

3D Printing

(which I consider to be a legitimate form of Computer Graphics display...)



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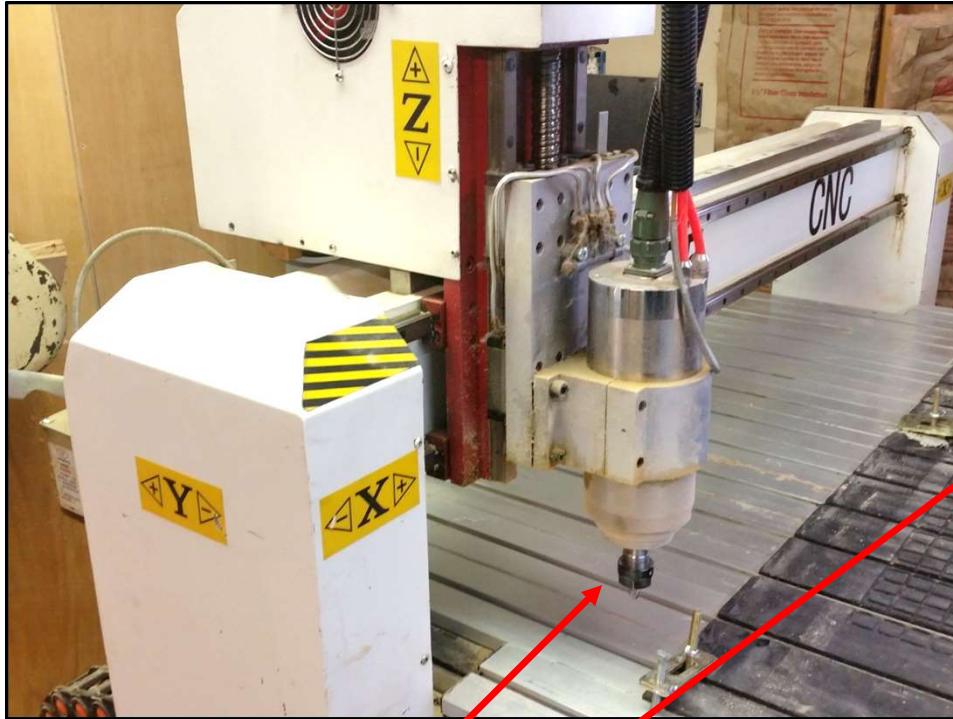
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In the Beginning, All Manufacturing was “Subtractive”



1. The whirling drill bit follows a 3D path around a block of metal, wax, or wood
2. Chips fly
3. A block of metal becomes a part



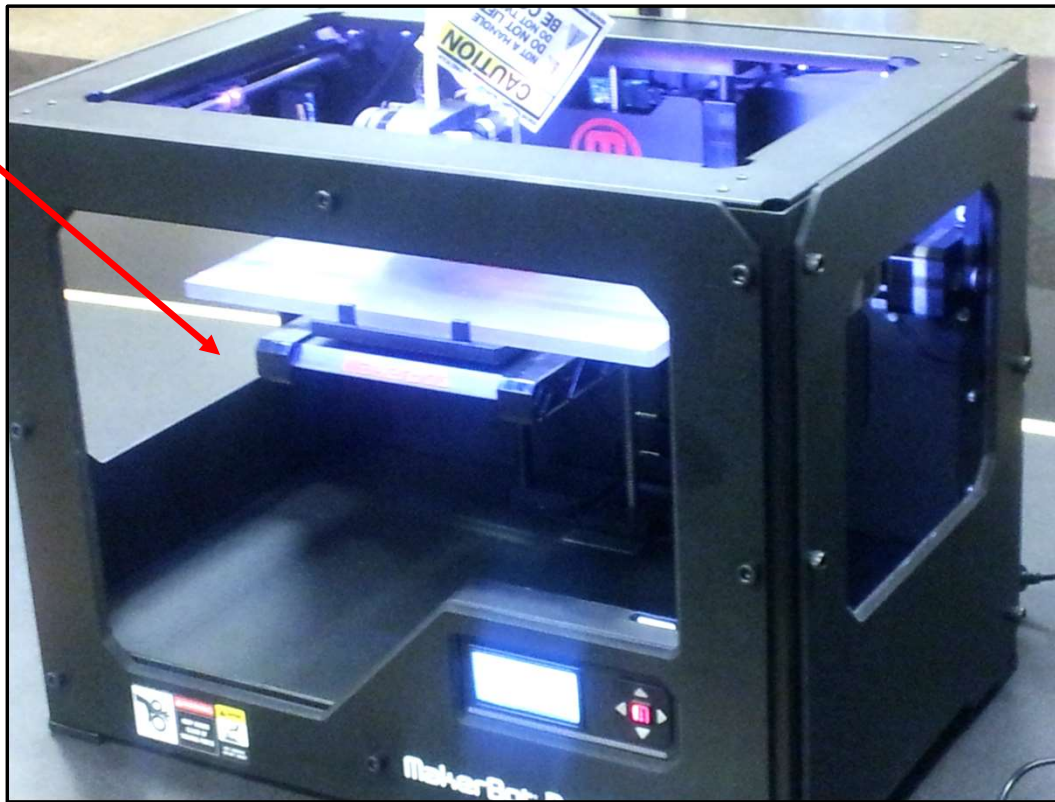
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Today's 3D Printing Process

“3D Printing” is generally considered to be some sort of “**Additive**” process in which layers of material get deposited on previous layers. (Additive manufacturing is also sometimes called *Stereolithography*.)

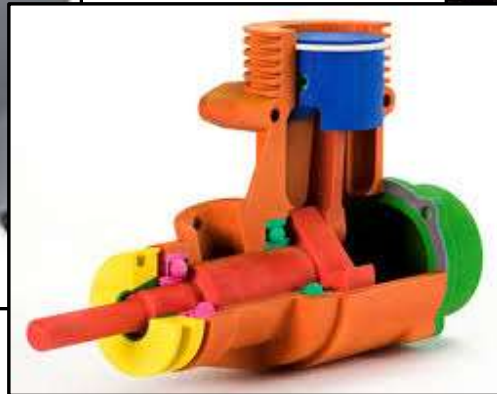
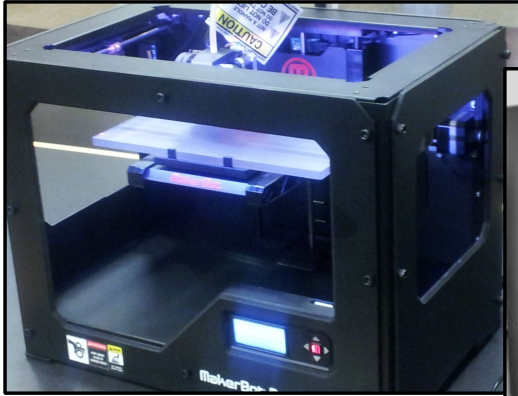
The current frenzy in 3D Printing consists mostly of desktop systems that deposit layers of molten plastic, like this one. But there are many others.



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Examples of 3D Printing using a Variety of Materials



Portland's Laika uses Color 3D Printing to Make Faces for Stop-motion Movies

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From *Kubo and the Two Strings*



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The 3D Printing Geometry File

3D Printers are fed a file called an “STL File”, which lists all the triangles in the object. All 3D CAD-ish systems (as well as TinkerCad, Thingiverse, and Blender) can produce this type of file for you.

```

solid

  facet normal  0.00  0.00  -1.00
    outer loop
      vertex -2.000000 -2.000000  0.250000
      vertex -1.980000 -1.980000  0.250000
      vertex -1.980000 -2.000000  0.250000
    endloop
  endfacet

  facet normal  0.00  0.00  -1.00
    outer loop
      vertex -2.000000 -2.000000  0.250000
      vertex -2.000000 -1.980000  0.250000
      vertex -1.980000 -1.980000  0.250000
    endloop
  endfacet

  ...

endsolid
  
```

In this particular file, these coordinates were in units of inches.

Some 3D Printers still use **inches**, but most now seem to use **millimeters**.

Check! It matters!

Note: there are 25.4 mm/inch

If you sent this file to a millimeter-based 3D printer, the part would come out very, very tiny! 😊



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MakerBot Thingiverse DASHBOARD EXPLORE CREATE You

Customizer by MakerBot App Center | App Info

Home My Things Queue Browse

Customizable pendant by kakaroto

parameters

- A** Parameter 'a' of the curve 2
- B** Parameter 'b' of the curve 1
- C** Parameter 'c' of the epitrochoid and hypotrochoid curves 5
- Curve** The curve to draw (See instructions for curve equation and parameters) Rhodonea curve
- Rose Thickness** 1 Thickness in millimeters of the rose

