LXX. On the resistance of solids; with tables of the specific cohesion and the cohesive force of bodies

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To cite this article: Mr. Thomas Tredgold (1817) LXX. On the resistance of solids; with tables of the specific cohesion and the cohesive force of bodies , Philosophical Magazine Series 1, 50:236, 413-428, DOI: [10.1080/14786441708637810](https://doi.org/10.1080/14786441708637810)

To link to this article: <http://dx.doi.org/10.1080/14786441708637810>

Published online: 27 Jul 2009.

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2. You may, thereby, with certainty, get fruit of every good sort, of which you wish to see the produce, in the next year.

3. This method may probably serve to increase considerably the quantity of fruit in the country.

The branches so operated upon are hung full of fruit, while the others that are not ringed, often have nothing, or very little on them. This effect is easy to be explained from the theory of the motion of the sap. For, when the sap moves slowly in a tree, it produces fruit-buds, which is the case in old trees; when it moves vigorously, the tree forms wood, or runs into shoots, as happens with young trees.

Though I arrived at this discovery myself, in consequence of trying the same process with a different view, namely to increase only the size of the fruit, but not to force barren branches, that were only furnished with leaf-buds, to bear, this latter application being before quite unknown to me; I will on that account by no means give myself out for the first inventor of this operation; but I was ignorant of the effects to be produced by this method, and only discovered them by repeated experiments of my own, which I made for the promotion of pomology. Frequent experience of the completest success has confirmed the truth of my observations. Nor do I think that this method is generally known; at least, to all those to whom I showed the experiment, the effect produced appeared new and surprising. At all events, that method, supposing it even to be an invention of older date, has, as far as I know, not yet been fully described by any one, and published in print.

LXX. *On the Resistance of Solids; with Tables of the specific Cohesion and the cohesive Force of Bodies.* By Mr. THOMAS TREDGOLD*.

Definitions, &c.

1. **COHESION**, or *attraction of cohesion* †, is that force by means of which the particles of bodies are held together.

When the particles of a body cohere so slightly that they are easily moved among one another, in every direction, by a very small force, the body is called a *fluid*.

* Communicated by the Author.

† Of the nature of attraction of cohesion, nothing is known; but the phenomena prove the existence of that property of bodies to which the name is applied. It is known that the parts of bodies do cohere, and that, when accidental circumstances are excluded, a determinate force will separate them; and this force being given, the theory of the resistance of solids consists in nothing more than applying the principles of mechanics to determine the power which will destroy that cohesion, when the direction of the power, and the position and magnitude of the body, are given.

When

When the particles of a body can be moved only in a very small degree, without destroying their cohesion, the body is called a *solid*.

2. The *absolute cohesion* of solids is measured by the force necessary to pull them asunder. Thus, if a rod of iron be suspended in a vertical direction, and weights be attached to its lower extremity till the rod breaks, the whole weight attached to the rod, at the time of fracture, would be the measure of its cohesive force, or absolute cohesion.

3. The particles of solid bodies, in their natural state, are arranged in such a manner that they are in equilibrium in respect to the forces which operate on them. Therefore, when any new force is applied, it is evident that the equilibrium will be destroyed, and that the particles will move among themselves till it be restored.

When the new force is applied to pull the body asunder, the body becomes longer in the direction of the force; which is called the *extension*; and its area at right angles to the direction of the force contracts.

When the force is applied to compress the body, it becomes shorter in the direction of the force, which is called the *compression*; and the area of its section, at right angles to the force, expands*.

In either case, a part of the heat, or any other fluid, that occupied the pores or interstices of the body, before the new force was made to act upon it, will be expelled†.

4. The *depth* of a beam, or bar, is the dimension in the direction of the pressure.

Phænomena.

5. All bodies, as far as experience reaches, are extended or compressed by an adequate force.

The extensibility of the most brittle bodies may be rendered sensible by forming them into thin plates. Plates of glass bend considerably when they are only supported at the ends; and this bending could not take place unless the body were both compressible and extensible. Marriotte succeeded in extending some

* The resistance to compression does not arise from any repulsive power in the particles of bodies; indeed, we have not any facts to prove that the particles of any class of bodies actually repel each other;—as, whenever a body is forced into a less space than it occupies in its natural state, one of its constituents, at least, is always expelled; and is restored by a species of capillary attraction, as soon as the external force is removed.

