Special Lecture

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Compartmentalized knowledge

Your foundation courses are compartmentalized into Physics Chemistry Biology and some Engineering disciplines.

This compartmentalization is only for the purpose of organizing knowledge so that we can make sense of it in a methodical way and develop appropriate tools.

Nature is out there in its full glory and has no obligation to recognize these compartments.

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What are the guiding elements of design?

- Utility
- Durability
- Economy

Challenge is to

- Satisfy all three without compromising aesthetics
- To break free from the shells of compartmentalization and draw inspiration from most unlikely of the sources.

Nature's engineering is the ultimate testimony to this, because she has perfected her 'technology' through the wear and tear of millions of years.

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An Engineering Challenge

How can you design something that is strongest as well as weakest depending on the need?

Is it even possible?
Has it ever been done?
What use is such an oxymoron technology anyway?

Let us look at the evidence of strong and stable things first.

An Engineering Challenge

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Let us look at the evidence of strong and stable things first.

Extraordinary stability of an Arch

Roman Alcantara Bridge across the River Tajo, Spain.

(image source: commons.wikimedia.org)

Extraordinary stability of an Arch

52 ft tall freestanding natural arch located in Arches National Park near Moab, Utah.

(image source: commons.wikimedia.org)

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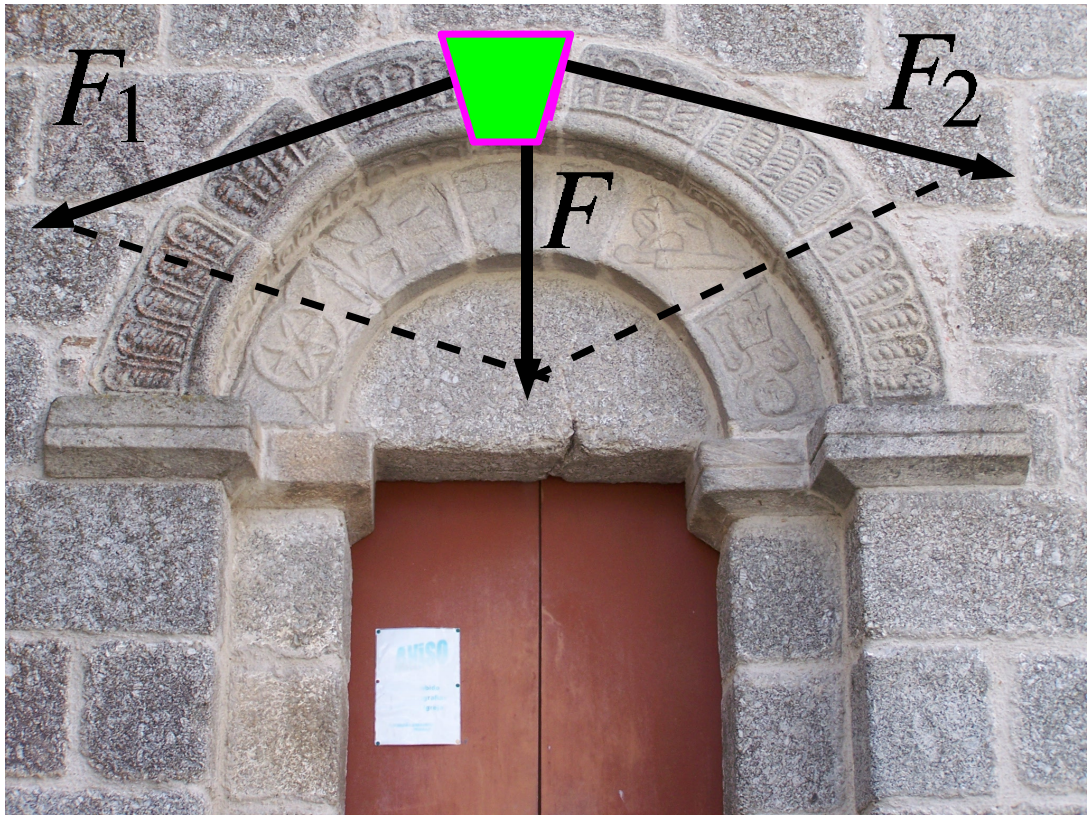
Extraordinary stability of an Arch

