How Bridges Work

The Basics

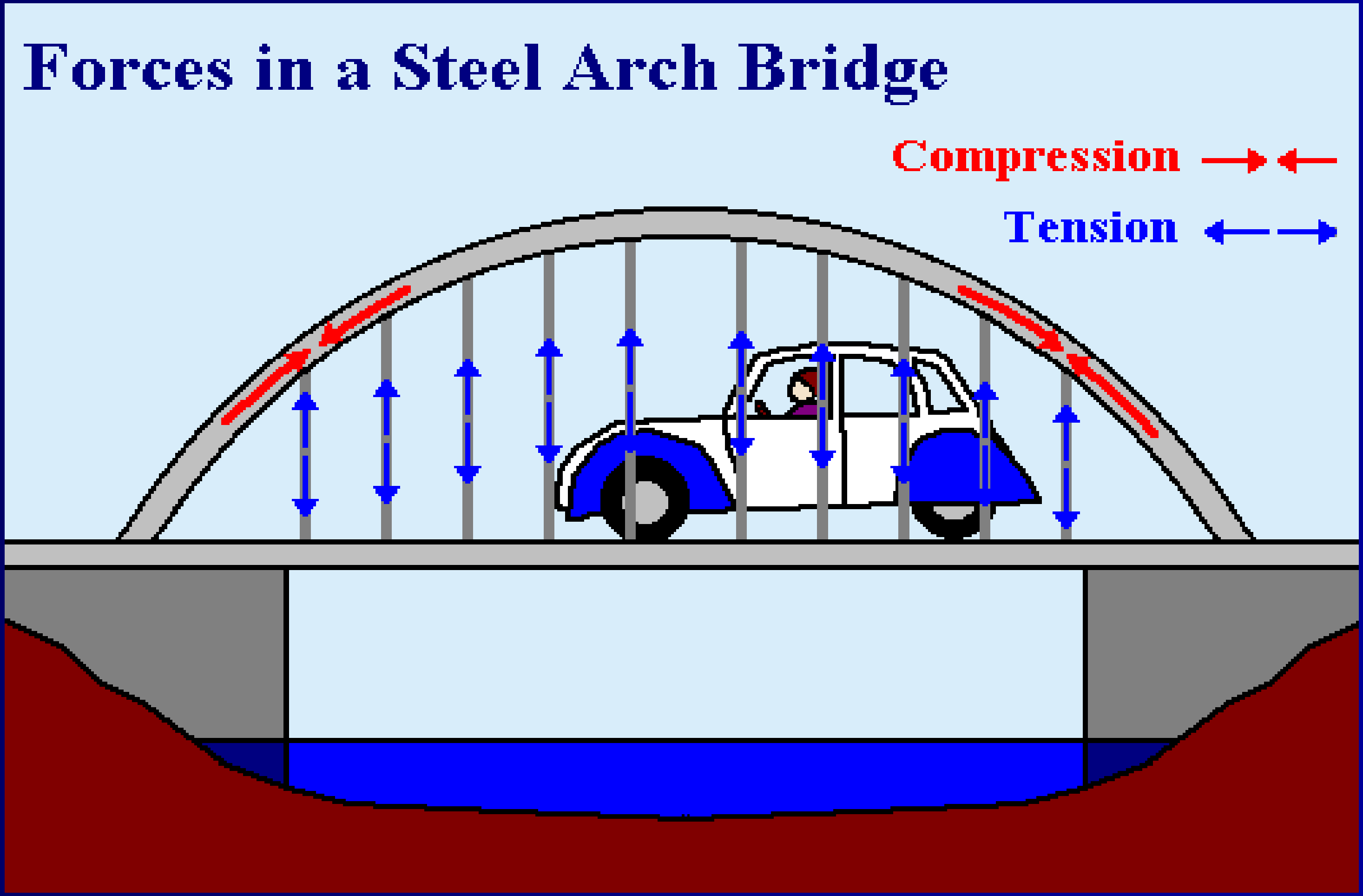
- There are three major types of bridges:
- The **beam bridge**
- The **arch bridge**
- The **suspension bridge**

- The biggest difference between the three is the distances they can cross in a single **span**.

- A modern beam bridge, for instance, is likely to span a distance of up to 200 feet (60 meters).