Parameters you can set

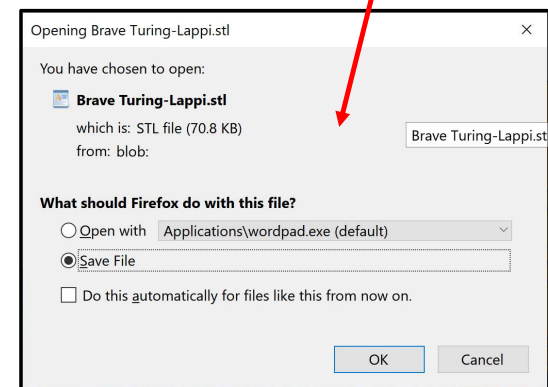
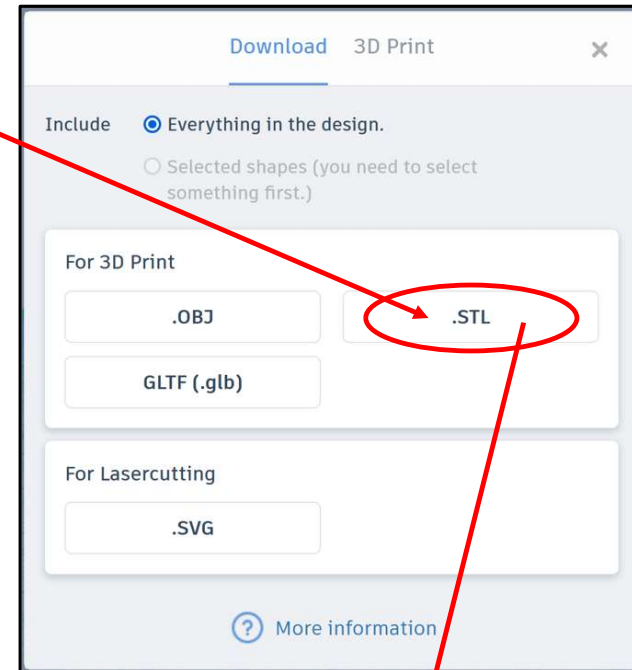
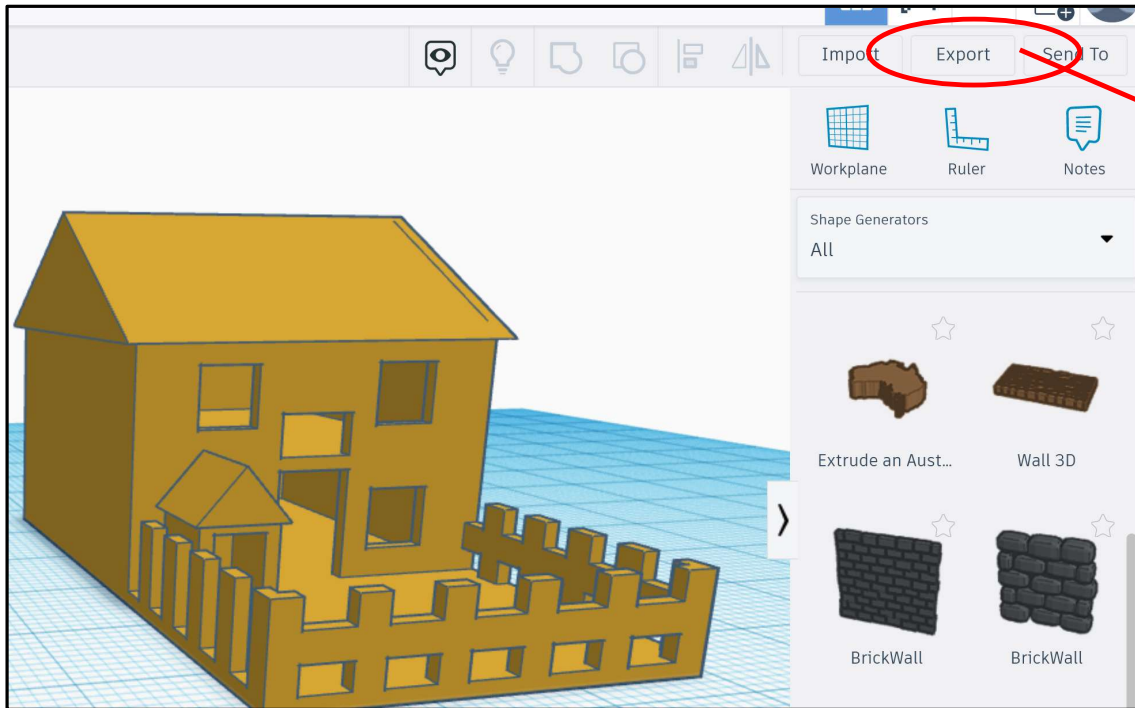
<http://www.thingiverse.com/apps> Copy View Source **Create Thing**

Retrieve the STL file



Tinkercad

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Click on **Import**→**STL**

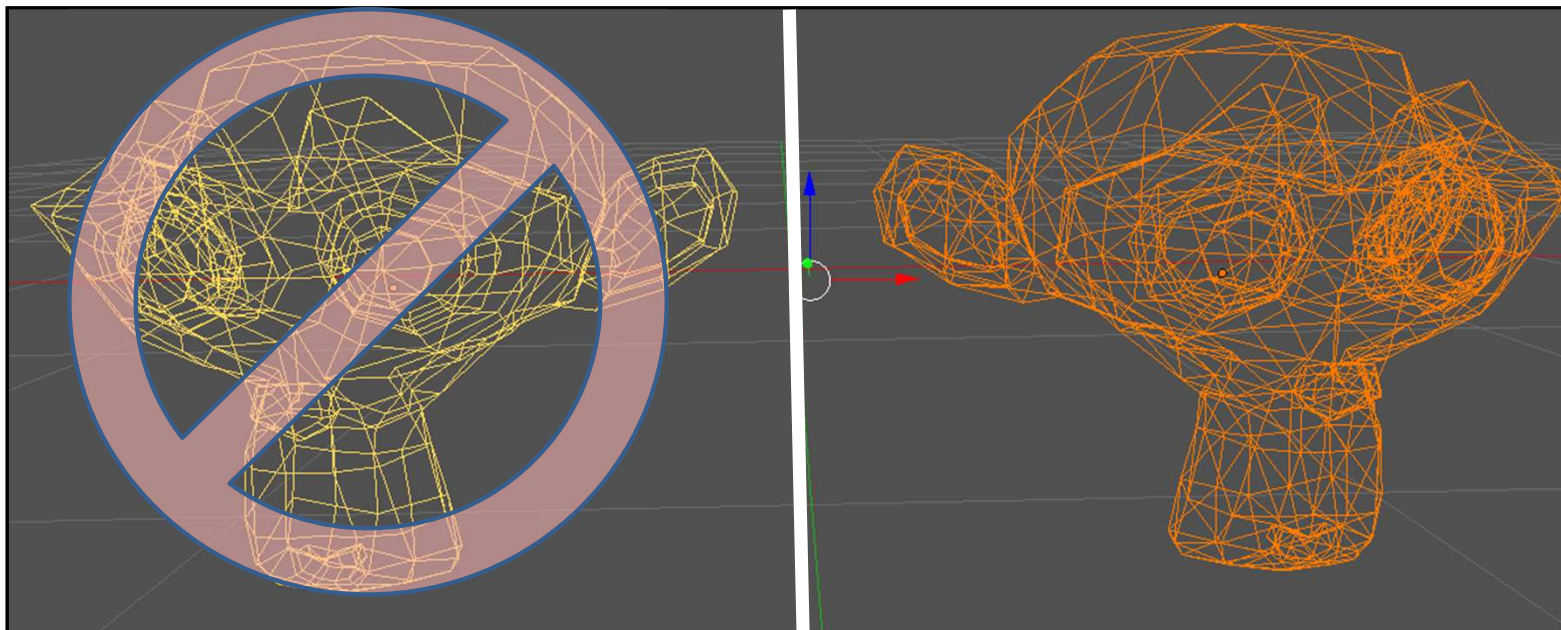


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Object Rules for 3D Printing

1. The object must be a mesh and ***consist only of triangles***.



Quads and triangles

Triangles only



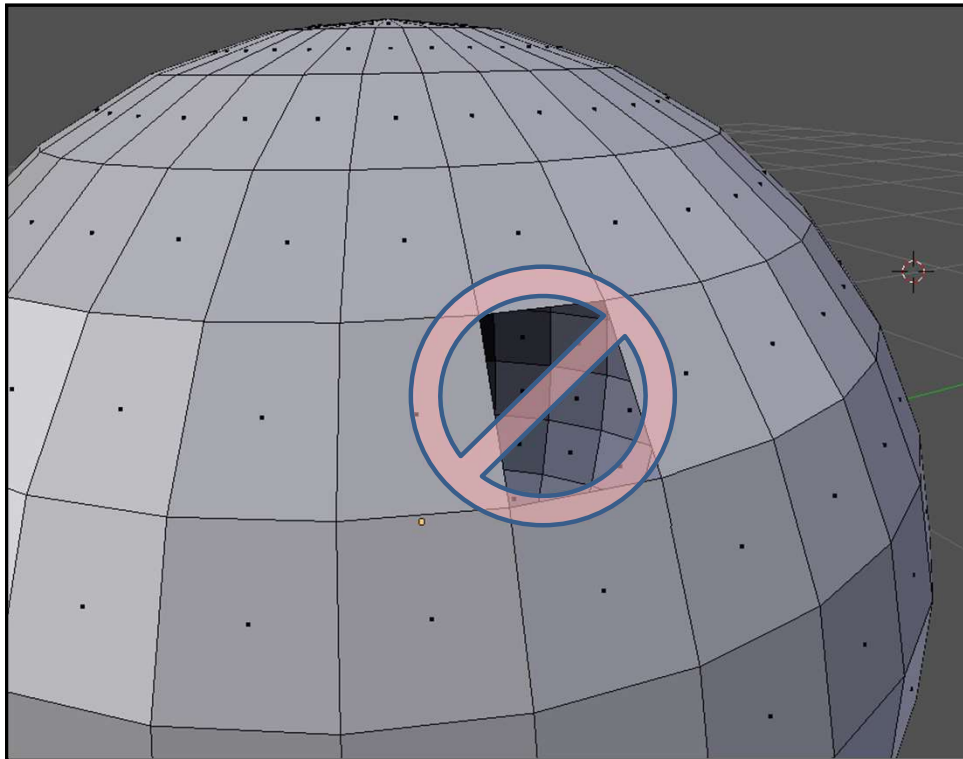
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In Blender: Modifiers → Add Modifier → Triangulate

Object Rules for 3D Printing

2. The object *must* be a legal solid. It *must* have a definite inside and a definite outside. It can't have any missing face pieces.



“Definite inside and outside” is sometimes called “Two-manifold” or “Watertight”



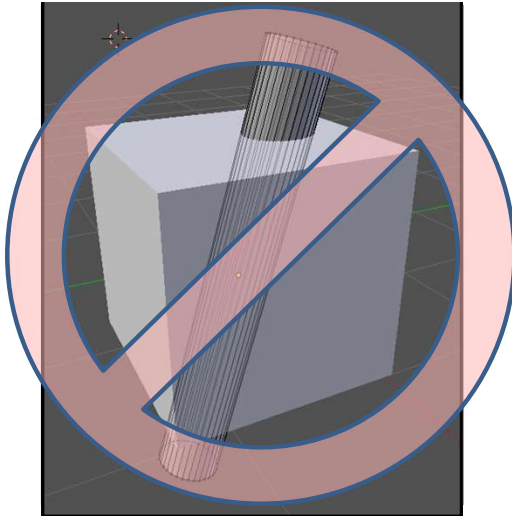
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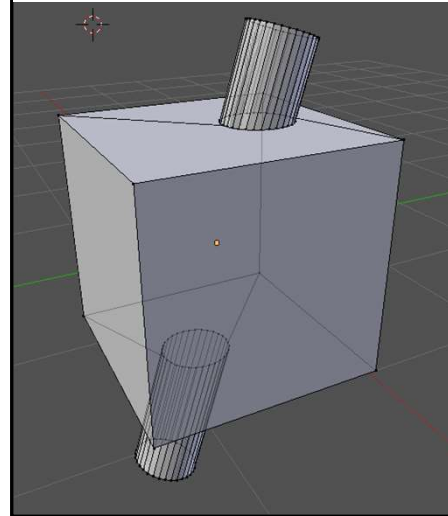
Object Modeling Rules for 3D Printing

3. You can't make a compound object by simply overlapping two objects in 3D. If you want both shapes together, do a Boolean union on them so that they become one complete, legal object.