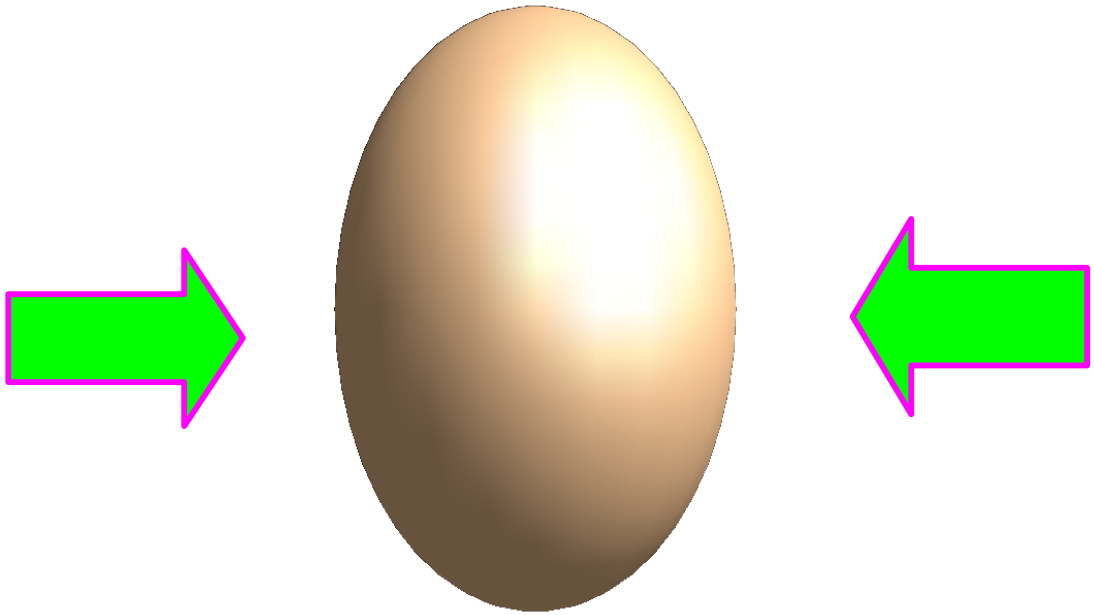
The force F on the wedge due to load above is resolved into $F_{1,2}$



Extraordinary stability of an Arch

Nature's Engineering !

Your palm or hen's weight wont brea
it and yet chiken breaks it easily.



An egg is afterall an arch.

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The Iconic Effiel Tower

Art, Economy, Power, and Engineering need not be divorced from each other!

Strangely this is what art critique had to say when it was made

"This belfry skeleton" (Paul Verlaine)

"This mast of iron gymnasium apparatus, incomplete, confused and deformed" (Francois Coppee)

"A half-built factory pipe, a carcass waiting to be fleshed out with freestone or brick, a funnel-shaped grill, a hole-riddled suppository" (Joris-Karl Huysmans)

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Gustave Effiel's Response

For my part I believe that the Tower will possess its own beauty. Are we to believe that because one is an engineer, one is not preoccupied by beauty in one's constructions, or that one does not seek to create elegance as well as solidity and durability ? Is it not true that the very conditions which give strength also conform to the hidden rules of harmony ? (...) Now to what phenomenon did I have to give primary concern in designing the Tower ? It was wind resistance. Well then ! I hold that the curvature of the monument's four outer edges, which is as mathematical calculation dictated it should be (...) will give a great impression of strength and beauty, for it will reveal to the eyes of the observer the boldness of the design as a whole

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Effiel's response: Continued...

...Likewise the many empty spaces built into the very elements of construction will clearly display the constant concern not to submit any unnecessary surfaces to the violent action of hurricanes, which could threaten the stability of the edifice. Moreover there is an attraction in the colossal, and a singular delight to which ordinary theories of art are scarcely applicable.

Effiel Tower's beauty is deeper and subtler than the skin-deep artistic perceptions of external form. It was an engineering marvel confirming to structural principles of economy, strength and durability. It achieved all this without compromising the beauty of form. This is what he meant when he said, " ..very conditions which give it strength also confirm to the hidden rules of harmony..".

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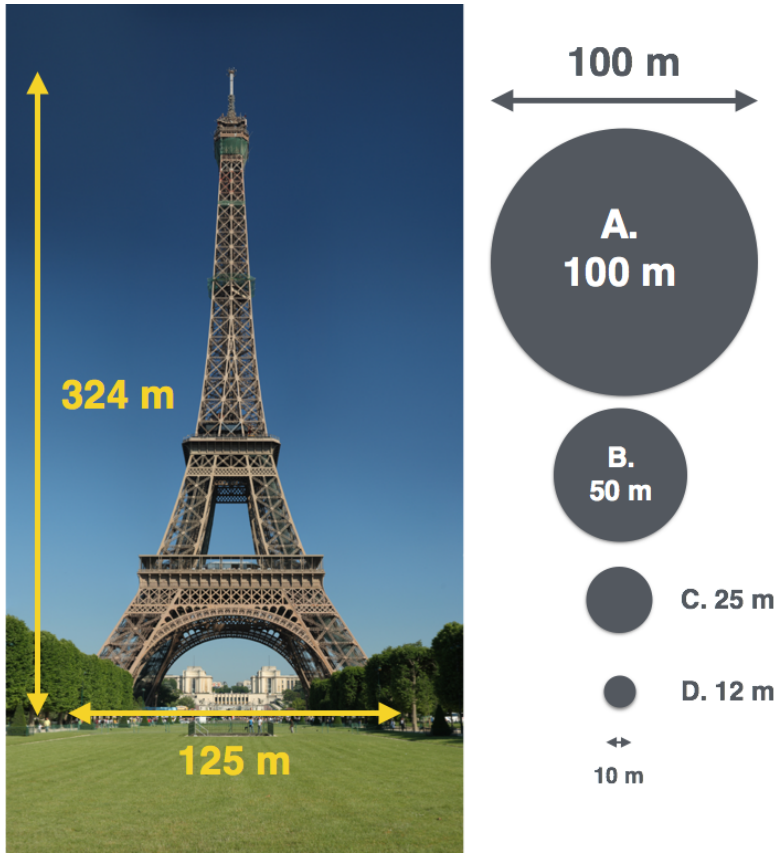
Proof of Economy: if you melt effiel tower into a solid ball, how big would the ball be?