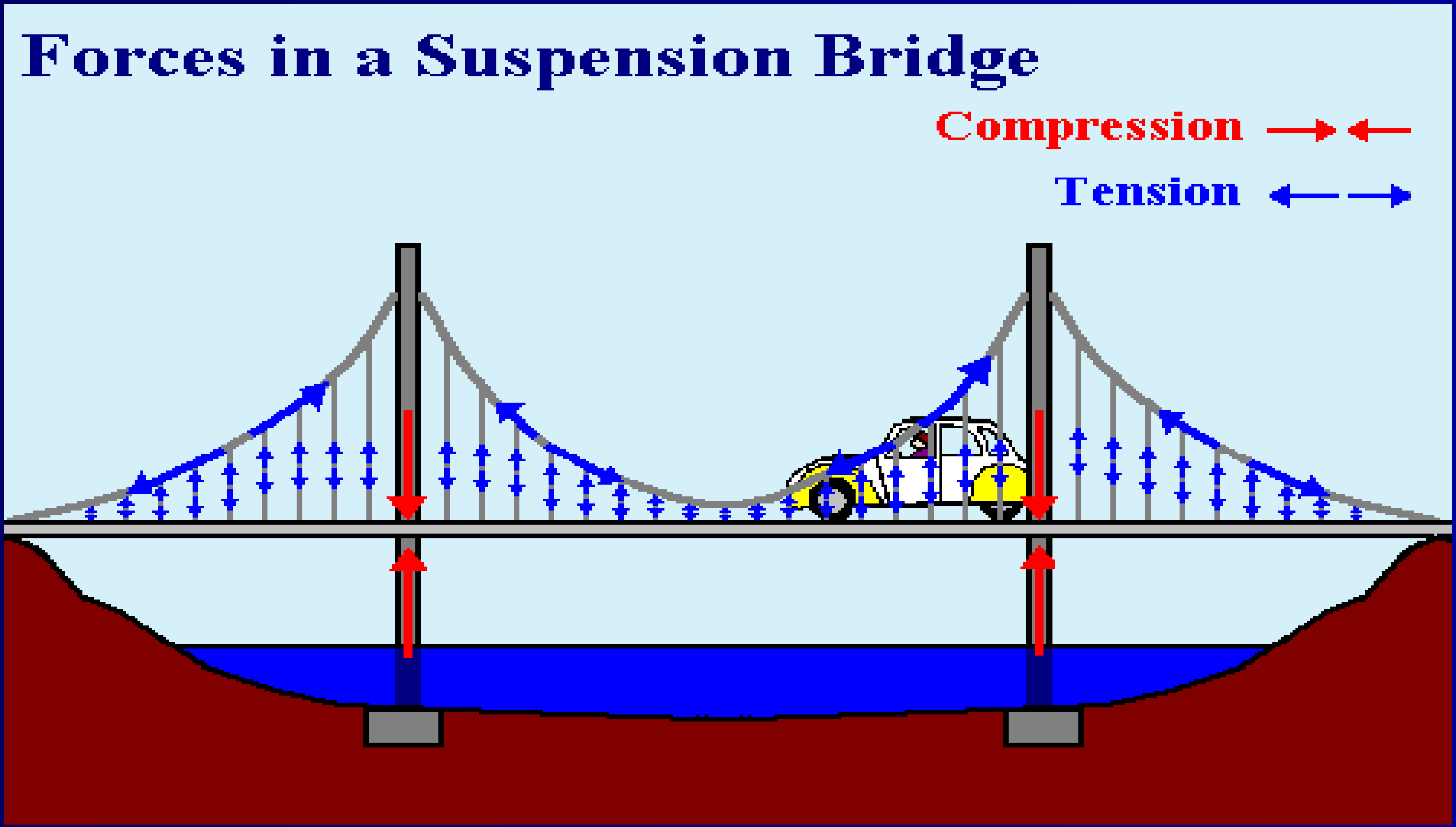
- A modern arch can safely span up to 800 or 1,000 feet (240 to 300 m).

Forces acting in a Steel Arch Bridge



A suspension bridge, the pinnacle of bridge technology, is capable of spanning up to 7,000 feet (2,100m).

Forces acting in a Suspension Bridge



- What allows an arch bridge to span greater distances than a beam bridge, or a suspension bridge to span a distance seven times that of an arch bridge?

- **Compression** is a force that acts to compress or shorten the thing it is acting on.

- **Tension** is a force that acts to expand or lengthen the thing it is acting on.

- **Buckling** is what happens when the force of compression overcomes an object’s ability to handle compression.
- **Snapping** is what happens when the force of tension overcomes an object’s ability to handle tension.

- The best way to deal with these forces is to either dissipate them or transfer them. To **dissipate** force is to spread it out over a greater area, so that no one spot has to bear the brunt of the concentrated force.

- To **transfer** force is to move it from an area of weakness to an area of strength, an area designed to handle the force. An arch bridge is a good example of dissipation, while a suspension bridge is a good example of transference.