Overlapped in 3D -- **bad**



Boolean union -- **good**

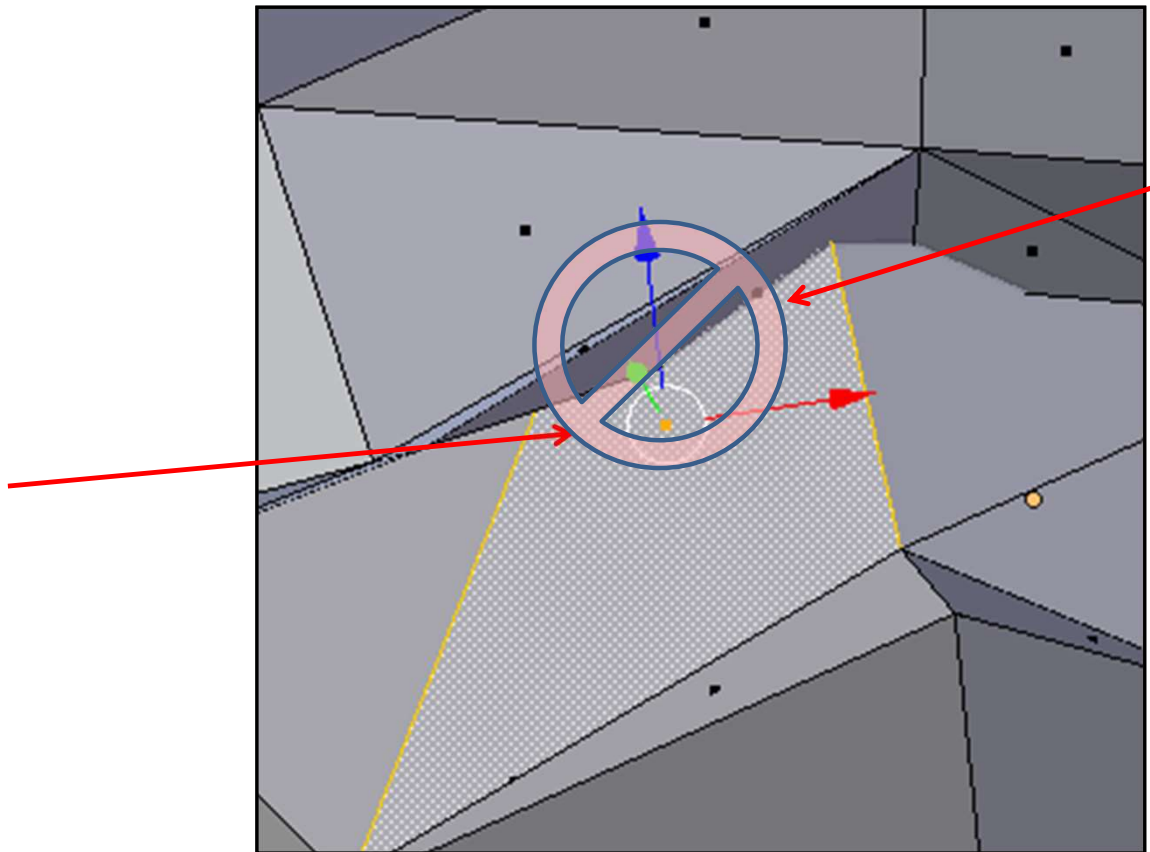


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Object Rules for 3D Printing

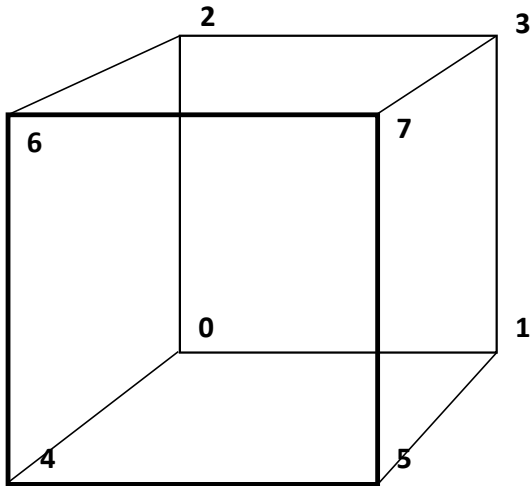
4. Each edge in the mesh must bound 2 and only 2 triangles (this is known as the **Vertex-to-Vertex Rule**)



The Simplified Euler's Formula* for Legal Solids

$$F - E + V = 2$$

F	Faces
E	Edges
V	Vertices



$$\text{For a cube: } 6 - 12 + 8 = 2$$

*sometimes called the Euler-Poincaré formula

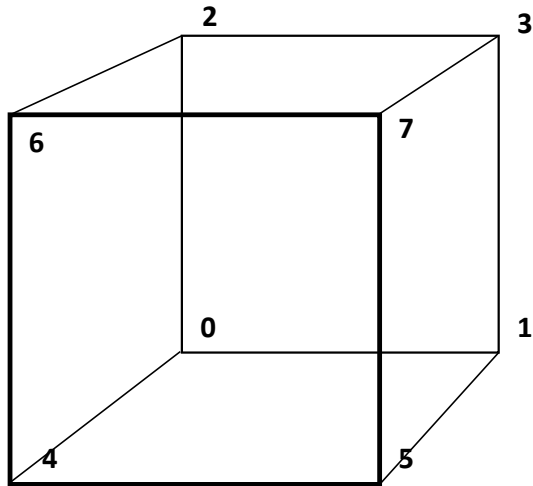


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The Full Euler's Formula* for Legal Solids

$$F - E + V - L = 2(B - G)$$



F	Faces
E	Edges
V	Vertices
L	Inner Edge Loops (within faces)
B	Bodies
G	Genus (number of through-holes)

$$\text{For a cube: } 6 - 12 + 8 - 0 = 2(1 - 0)$$

*sometimes called the Euler-Poincaré formula



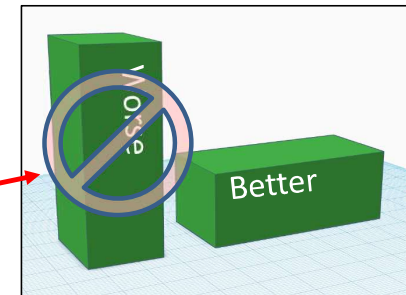
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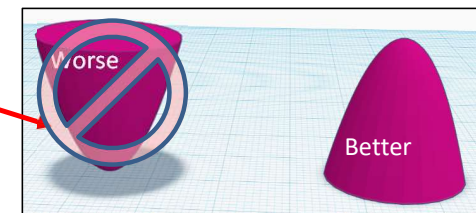
Advice on 3D Printing

Don't make the part too big to start – it will take a long time to 3D print. It's nice if you can fit several models in a single run.

Try to rotate the part so the smallest dimension is vertical. It's stronger that way, and it builds faster.

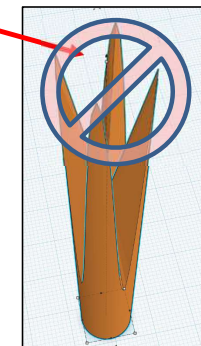
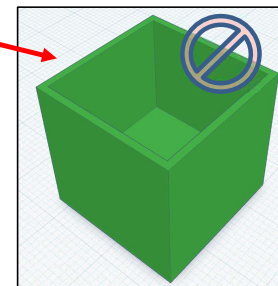


The 3D Printer will like it better if the part gets smaller as it goes up, not the other way around.

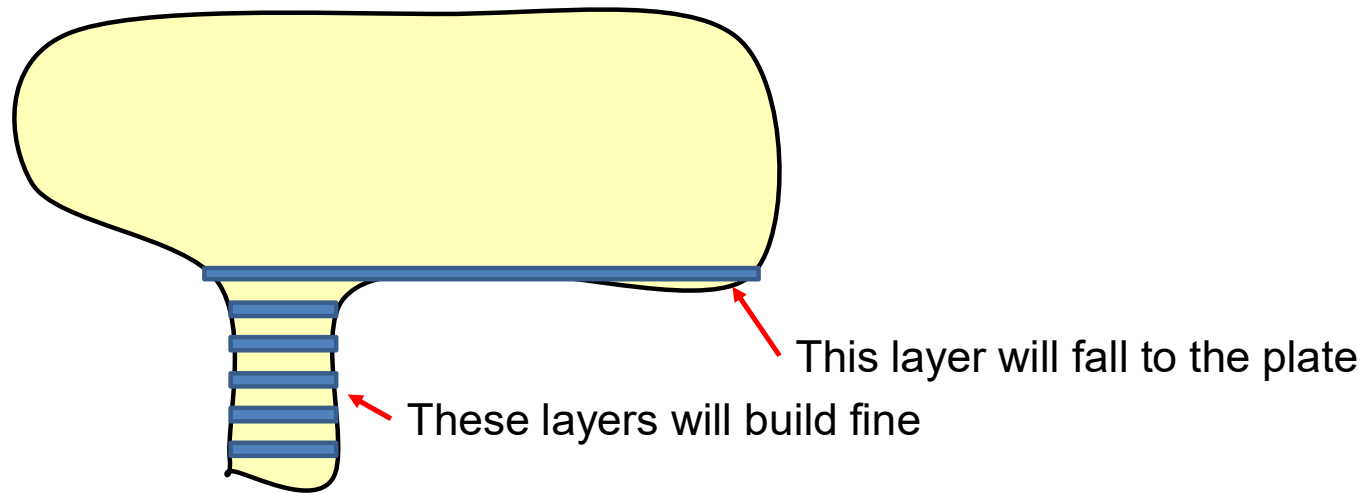


Don't design the part with long, thin edges. They will snap right off.