It would be 12*m* in diameter.

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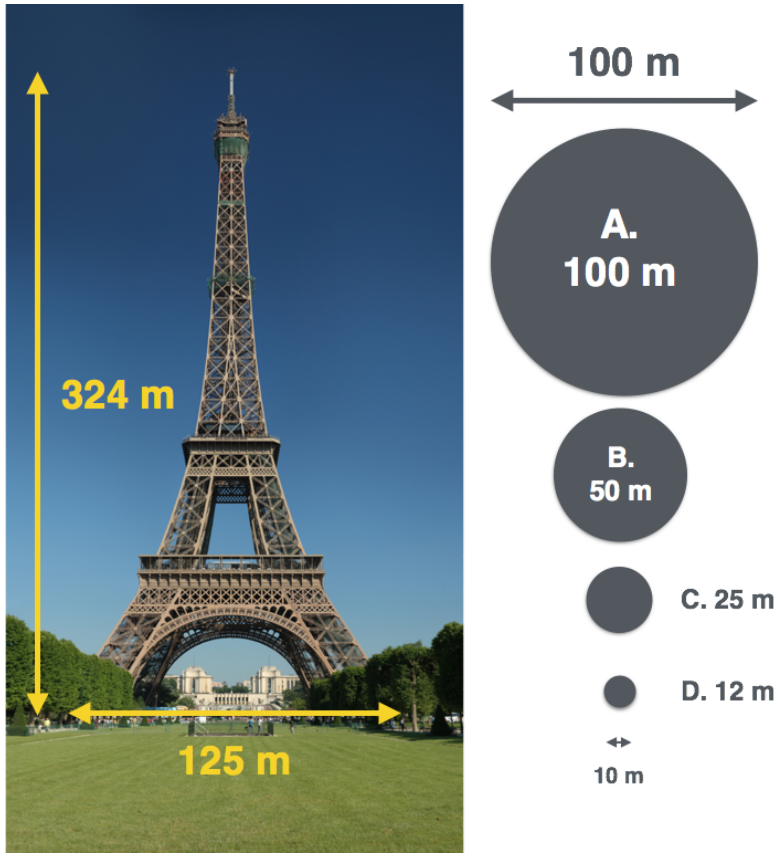

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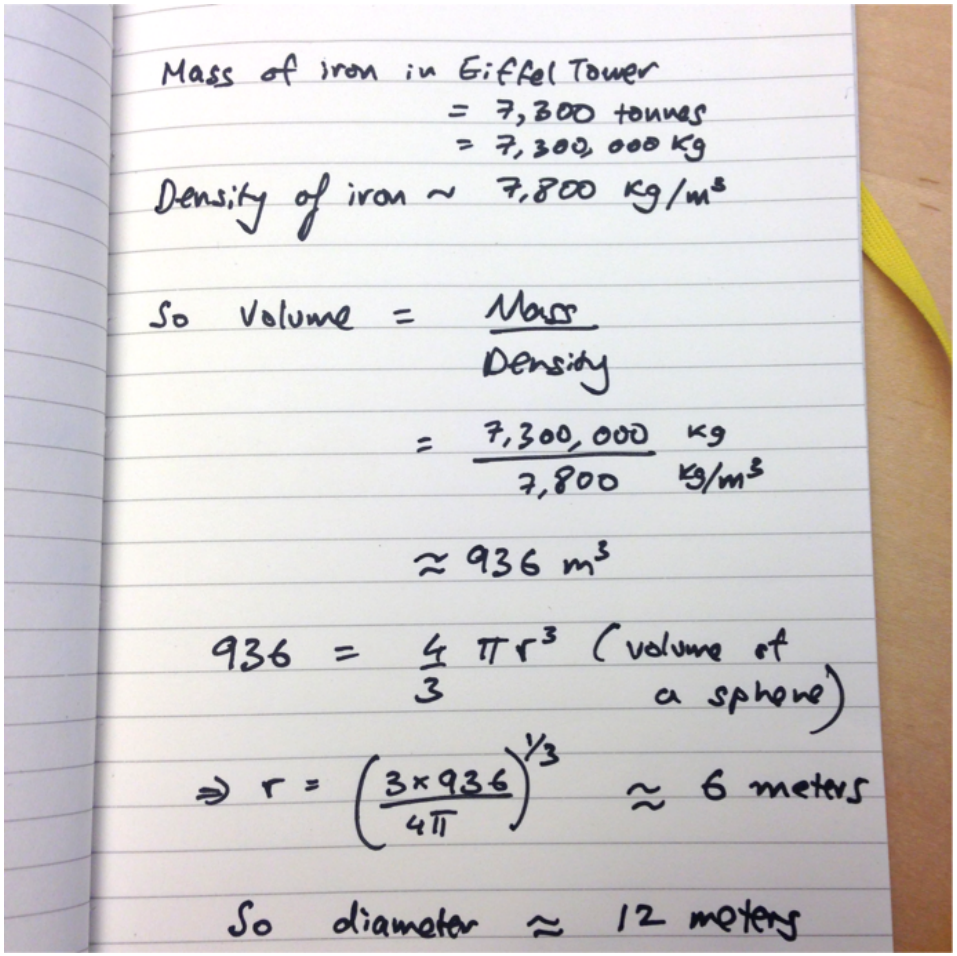
Here is the math