The Beam Bridge

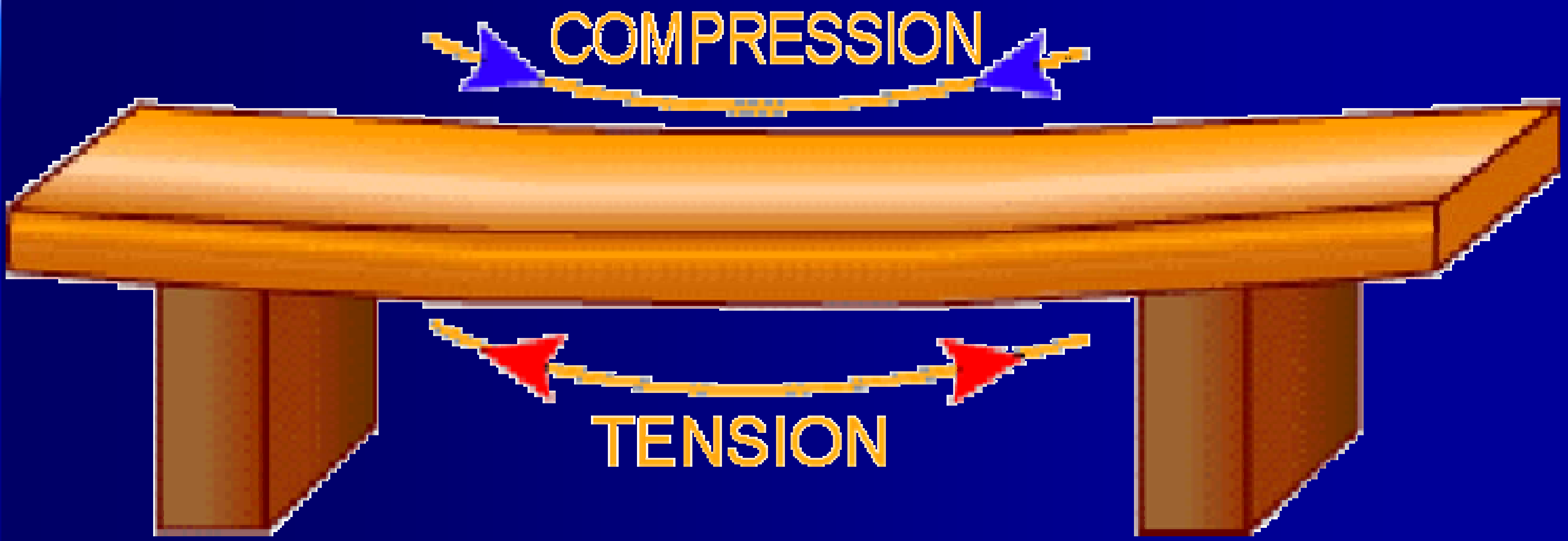
A beam bridge is basically a rigid horizontal structure that is resting on two piers, one at each end. The weight of the bridge and any traffic on it is directly supported by the piers. The weight is traveling directly downward

- **Compression**

The force of compression manifests itself on the top side of the beam bridge's deck (or roadway). This causes the upper portion of the deck to shorten.

- **Tension**

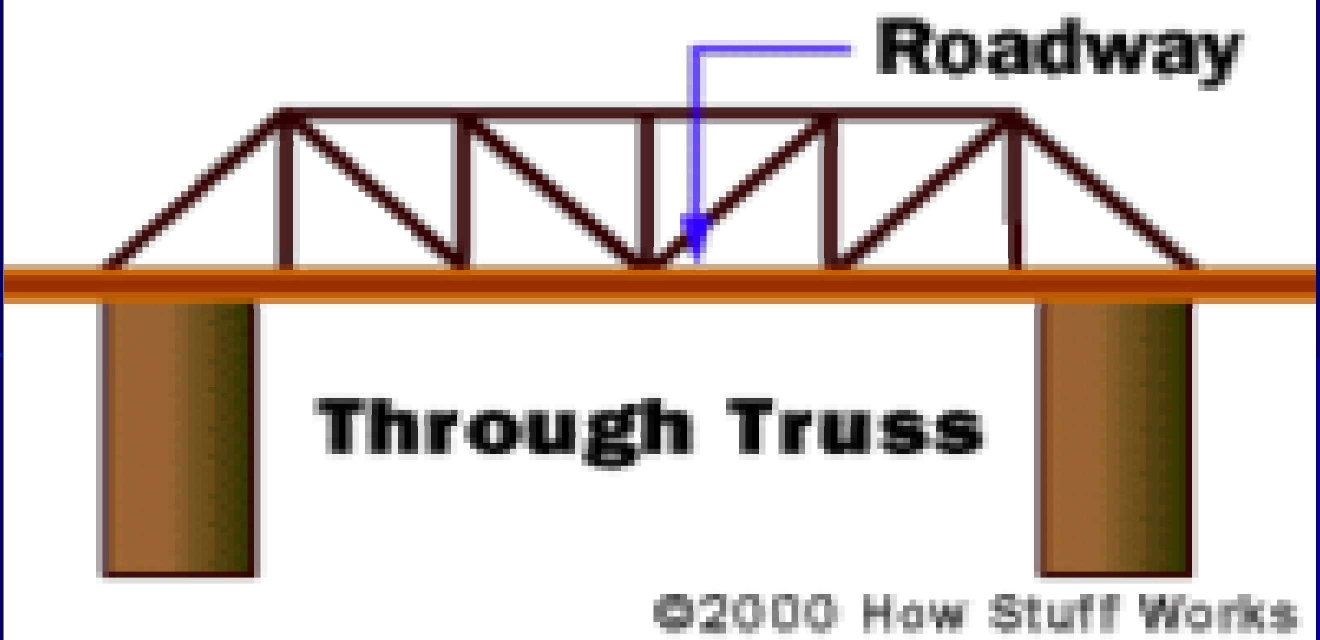
The result of the compression on the upper portion of the deck cause tension in the lower portion of the deck. This tension causes the lower portion of the beam to lengthen.