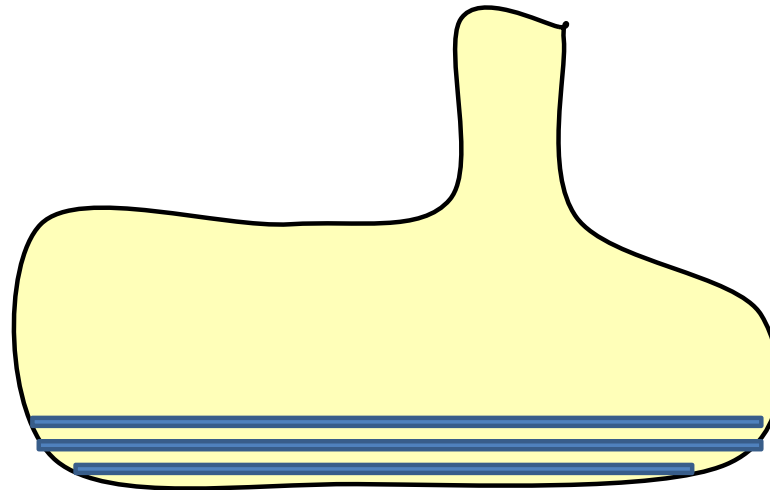
Don't make walls too thin – they will break.



Watch Out for Overhangs!

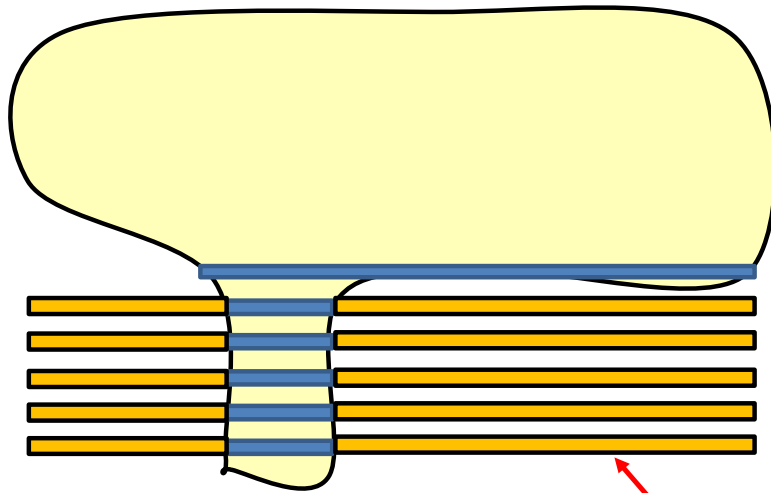


**Note that, if you build this object upside-down,
it will probably be fine**



Watch Out for Overhangs!

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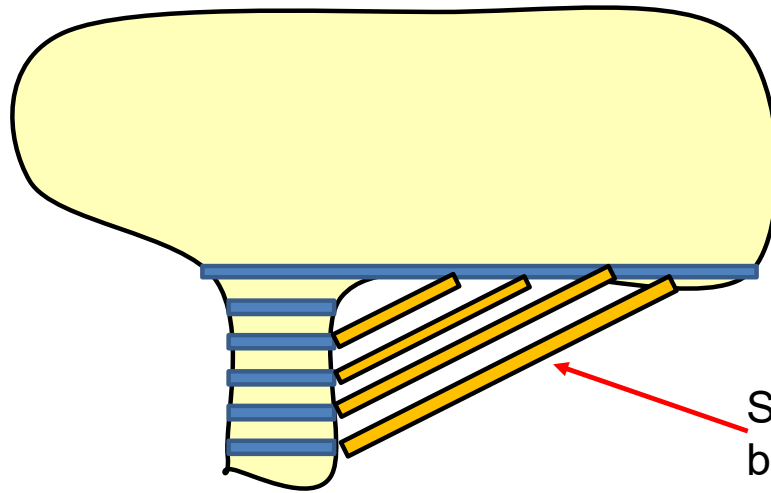
Some 3D printers handle overhangs by leaving unused material in place to support the overhangs



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Watch Out for Overhangs!



Some 3D printers handle overhangs by using software to add “support structures” to the overhangs

Some 3D printers handle this better than others...



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What Happens if You Don't Follow the Rules?

Check here:

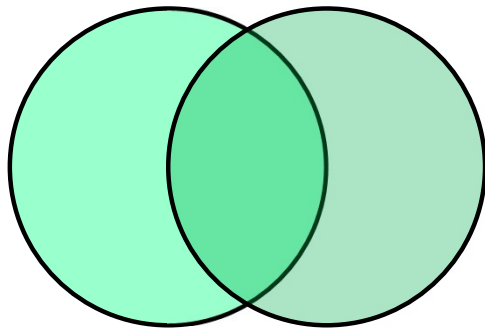
<http://twistedsifter.com/2013/08/when-3d-printing-goes-wrong/>



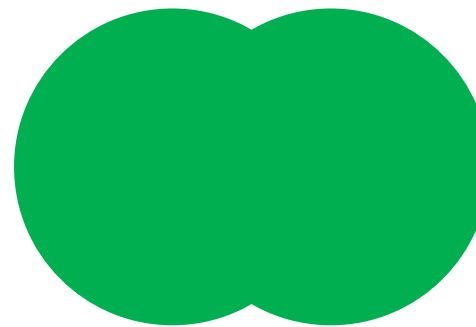
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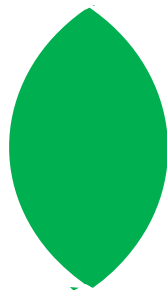
How Can You Guarantee That You Are Modeling With Legal Solids? Remember the “3D Venn Diagrams”



Two Overlapping Shapes



Union



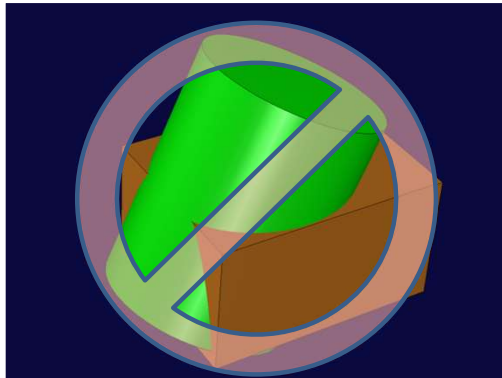
Intersection



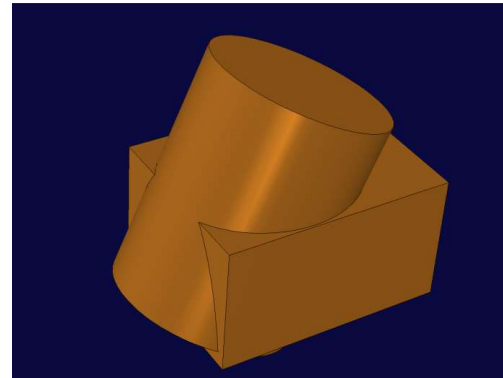
Difference



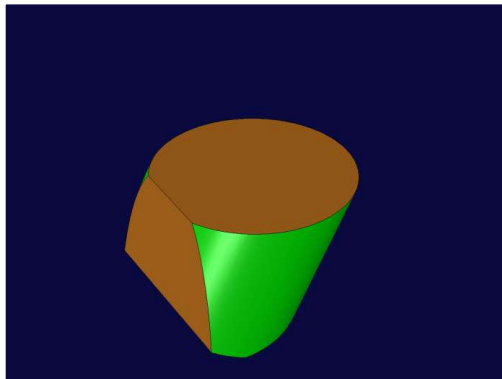
How Can You Guarantee That You Are Modeling With Legal Solids? Remember the “3D Venn Diagrams”