Source:

https://www.wired.com/wp-content/uploads/2015/03/eiffel-tower-air-weight-calculation.png

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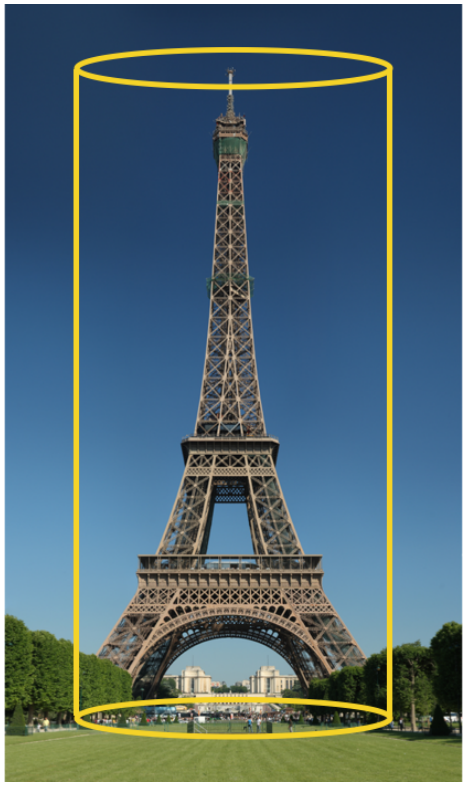
It is incredibly light!



Mass of Eiffel Tower: 7300 tonnes, Mass of cylinder of air: 9540 tonnes ! Now this is some serious engineering.

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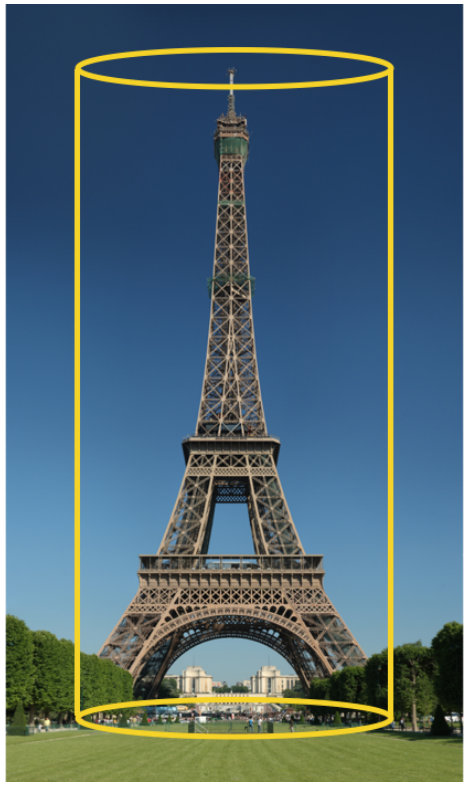

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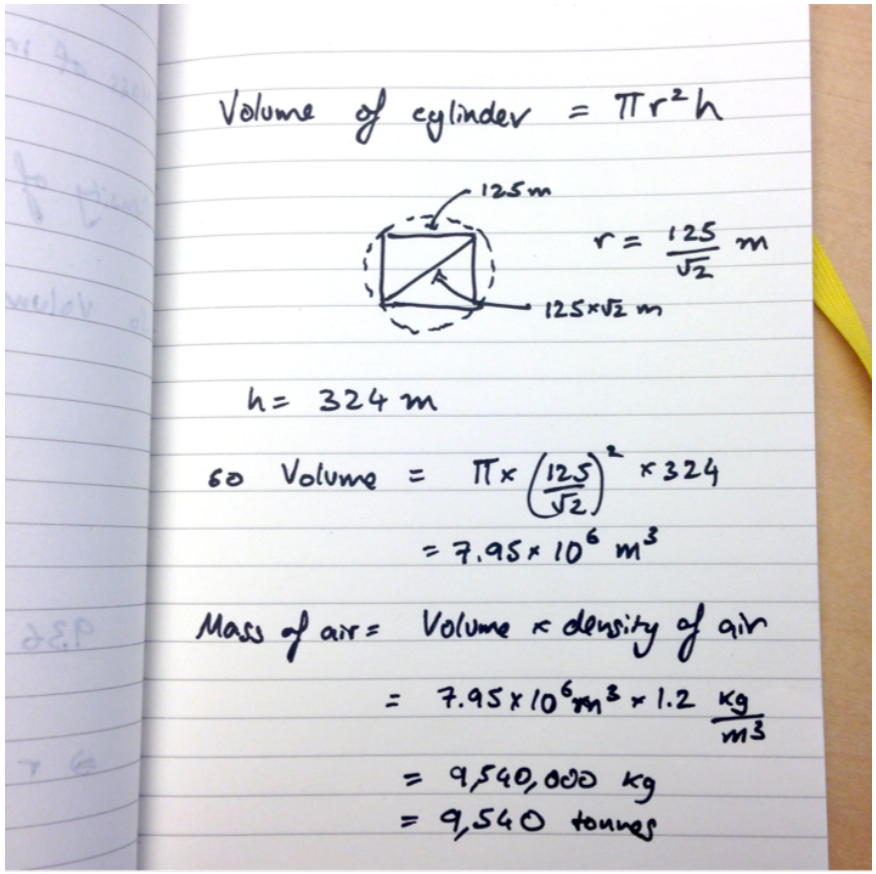