† The disengagement of heat in experiments on the direct cohesion of bodies, appears to have been first noticed by Perronet in his experiments on the strength of iron. Mr. Barlow has lately observed the same phenomena in a greater degree, owing to the large size of the bar that was experimented upon—(Ann. of Phil. x. 311)—as it is obvious that the quantity of heat disengaged must be proportional to the magnitude of the body.

canes of glass, in the direction of their length, which returned to their original length when the weight was removed*.

6. The extension or compression of homogeneous bodies is directly proportional to the force which occasions it; at least in the first degrees of extension or compression.

Thus, if a wire of any metal be extended 1-10th of an inch by a weight of 100 pounds, it would be extended 2-10ths by a weight of 200 pounds; 3-10ths by 300 pounds, &c.†; also, if a body be compressed 1-10th of an inch by 100 pounds, it would be compressed 2-10ths by 200 pounds, &c.

7. In the first degrees of extension or compression, all homogeneous bodies are extended and compressed in an equal degree by equal forces. That is, if a force of 1000 pounds would extend a body 1-10th of its natural length, it would be compressed 1-10th of its natural length by the same force.

It is justly observed by a late writer on this subject, that “so far as this doctrine has been investigated by experiments, its general truth has been amply confirmed; the slight deviations from the exact proportion, which have been discovered in some substances, being far too unimportant to constitute an exception, and merely tending to show that these substances cannot have been perfectly homogeneous, in the sense here attributed to the word ‡.” In making experiments on the extension and compression of bodies, the times of action have not often been attended to with a sufficient degree of accuracy. It is well known that a certain time must elapse before the weight produces its full effect upon the body, particularly when the weight is considerable; and from a few experiments of my own, I am inclined to think, that were the weight suffered to produce its full effect at each operation, we should find the extension exactly proportional to the force, even to the time of fracture, and it is most probable that the same observation will apply to compression.

8. When a bar or beam is fixed at one end, in a horizontal position, and a sufficient weight suspended at the other end, the bar will break at the point of support; and the following phenomena will take place.

9. The bar will bend, and the bending will be proportional to the extensibility of the material.

10. The upper side of the bar will be extended, and the lower

* *Traité du Mouvement des Eaux*, Sect. v. Discours ii.

† Some experiments of this kind were made by Emerson,—*Mechanics*, Prop. 76. Ed. 1773. Bérnoulli has attempted to demonstrate that the compression cannot be proportional to the force; but his reasoning applies to extreme cases only; and the result of the solitary experiment he made is completely different from those of every other writer that I have consulted. See his paper in the *Mem. de l'Acad. des Scien.* Paris 1705, p. 179.

‡ Supplement to *Encyclop. Britannica*, art. *Bridge*, p. 497. 1817.

side compressed; but a horizontal stratum of particles, at or near the middle of the depth, will neither be extended nor compressed. Hence the line representing this stratum, in the section of the bar, is called the *neutral line*.

11. The extension and compression of any part of the section is proportional to its distance from the neutral line.

The quantity of extension and compression, and the position of the neutral line, may be observed in some soft woods, with a considerable degree of accuracy, by drawing two vertical lines, very near to each other, against one of the vertical sides of the bar at the place of fracture, before the weight is applied.

Sometimes the parts that have been extended may be distinguished from those which have been compressed by the fracture, and in fibrous substances, by stopping the descent of the bar before the fracture is completed, the position of the neutral line may be observed. The last is the best method.

Du Hamel made some experiments on bars of willow, with the view of determining the position of the neutral line, by cutting the bars to different depths, with a saw, on the compressed side*, but this method is not susceptible of much accuracy.

12. From many observations, I have found that when the section is rectangular or circular, the neutral line passes through the centre of gravity of the section, or extremely near it. Or, more generally, that when the neutral line divides the section into two parts, that are equal and similar, it passes through its centre of gravity;—and that in triangular sections the distance of the centre of gravity from the vertex is about seven-tenths of the height.