COMPRESSION
TENSION

- By increasing the height of the beam, the beam has more material to dissipate the tension. To create very tall beams, bridge designers add supporting lattice work, or a **trus**s, to the bridge's beam.

- One approach is to still build a bridge that is supported just at the two ends, but use cross members to make the bridge stronger so it doesn’t sag. This is called a **truss bridge.**

One of the most popular early designs was the Howe Truss, a design patented by **William Howe** in 1840.


Roadway
Through Truss
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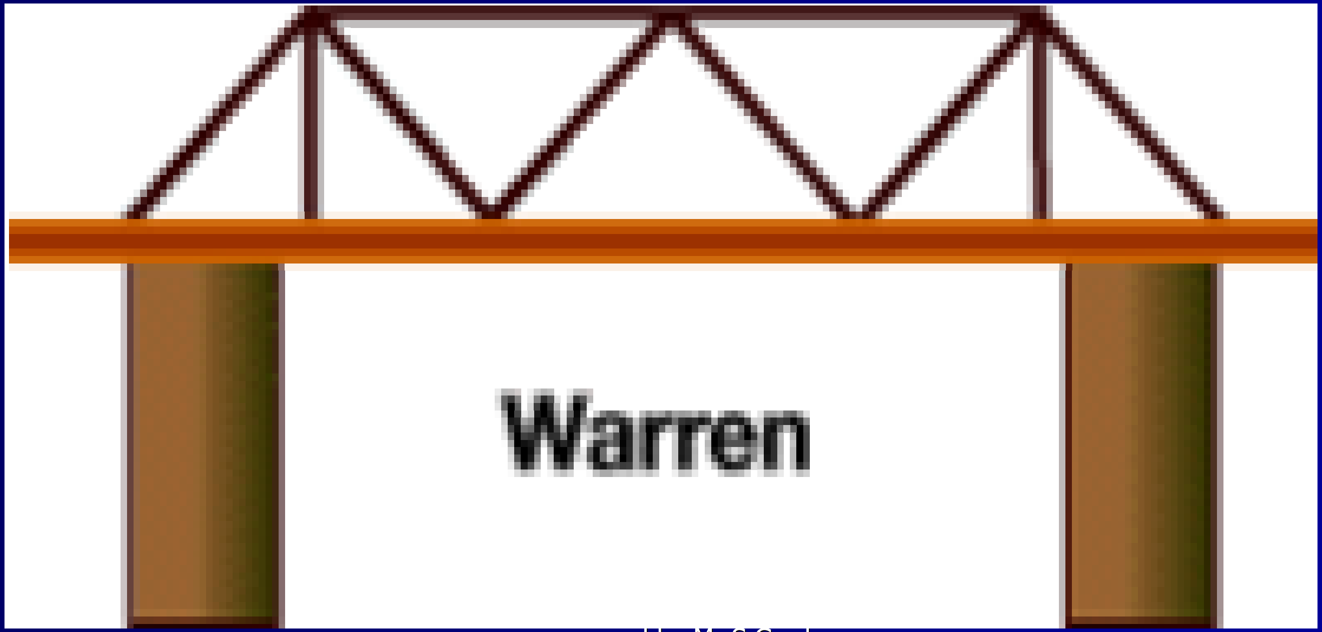
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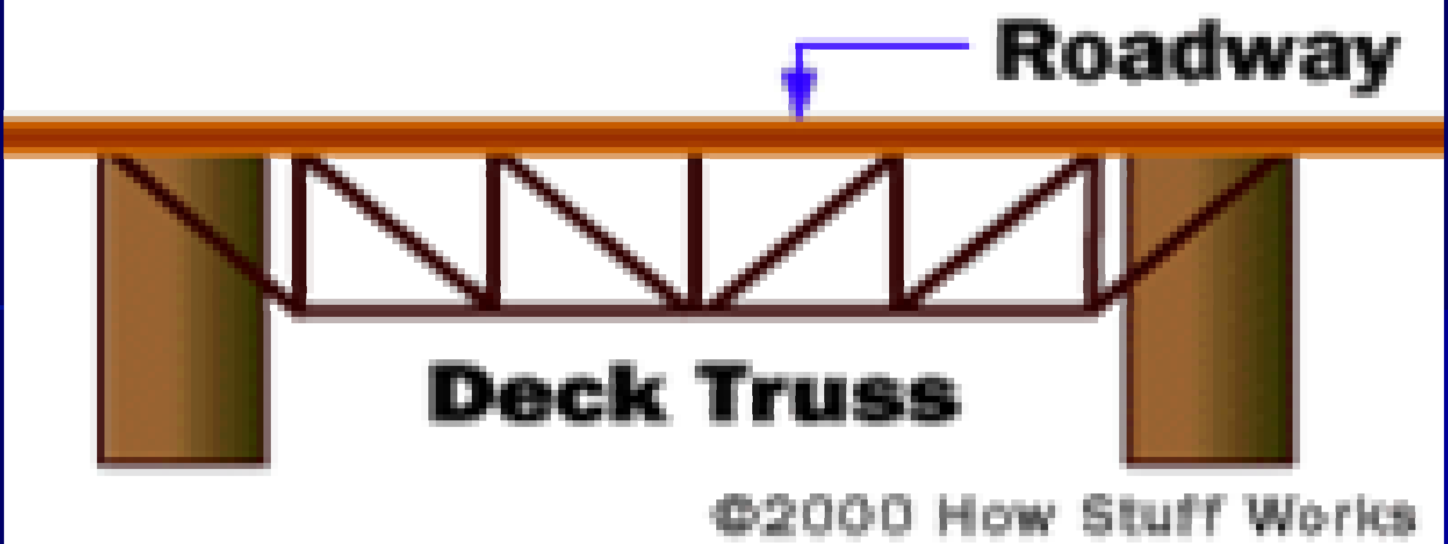
Roadway
Deck Truss
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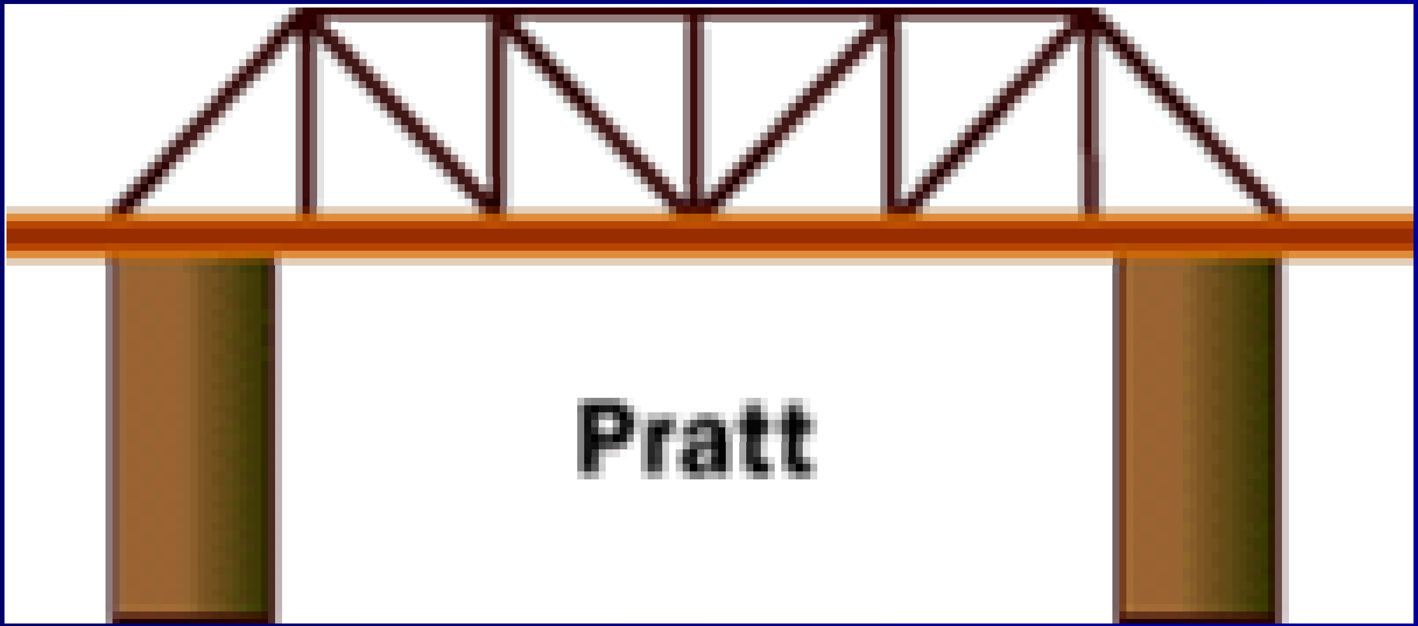