Mass of iron in Eiffel Tower = 7,300 tonnes

Source:

https://www.wired.com/wp-content/uploads/2015/03/eiffel-tower-air-weight-calculation.png

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Durability

Any structure that that has stood tall and strong weathering countless typhoons and hurricanes for over 120 years need give no proof of durability The shape of the tower is such that the combined force of the winds and its weight flows down the legs of the tower. Thus it efficiently transfers weight from where it does not want to where it wants.

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That's my crane!

Engineer Prof.Culmann visits his anatomist friend Meyer's dissection room, and he was shocked when he saw the section of bone.

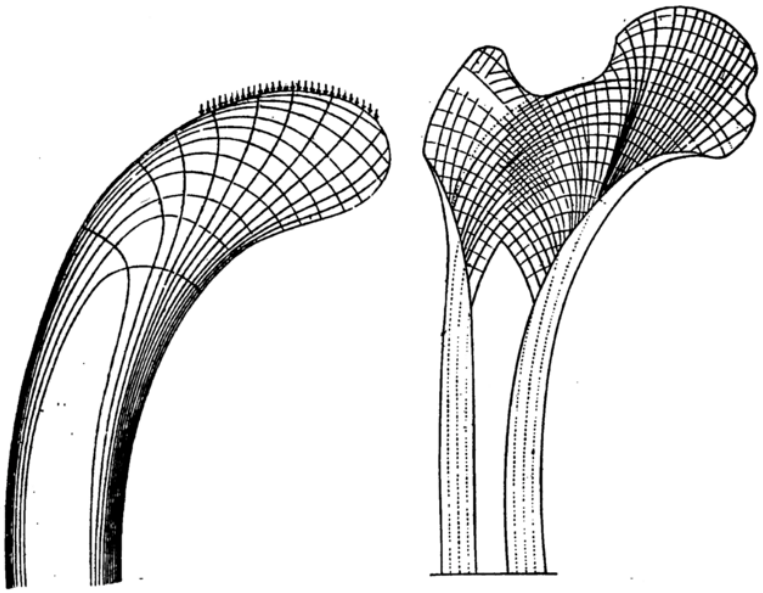
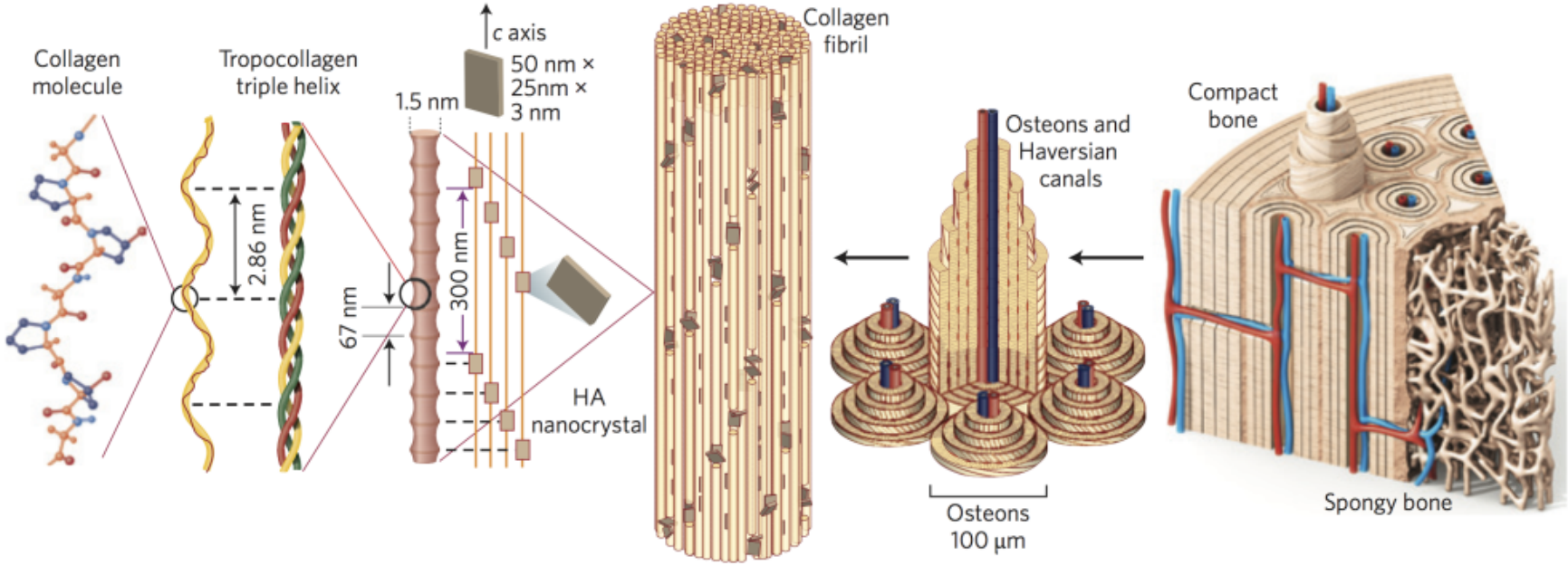


