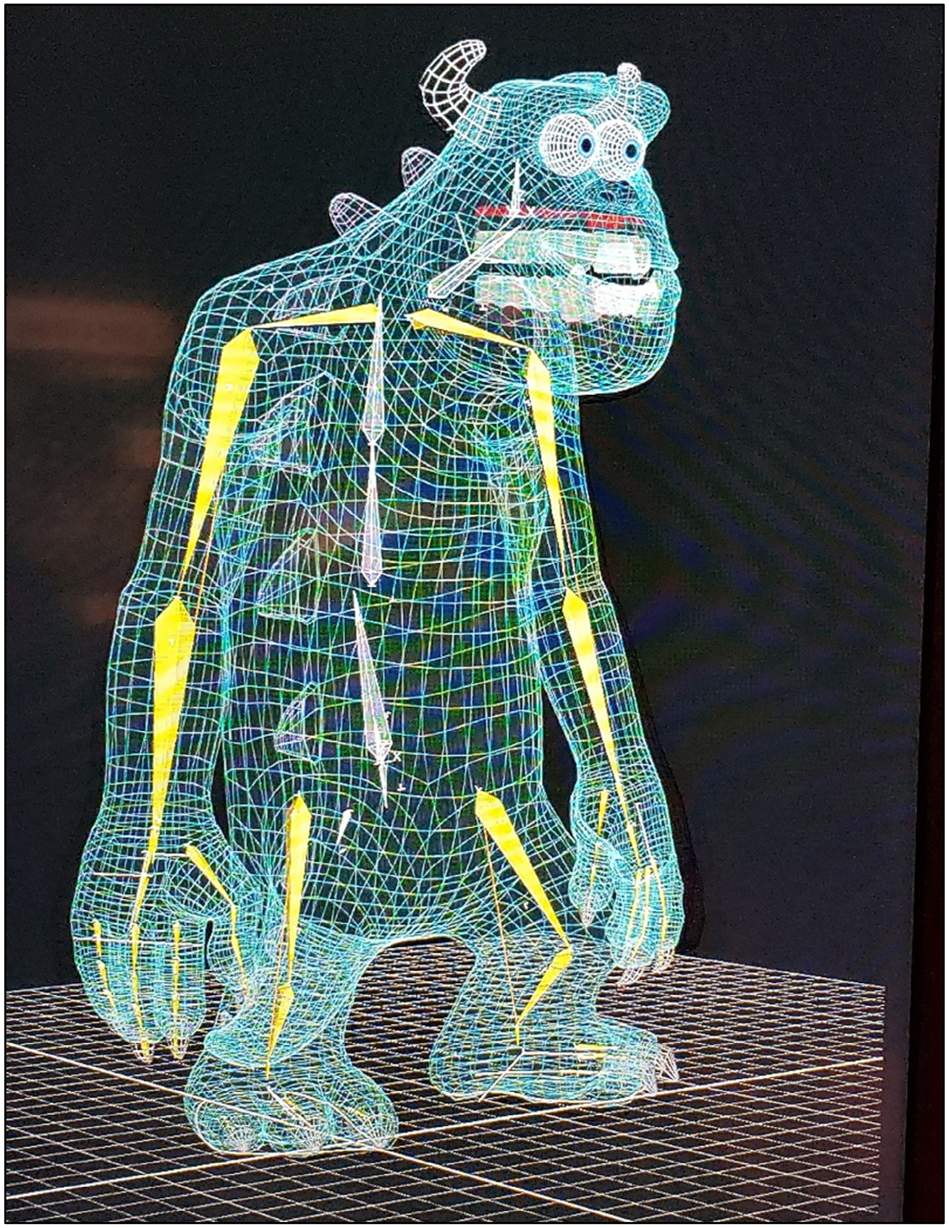

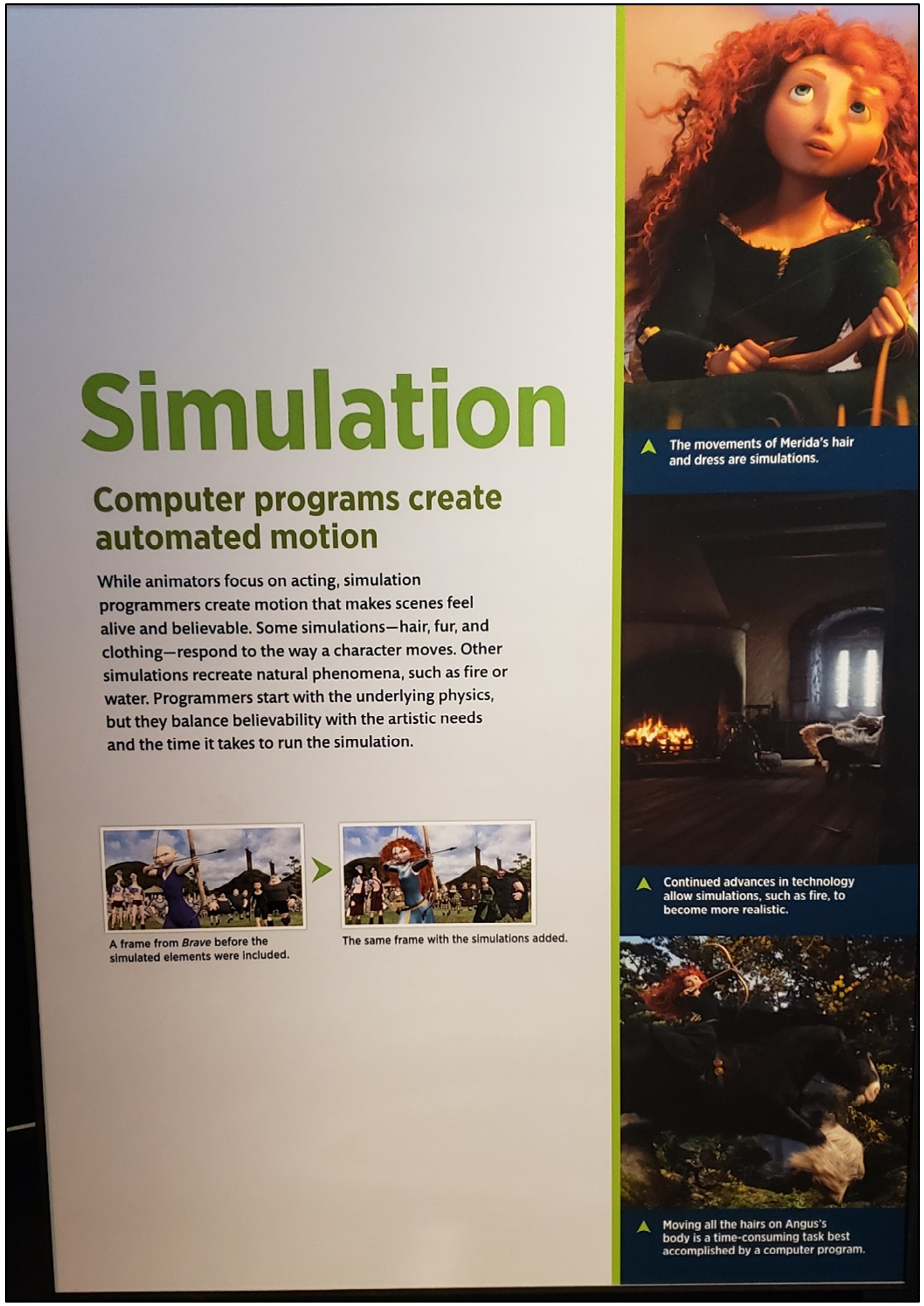
Simulation
Computer programs create automated motion
While animators focus on acting, simulation programmers create motion that makes scenes feel alive and believable. Some simulations—hair, fur, and clothing—respond to the way a character moves. Other simulations recreate natural phenomena, such as 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 Brave 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 Angus's body is a time-consuming task best accomplished by a computer program.