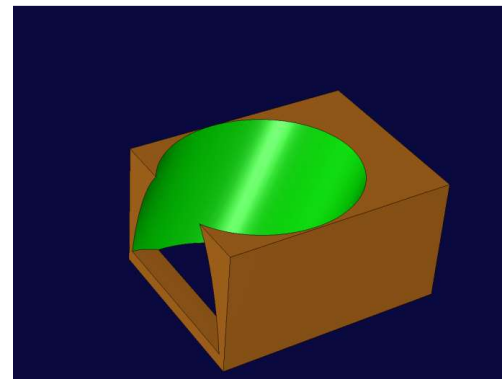
Two Overlapping Solids



Union



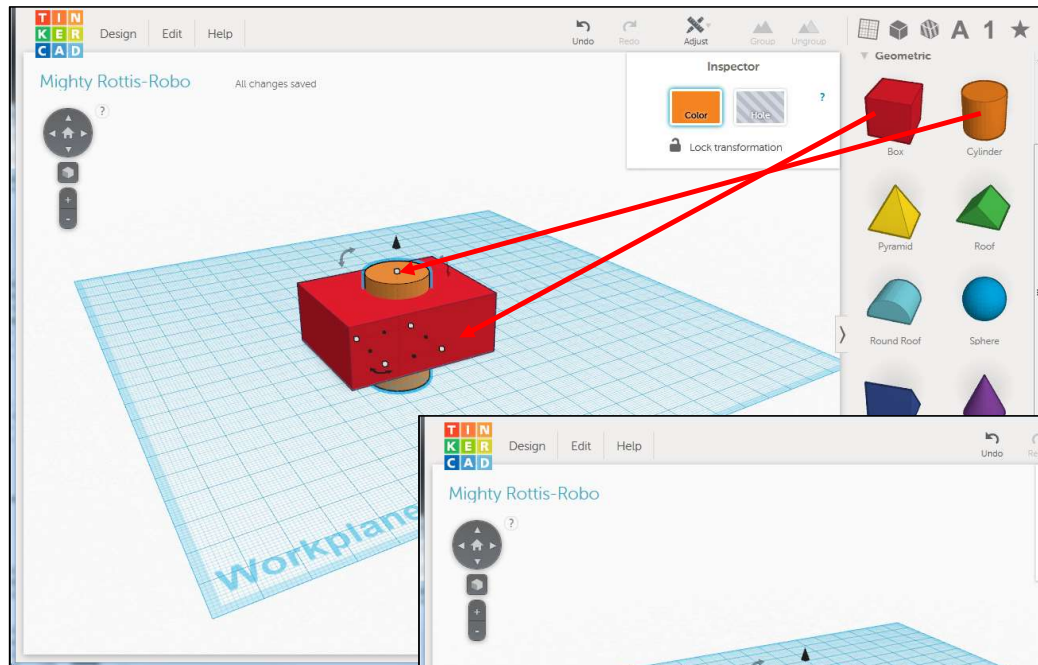
Intersection



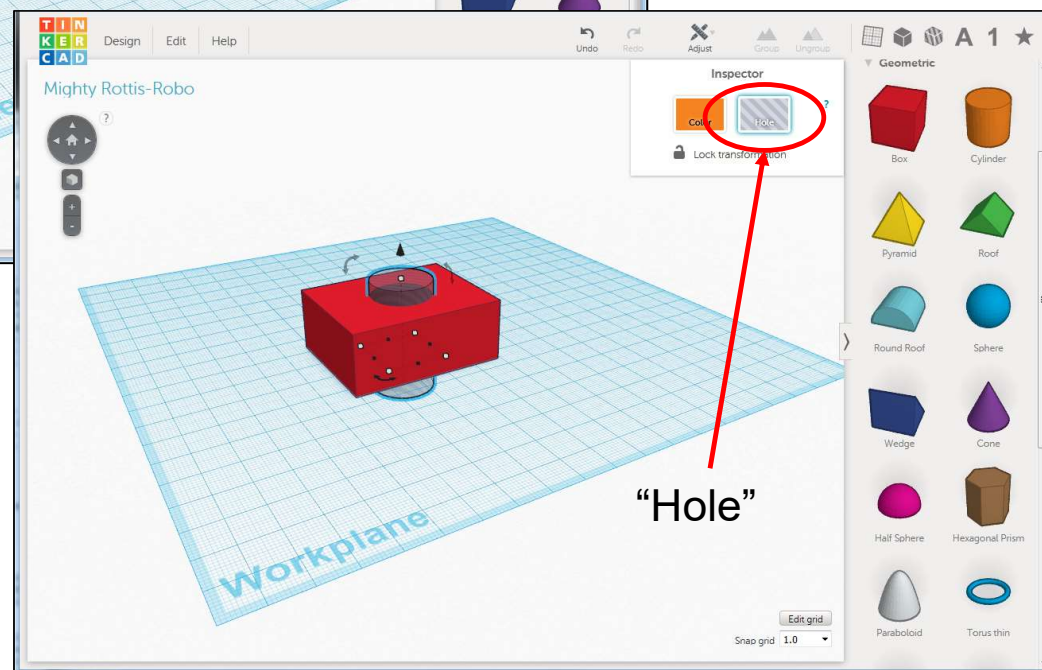
Difference

This is often called Constructive Solid Geometry (CSG)





Like many CAD systems, TinkerCad uses 3D Boolean operators (3D Venn diagrams). This guarantees a legal solid for 3D Printing.



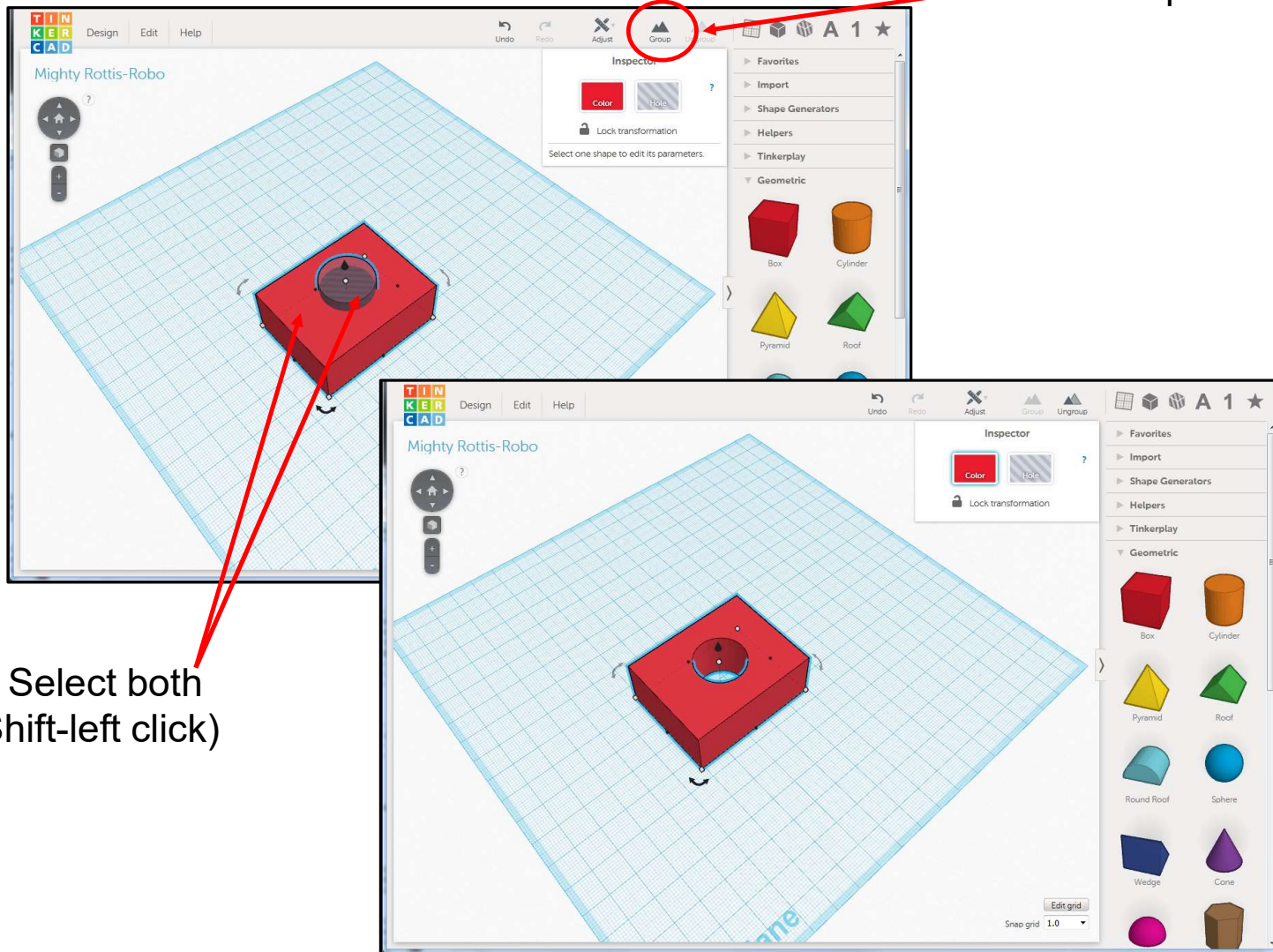
“Hole”



TinkerCad

2. "Group"