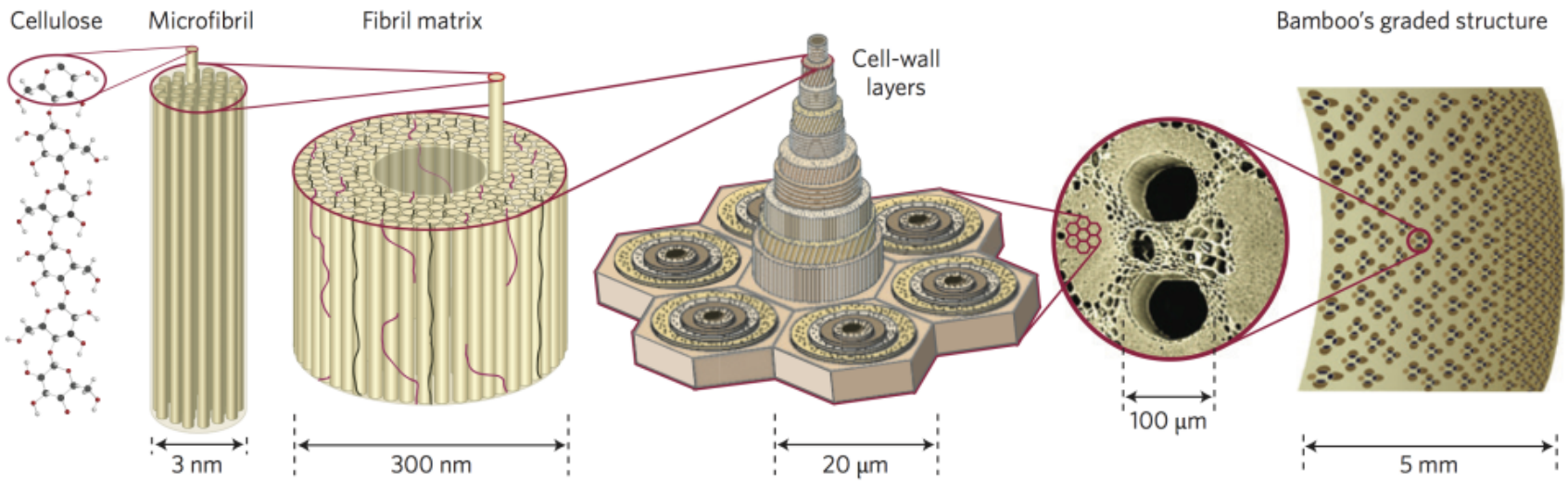
Fig. 463. Crane-head and femur. After Culmann and J. Wolff.