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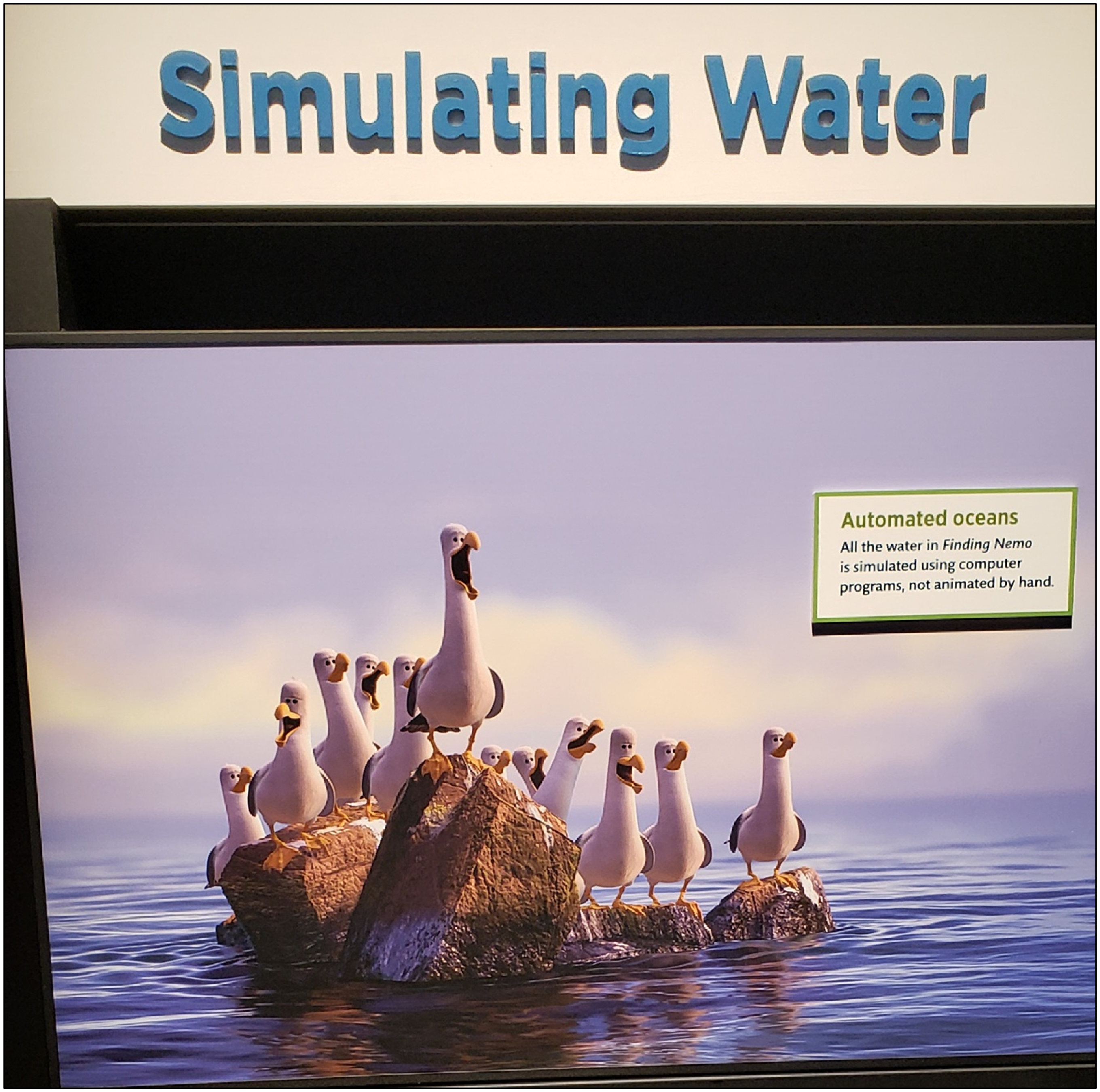
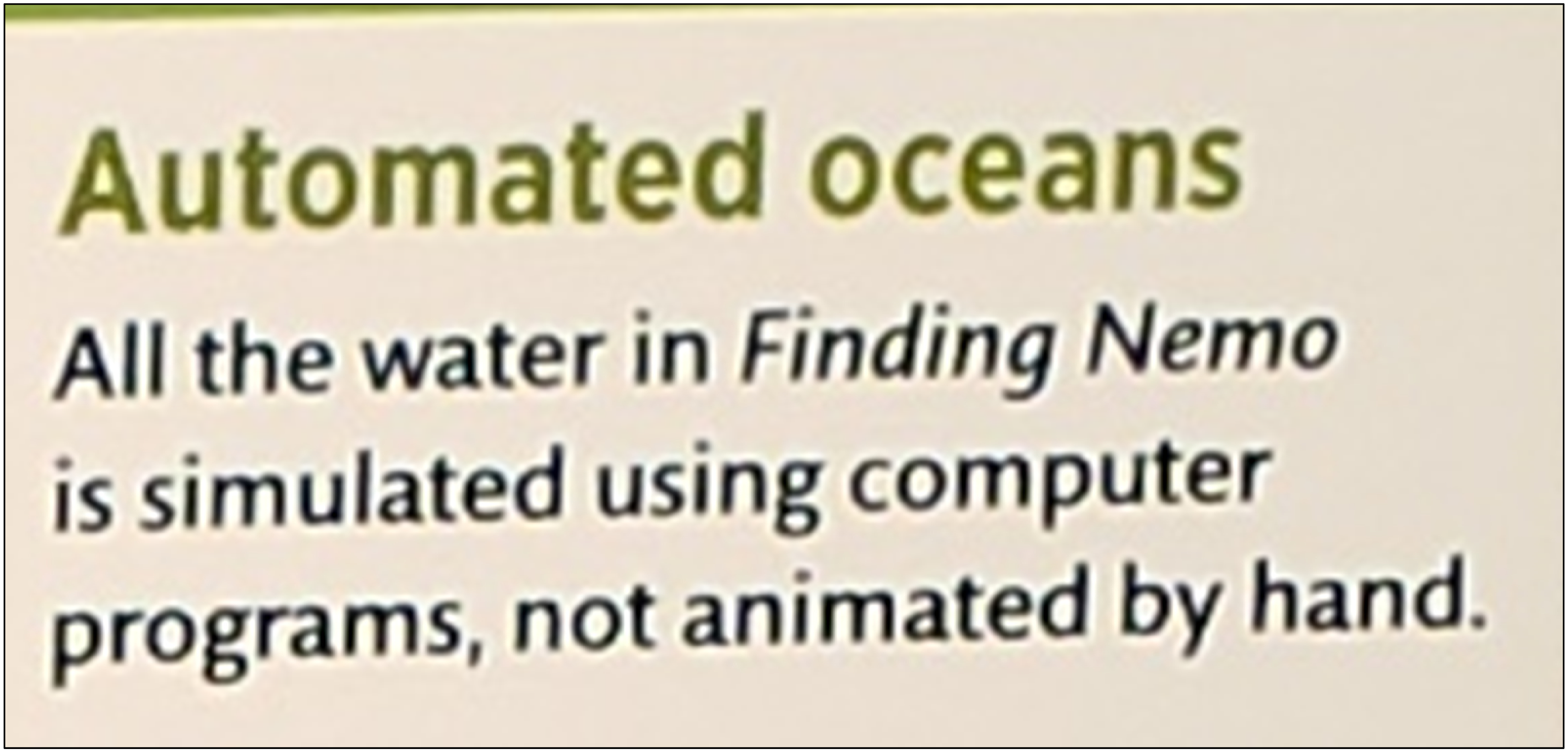

Simulating Water
Automated oceans
All the water in Finding Nemo
is simulated using computer
programs, not animated by hand.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