1. Select both
(Shift-left click)

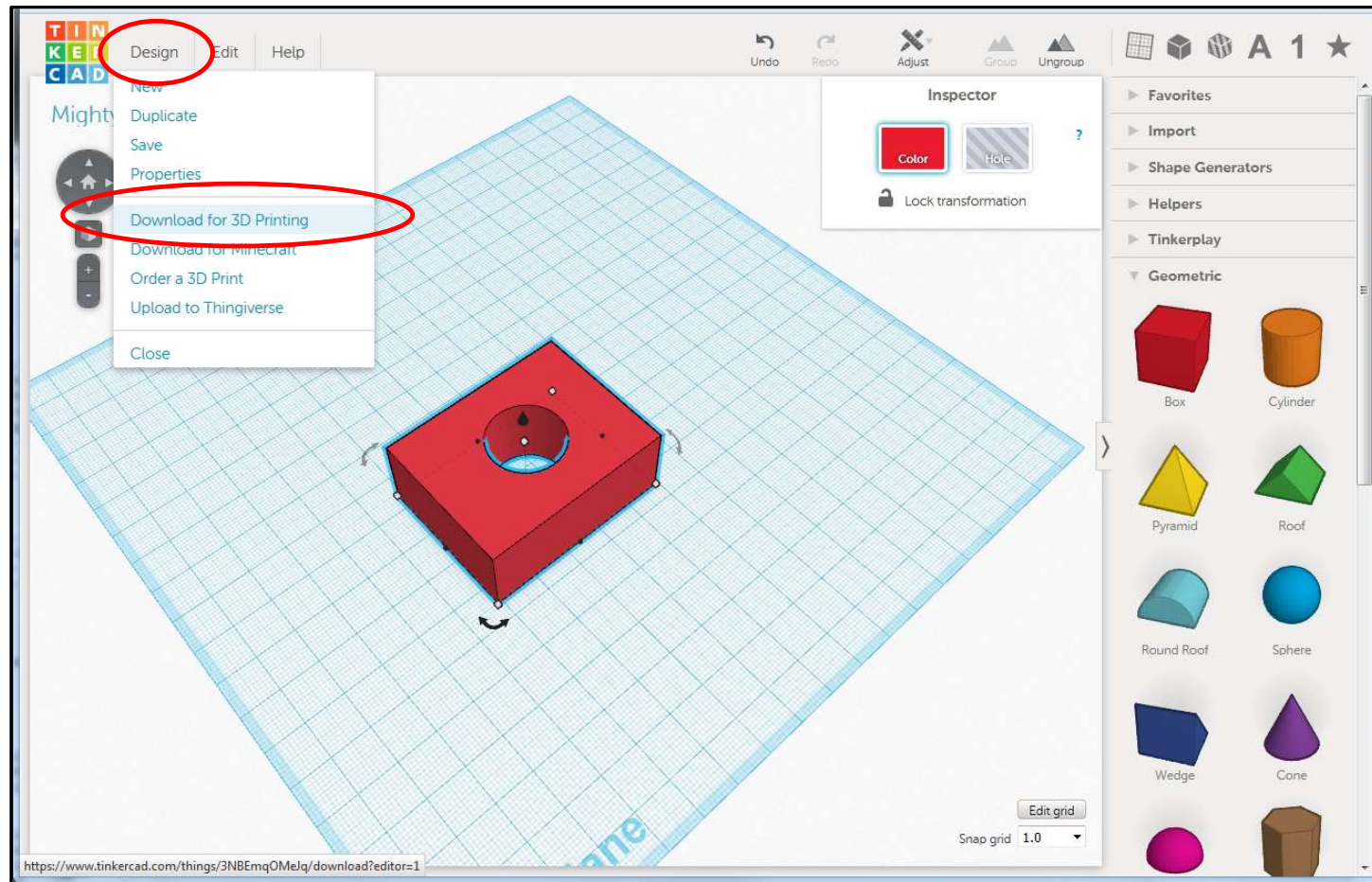


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Tinkercad

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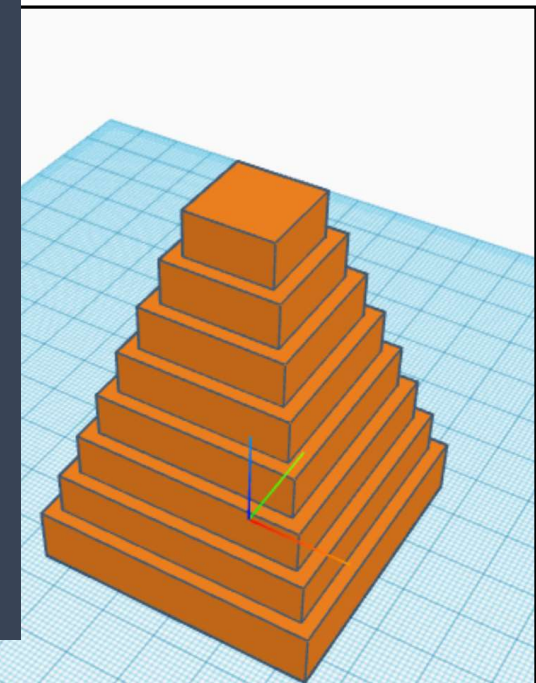
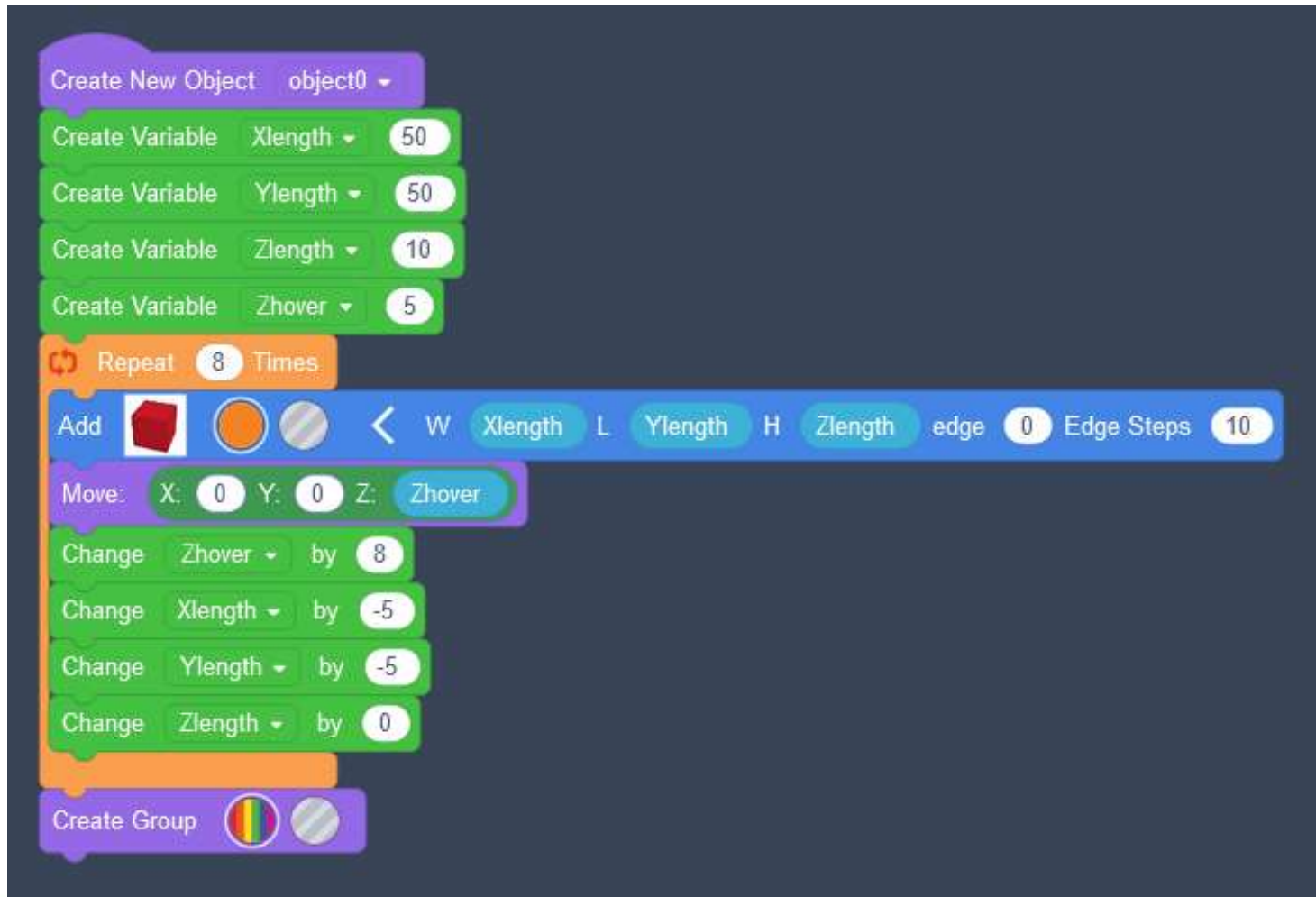


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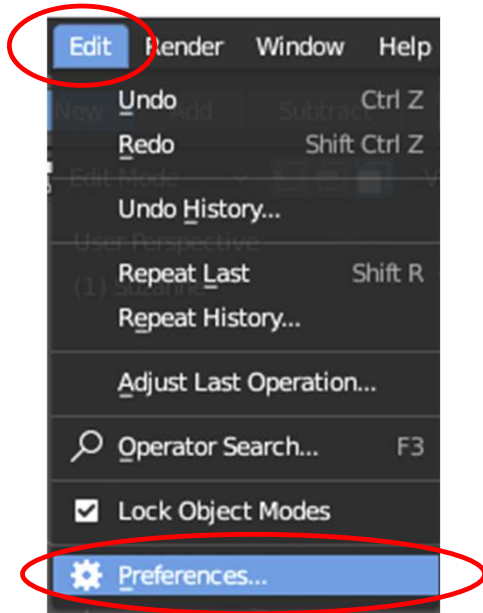
Procedural CSG Using TinkerCad/Codeblocks

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Blender's 3D Printing Utility isn't there by Default

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By default, Blender doesn't let you see its 3D Printing utility. You need to tell Blender to turn it on.

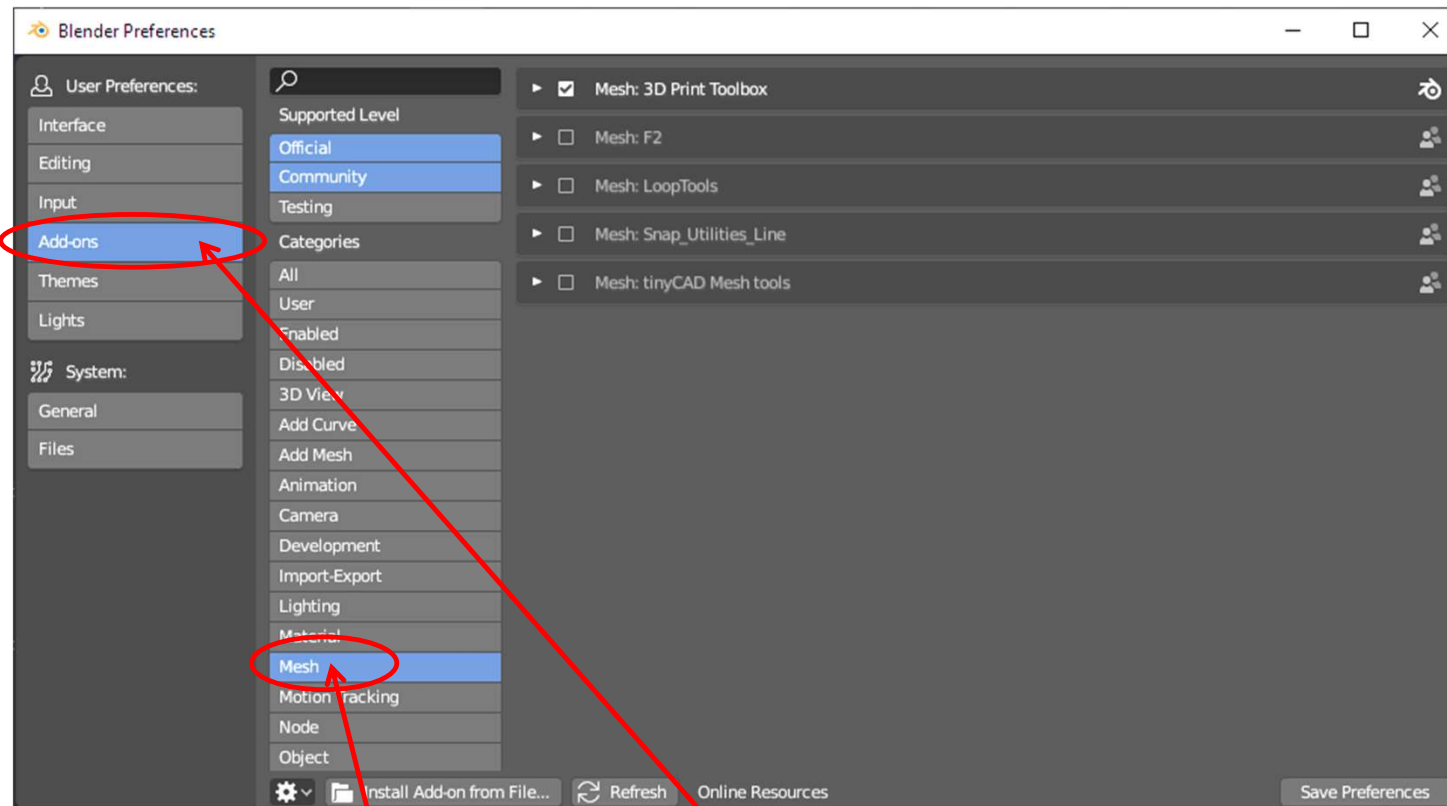
1. Click **Edit** → **Preferences**



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Blender's 3D Printing Options aren't there by Default