Secret of a bone's strength: Shapes within shapes

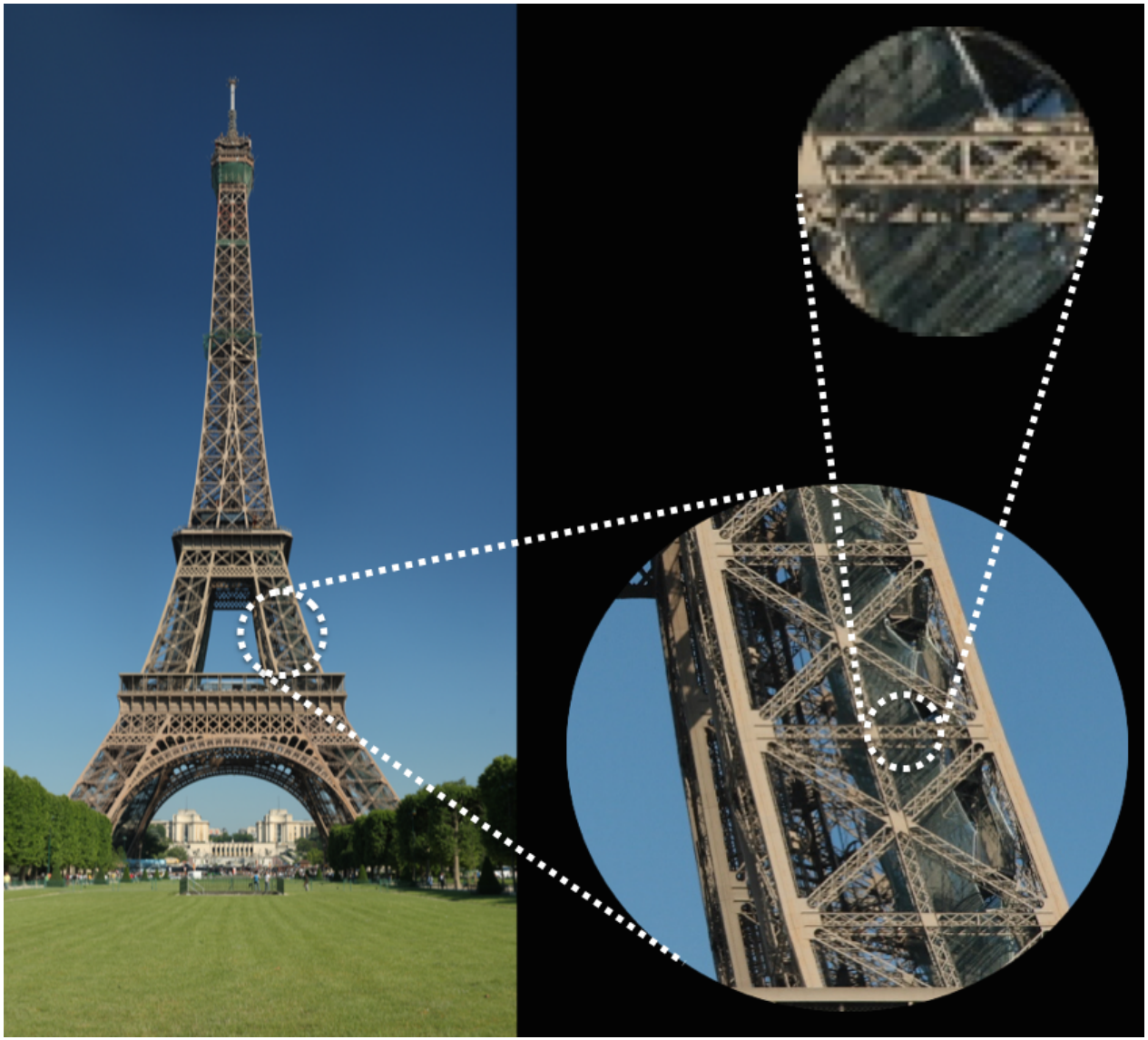


Biology inspired fracteslque engineering!

Secret of a bamboo's strength and growth: fractal structure –shapes within shapes.



Eiffel Tower uses $X - shaped$ criss-crossing (truss)



Kolkata's iconic Howrah bridge

Figure 3. Shape-hierarchy in the Howrah Bridge, Kolkata. The overall iconic shape of the bridge is one level. Within that we see cross-beams, which is the second level. Some of those cross-beams have smaller cross-beams within them, which is the third level.

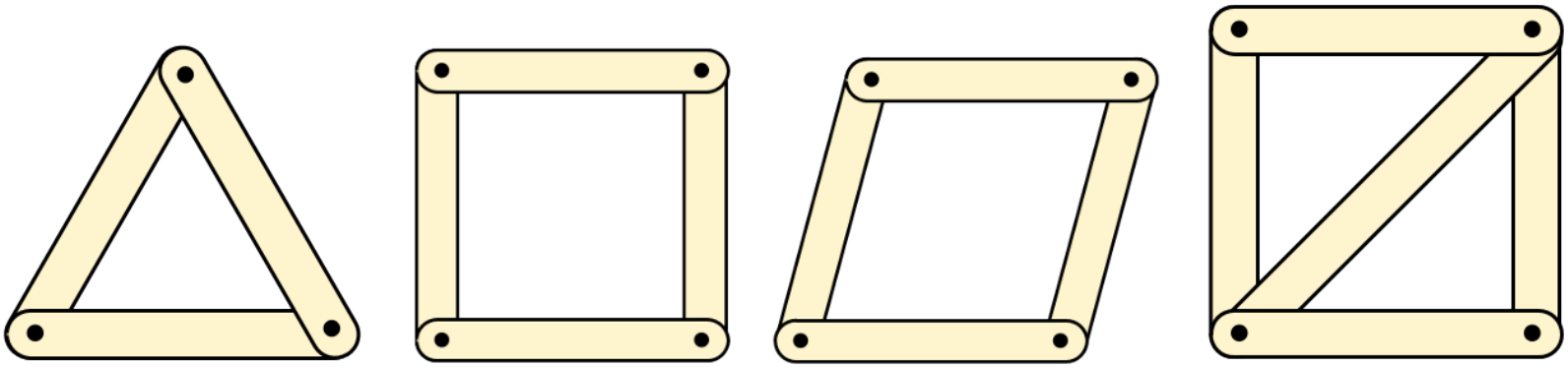
Adapted from http://www.fotothing.com.

Trusses work by transferring load

They transfer load from where you do not want them to where you do. They are light weight as they take advantage of geometry and laws of statics.

Triangular geometry preferable over squarish

A triangle transfers load more efficiently and hence cannot be easily deformed.



Because triangle is the only polygon that is rigidly determined by its sides thanks to law of cosines.