Pratt

Truss Strength

The very top of the beam experience the most compression, and the very bottom of the beam experience the most tension.

The middle of the beam experiences very little compression or tension.

If the beam were designed so that there was more material on the top and bottom, and less in the middle, it would be better able to handle the forces of compression and tension. (For this reason, I-beams are more rigid than simple rectangular beams.)

Truss Strength

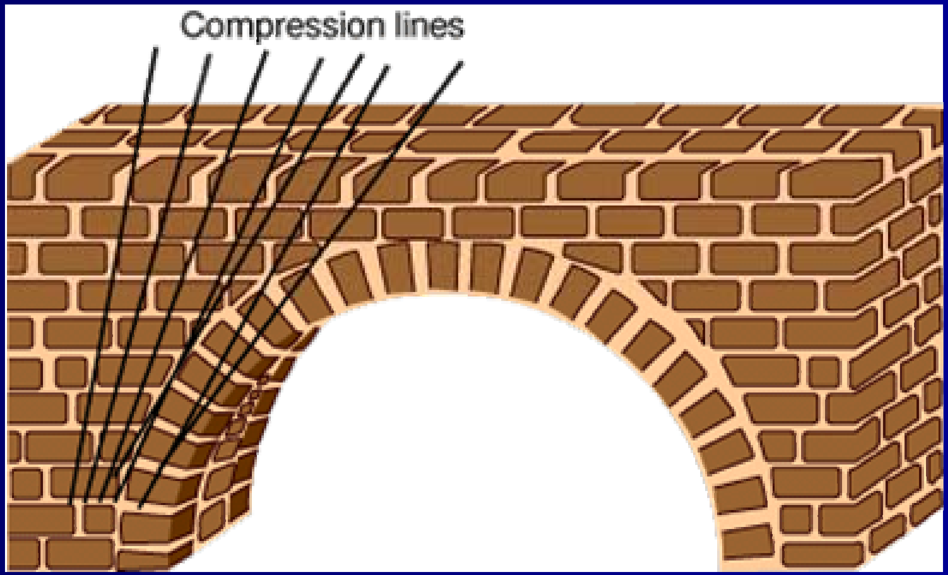
A truss system takes this concept one step further. Think of one side of a truss bridge as a single beam. The center of the beam is made up of the diagonal members of the truss, while the top and bottom of the truss represent the top and bottom of the beam. Looking at a truss in this way, we can see that the top and bottom of the beam contain more material than its center (corrugated cardboard is very stiff for this reason).

- The Arch Bridge

An arch bridge is a semicircular structure with abutments on each end. The design of the arch, the semicircle, naturally diverts the weight from the bridge deck to the abutments.

Compression

Arch bridges are always under compression. The force of compression is pushed outward along the curve of the arch toward the abutments.



The Suspension Bridge

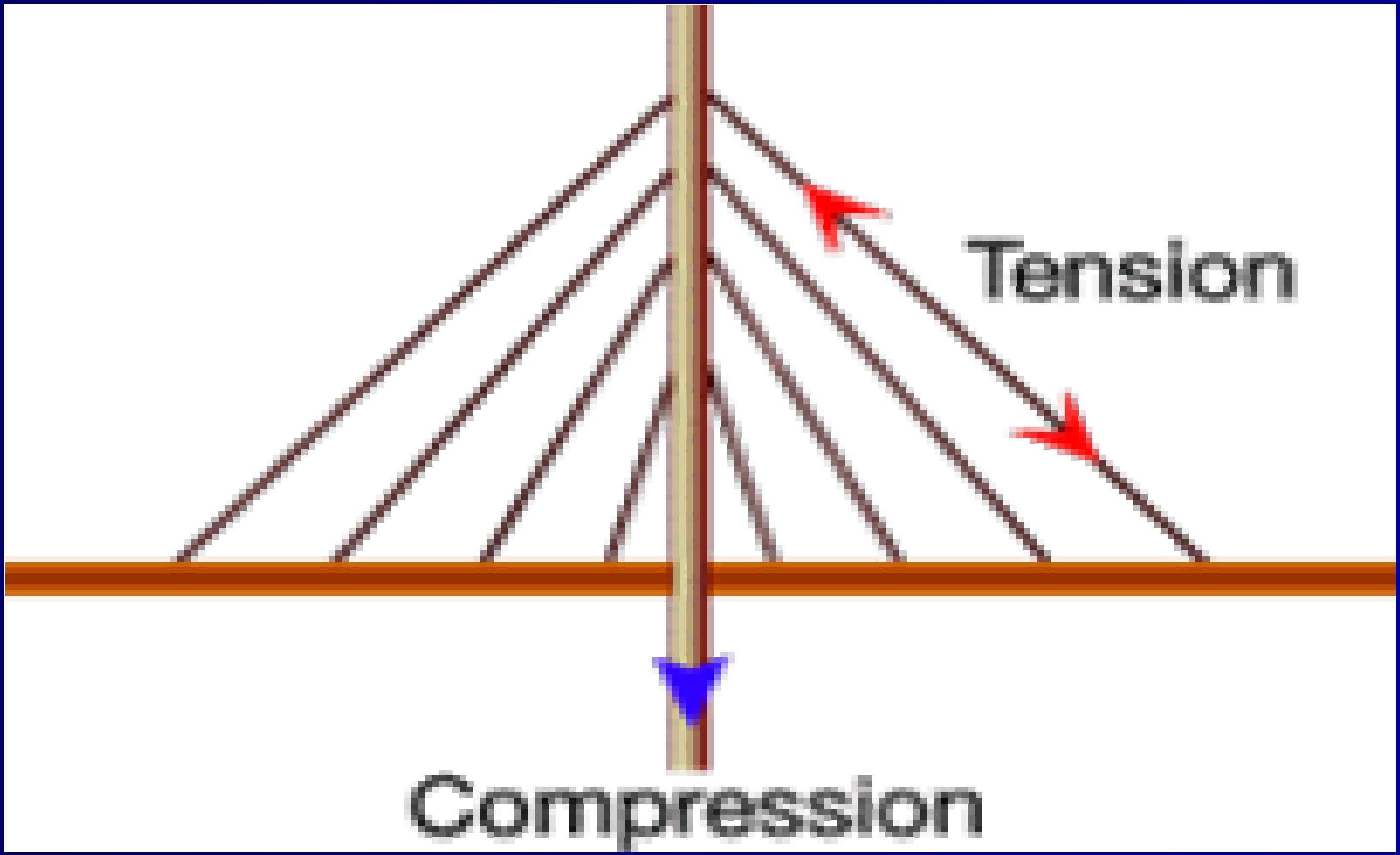
A suspension bridge is one where cables (or ropes or chains) are strung across the river.