2. Click on the **Addons** tab
3. Click on **Mesh**

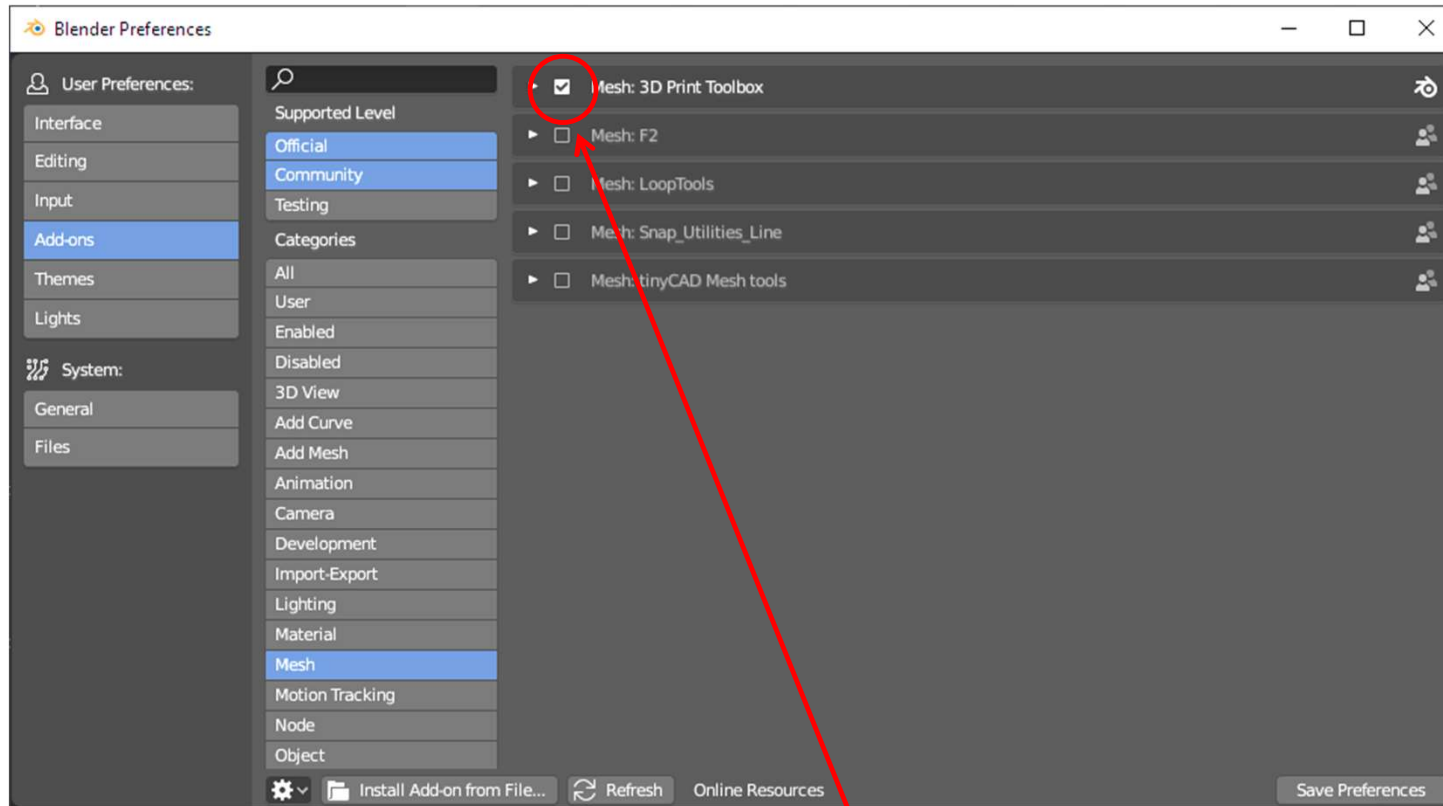


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Blender's 3D Printing Options aren't there by Default

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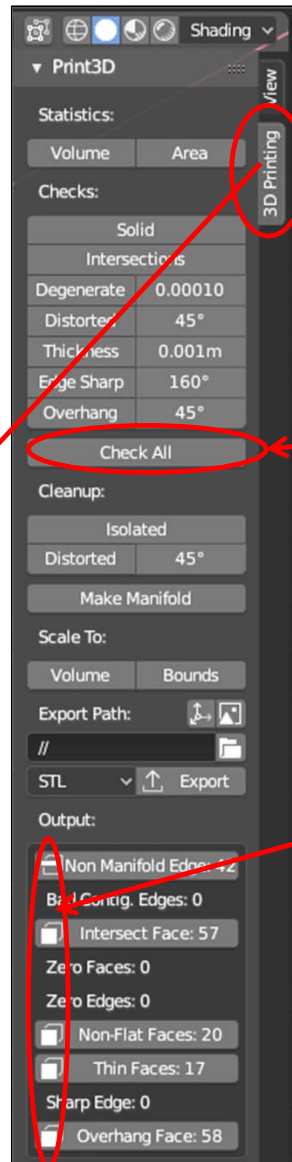
4. Click the **Mesh: 3D Print Toolbox**



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Blender Options for 3D Printing

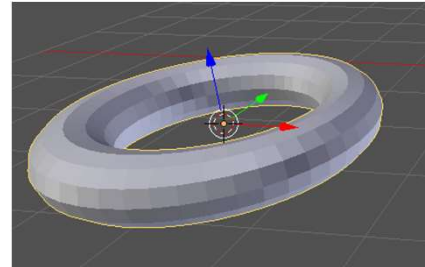
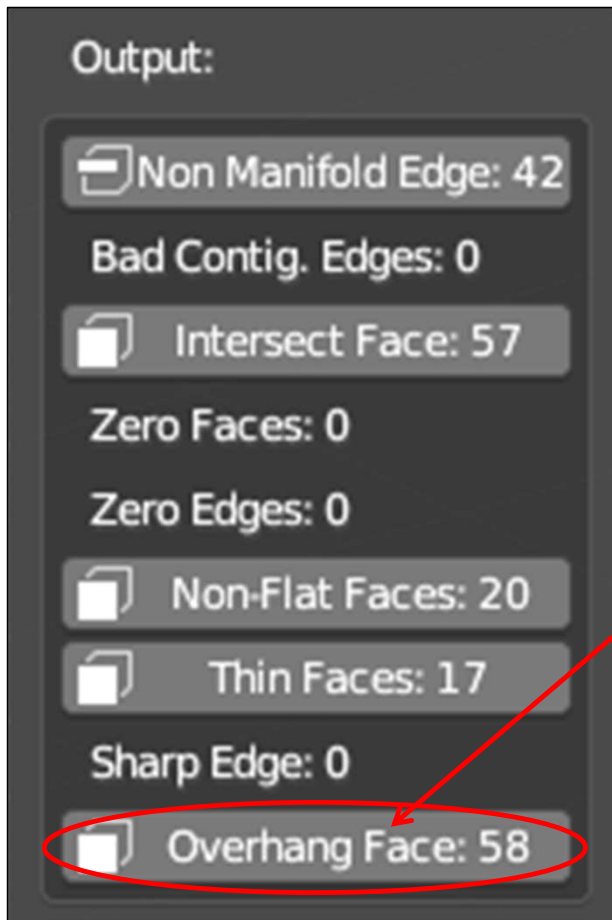


3D Printing now shows up in your Properties Region (hit the 'n' key if you're not seeing it)

Objects destined for 3D Printing must be "legal solids". Clicking on object and then on **Check All** will try to determine that

Tab over to Edit Mode. Clicking on any of these will highlight where they are on your object.

Blender Options for 3D Printing



An overhang face is not necessarily a bad thing. The entire bottom of the part will consist of, by necessity, overhang faces.

However, overhang faces that are not the bottom of the part could be a problem.

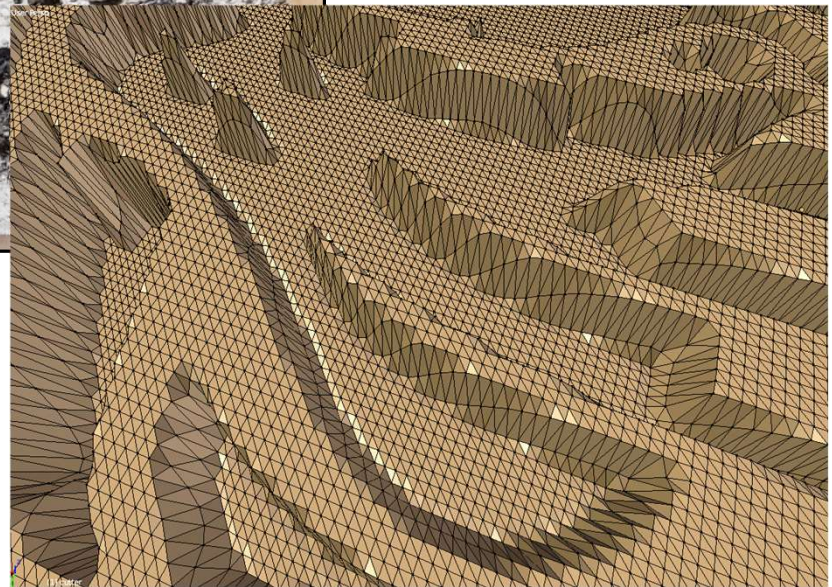


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Heightmap Files are Straightforward to use with 3D Printing

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A Very Special Heightmap 3D Printing Model (mmm...)

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A Very Special Heightmap 3D Printing Model (mmm...)