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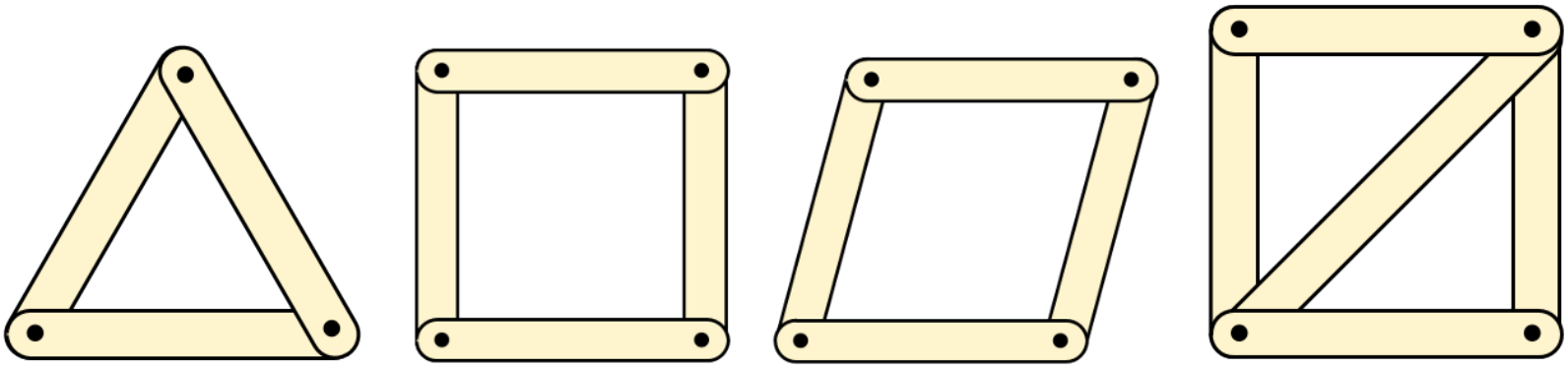

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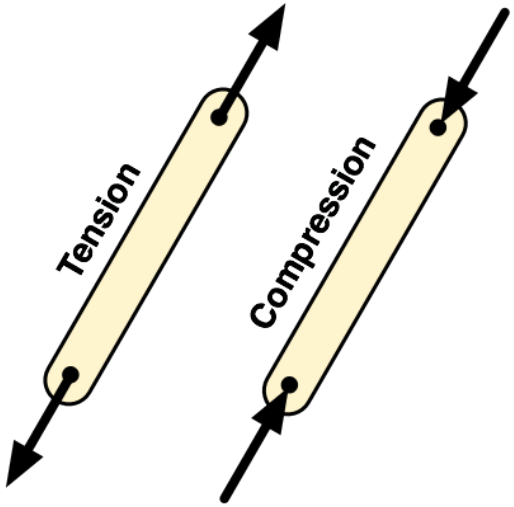
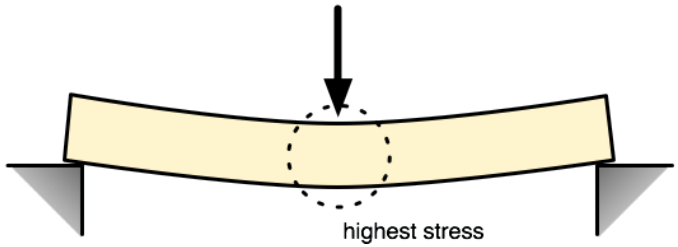
Laws of Statics

It can be shown that if the body is loaded at two points only, the resultant forces at these two points:

- are equal in magnitude
- are opposite in direction
- act along the line between the two points.

For the elements of truss, this means that forces are axial- tension or compression and shared equally by every part of the body. This is unlike that of a beam.





That is why we can break the pencil by bending from the middle but not by tension or compression.

My commonsense suggestions worth considering

- Design of toilet flush
  - 'digital vs. analog'
  - simple re-use of bath water in multi-storyed building. Design portable small scale water purification plants.
- Arresting water waste in summer(hot pipes) and winter (cold) pipes. Just insulate the tank as well as pipes better
- Rethink rain water harvesting. Design and implement Portable small scale water purification plants.
- We can't stop production of half-turn taps but we can stop purchasing them in the interest of saving water.

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So what is it all about

This lecture was not intended to explain the physics of civil engineering as much it was about inspiring design principles. Often ultimate design principles draw inspiration from math, physics, biology, and various other branches of science and engineering. It is very important to have questions in mind and approach every subject as a pursuit of those answers. You need not start with great questions but you can work them from the answers you get and constantly refine them. Answers have a way of happening to you when and where you least expect to find them. If you approach every subject with openness and are willing to learn something, then, as Steve Jobs said, you never know when you would "connect the dots backwards".

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Thoughts on Teaching (note from my Diary)

"I can only explain it to you and not necessarily make you understand things; for my explanation is only a story of how I have made sense of things. To understand, you must make sense of things yourself – experience it directly; yourself. It is possible that in your quest for understanding you are almost there, in which case my 'explanation' may help you past that penultimate layer of understanding. Not to forget, this assumes that I have made sense of things and you are almost there. Does it prove the futility of teaching in the process of learning? Not in the least. It only shows how grossly misunderstood is this thing called understanding and our take on teaching and learning.

Thoughts on Teaching (note from my Diary)

Good teaching is not as much about explaining, as much it is about inspiring. The only way to inspire is to recount a personal story of the discovery of understanding (or whatever you make of it). Such a teaching is not a guided tour to adventure climb to the summit – but only a snapshot of the view from the summit and an account of how the teacher made it. If the account is a true story of personal experience, it will inspire a climb. ”

References

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2. What Your Bones Have in Common With the Eiffel Tower – Aatish Bhatia

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