The deck is suspended from these cables.

Modern suspension bridges have two tall towers through which the cables are strung. Thus, the towers are supporting the majority of the roadway's weight.

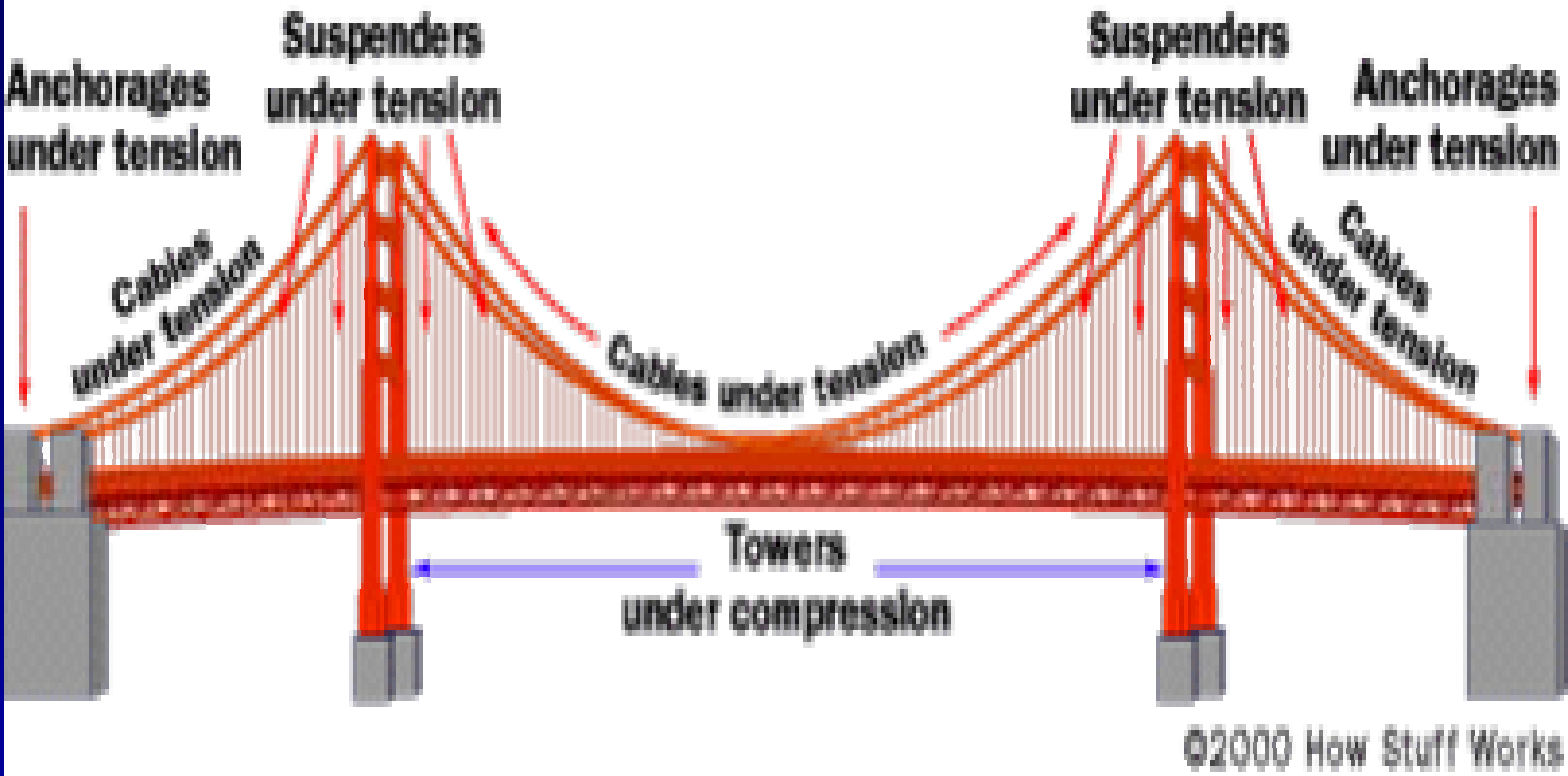
Compression

The force of compression pushes down on the suspension bridge’s deck, but because it is a suspended roadway, the cables transfer the compression to the towers, which dissipate the compression into the earth where they are firmly entrenched.