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Most Any *Data* Can be Turned into a 3D-Printable Model



Mars



Mars



3D Ultrasound



3D Ultrasound

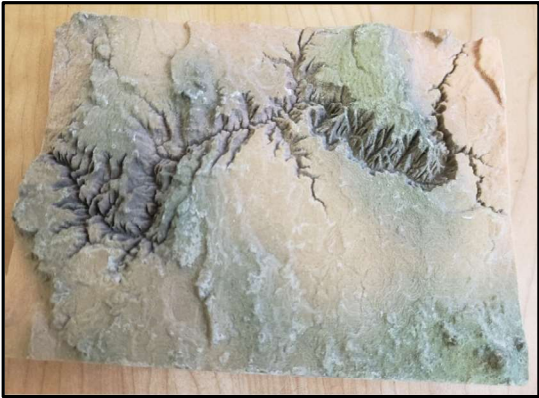


Molecular Modeling

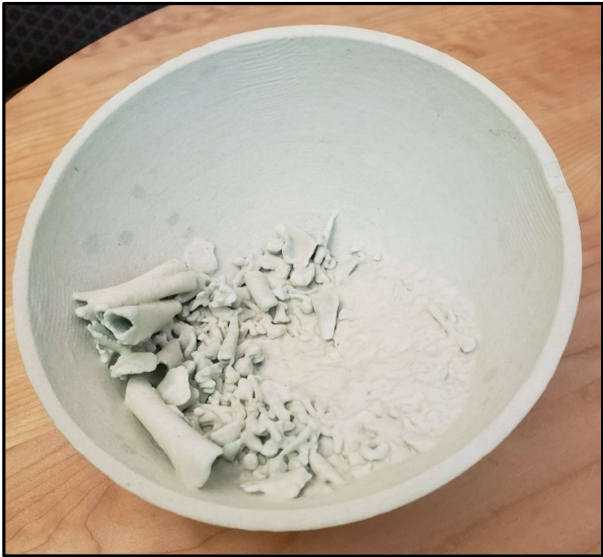
Most Any *Data* Can be Turned into a 3D-Printable Model



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Grand Canyon



Dinosaur Egg



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MRI Scan

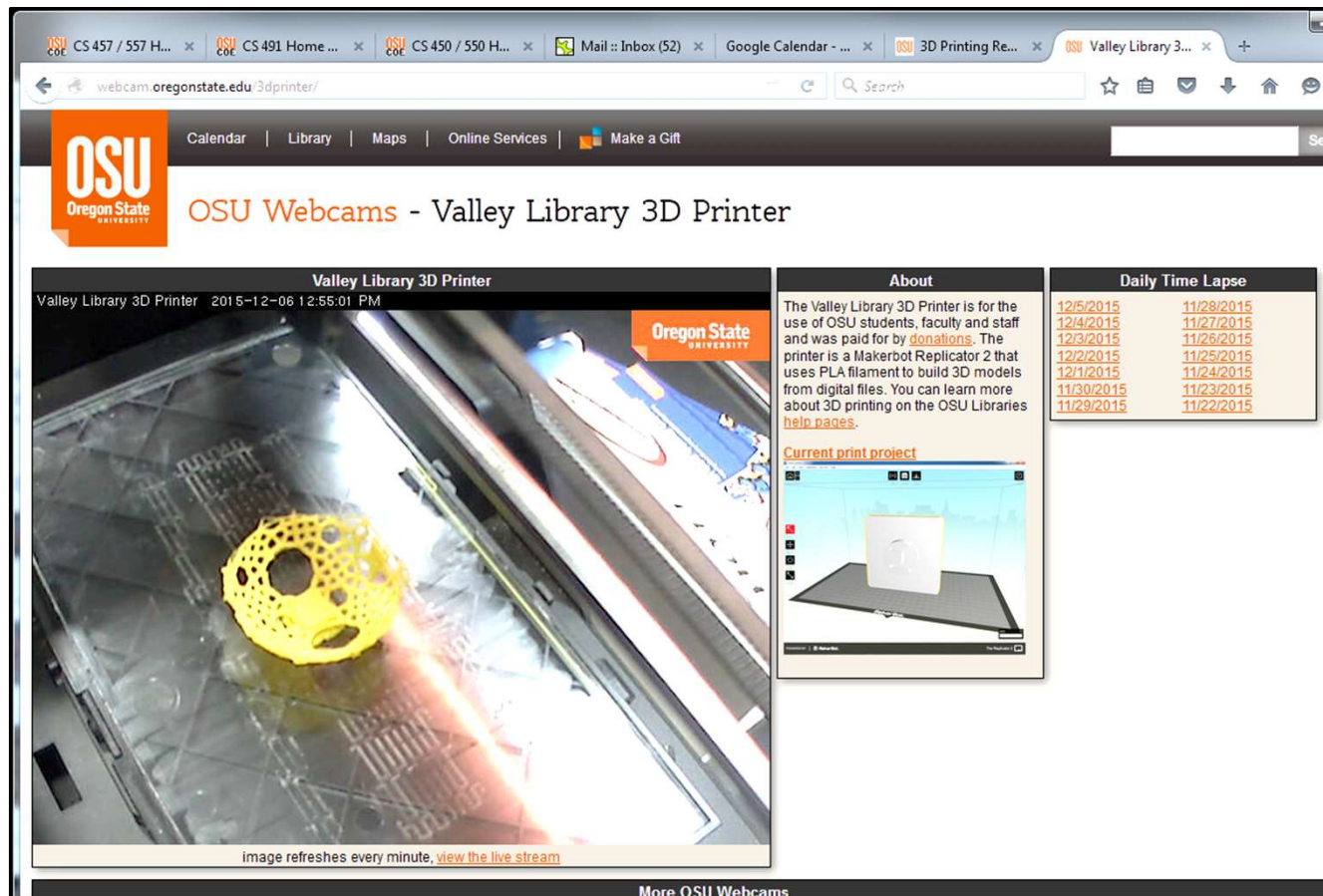


Earth

The OSU Library Has Four 3D Printers for Student Use

To watch the OSU Library's 3D Printers, go to:

<http://webcam.oregonstate.edu/3dprinter/>



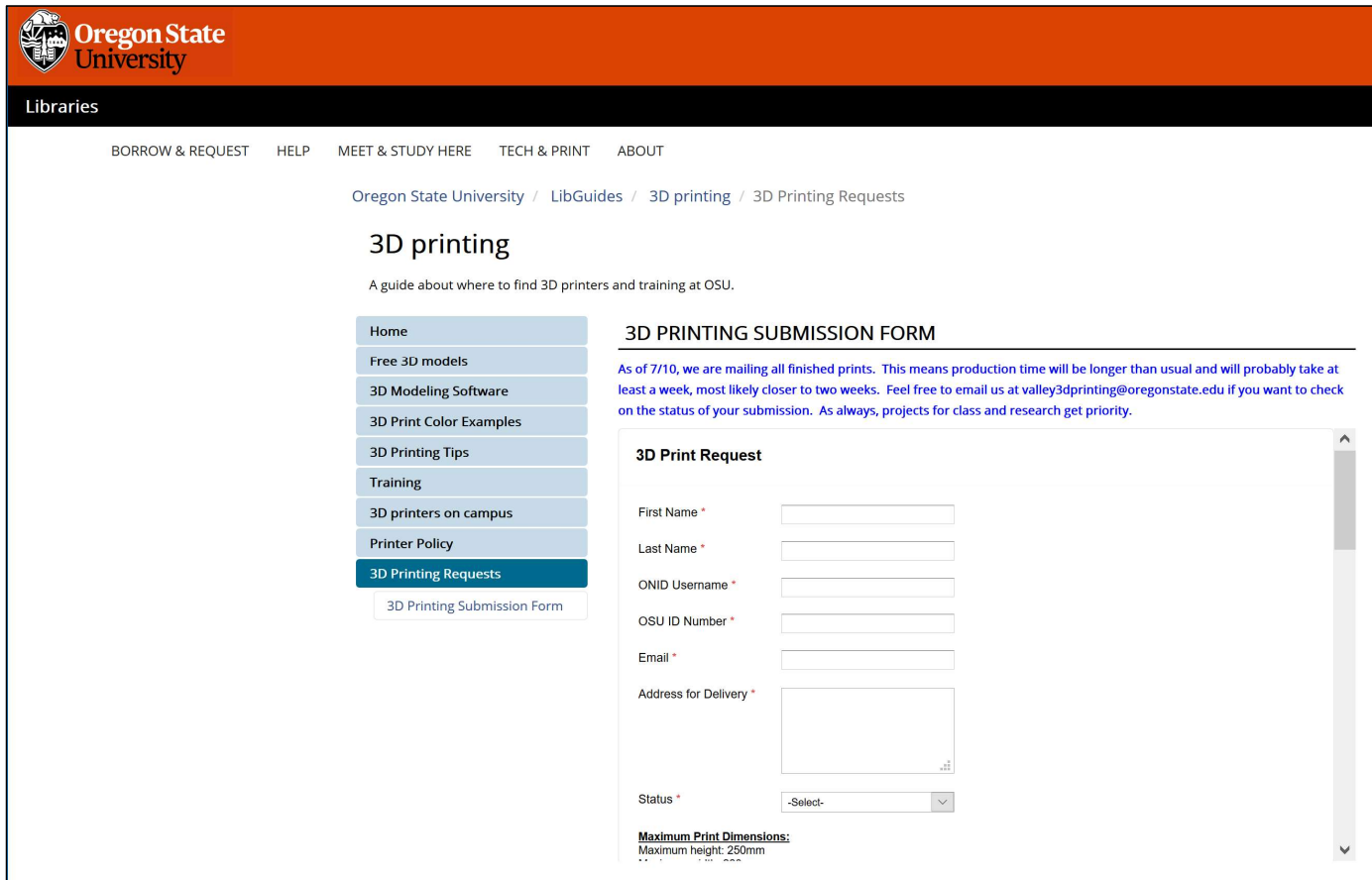
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The OSU Library Has Four 3D Printers for Student Use

To send an STL model to the OSU Library's 3D Printers, go to:

<http://guides.library.oregonstate.edu/3Dprinting/3Dprintform>



The screenshot shows the Oregon State University LibGuides website. The header is orange with the OSU logo and name. Below the header is a black bar with the word "Libraries". A navigation menu includes "BORROW & REQUEST", "HELP", "MEET & STUDY HERE", "TECH & PRINT", and "ABOUT". The breadcrumb trail reads "Oregon State University / LibGuides / 3D printing / 3D Printing Requests". The main heading is "3D printing", followed by a subheading "A guide about where to find 3D printers and training at OSU." On the left is a sidebar with a list of links: Home, Free 3D models, 3D Modeling Software, 3D Print Color Examples, 3D Printing Tips, Training, 3D printers on campus, Printer Policy, 3D Printing Requests (highlighted), and 3D Printing Submission Form. The main content area is titled "3D PRINTING SUBMISSION FORM". A notice states: "As of 7/10, we are mailing all finished prints. This means production time will be longer than usual and will probably take at least a week, most likely closer to two weeks. Feel free to email us at valley3dprinting@oregonstate.edu if you want to check on the status of your submission. As always, projects for class and research get priority." Below this is the "3D Print Request" form with fields for First Name, Last Name, ONID Username, OSU ID Number, Email, and Address for Delivery. A Status dropdown menu is set to "-Select-". At the bottom, it says "Maximum Print Dimensions: Maximum height: 250mm".



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mjb – November 20, 2024