Tension
Compression

Tension

The supporting cables, running between the two anchorages, are the lucky recipients of the tension forces. The cables are literally stretched from the weight of the bridge and its traffic as they run from anchorage to anchorage. The anchorages are also under tension, but since they, like the towers, are held firmly to the earth, the tension they experience is dissipated.


Suspenders under tension
Anchorages under tension
Cables under tension
Cables under tension
Suspenders under tension
Anchorages under tension
Cables under tension
Towers under compression
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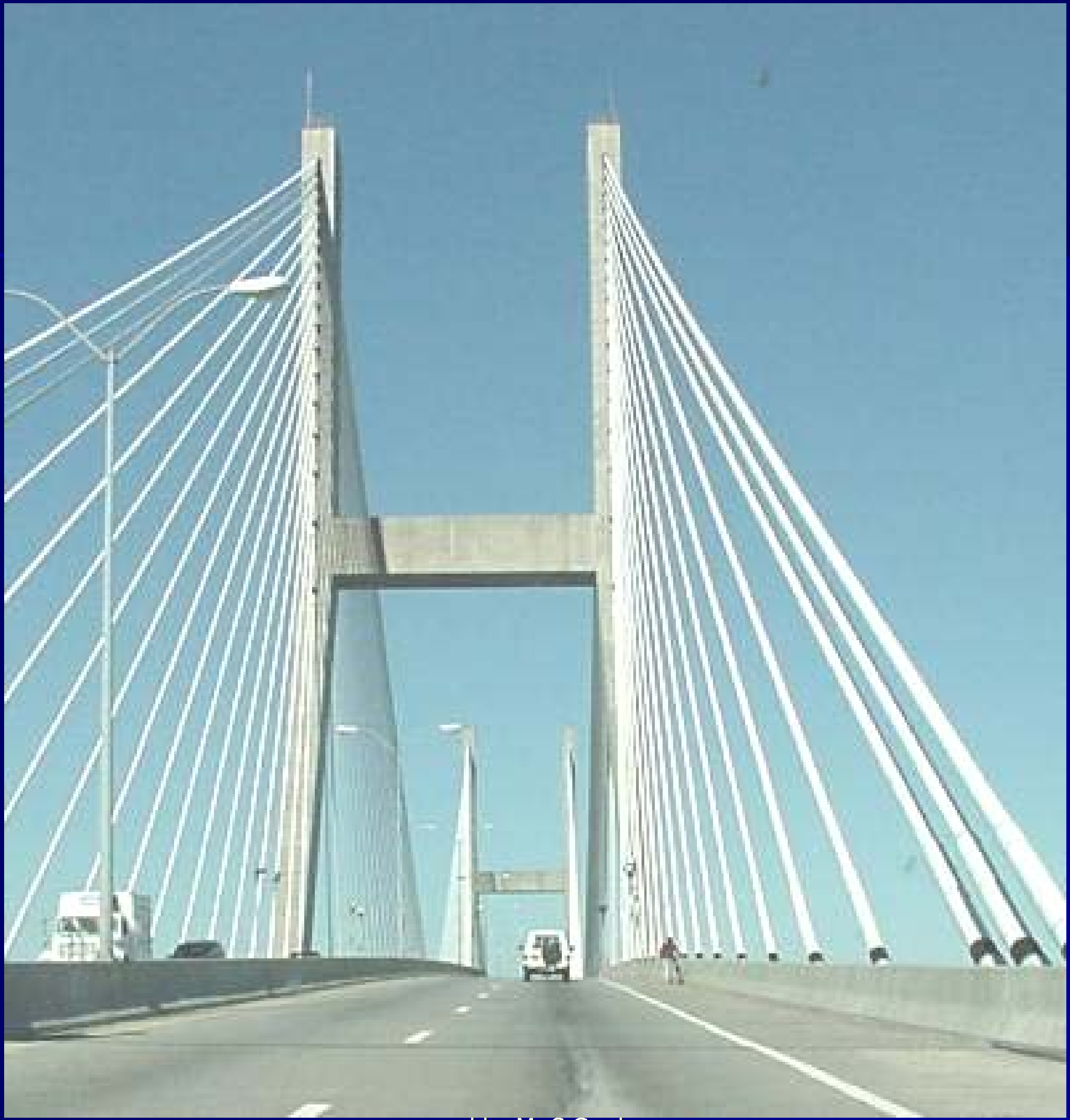

- Torsion, which is a rotational or twisting force, is one which has been effectively eliminated in all but the largest suspension bridges.

- **Resonance** (a vibration in something caused by an external force that is in harmony with the natural vibration of the original thing) is a force which, unchecked, can be fatal to a bridge. Resonant vibrations will travel through a bridge in the form of waves.

The End!

- I hope this was educational and enjoyable, and now understand the basics of bridges and there complexity, grace and beauty.
- sgrad