On the transverse Strength of Beams when the neutral Line divides the Section into two Parts that are equal and similar.

13. *Prop.* To determine the strength of a beam fixed at one end to support a weight suspended at the other end.

Let ABC represent the beam; where C is the point of sup-

port, EC the place of fracture, and D the place of the neutral line.

* Transport du Bois, p. 419.

Then,

Then, the weight W will act with the leverage AD ; and D will be the centre of motion. Now it is evident, that when the weight at A causes the beam to move round the centre D , the upper side at B will be extended and the lower side at C compressed (art. 10); and the strain on any part above or below the neutral line will be directly as its distance from that line; and the extension or compression will be as the strain (arts. 6 and 11).

Also, as the compressed part is the fulcrum which supports the lever till the extended part is torn asunder; and bodies are extended and compressed in equal degrees by equal forces (art. 7); therefore, the neutral line must divide the section into two equal and similar parts, because the forces on each side of the neutral line must be equal*.

Put l = the length of the beam AD ;

a = the distance of the neutral line from the upper side;

y = the breadth of the beam;

f = the cohesive force of an unit of the area;

$y\dot{x}$ = a variable part of the section of fracture;

and x = its distance from the neutral line.

Then the force of any variable part of the section is as its distance from the neutral line, or $a : x :: f : \frac{fx}{a}$; and as its area

$y\dot{x}$; hence, its whole force is $= \frac{fyx\dot{x}}{a}$; which being multiplied

by its distance from the centre of motion, gives $\frac{fyx^2\dot{x}}{a}$ = the fluxion of the force exerted by the part of the beam above the neutral line. But the forces on each side of the neutral line are equal; therefore, in the case of equilibrium, we have

$$\text{Fluent of } \frac{2fyx^2\dot{x}}{a} = lW; \text{ or flu. } \frac{2fyx^2\dot{x}}{la} = W.$$

* Most of the writers on the strength of materials have considered the point of support C , as the fulcrum to the extending forces, but the support is a fulcrum only in respect to a force at E ;—this mistake arises from the absurd method of demonstrating the properties of the lever, by supposing it to be an inflexible line; had the properties of the lever been sought for in the lever itself, this could never have happened.

In the natural order of science, the resistance of beams should occupy the place that is now assigned to the doctrine of the lever, as its properties are merely so many corollaries which naturally flow from propositions in the doctrine of the resistance of beams. For the strains excited in a beam may be investigated directly by means of the properties of the parallelogram of forces, without referring at all to those of the lever; and the properties of a beam considered as a lever, may be deduced from the strains excited in the beam, which appears to be the only legitimate mode of demonstrating its properties. See art. *Carpentry*, p. 167. Supplem. Encyclo. Brit. 3d ed. 1811; or art. *Carpentry*, p. 633, New Supp. 1817.

14. When the beam is rectangular, and its depth $= d$;
 $a = \frac{d}{2}$; and making $y = b$, we have $\frac{2fyx^2\dot{x}}{la} = \frac{4fbx^2\dot{x}}{ld}$; the
 fluent of which is $\frac{4fbx^3}{3ld}$, and when $x = \frac{d}{2}$, it becomes $\frac{fb d^3}{6l} =$
 $W =$ the transverse strength of the beam.

15. When a beam is supported at both ends, its strength to
 bear a weight in the middle of its length, is to that of a beam
 of the same length, supported at one end, as 4 is to 1. Hence
 $\frac{2fb d^3}{3l} = W =$ the strength of a beam supported at both ends.

16. When the beam is square, and the force acts in the di-
 rection of its diagonal BC; EF will be
 the neutral line, $BD = a$, and $EF = 2a$.
 Also, by sim. trians. $a : a - x :: 2a :$
 $2(a - x) = y$.

Therefore $\frac{2fyx^2\dot{x}}{la} = \frac{4f(a-x^2)\dot{x}}{la}$;
 and, when $x = a$, the fluent is $\frac{fa^3}{3l}$, or,
 because $2a = d =$ the diagonal; $\frac{fa^3}{24l} =$

$W =$ the strength of the beam supported at one end.

And when a beam of the same length is supported at both ends,
 $\frac{fa^3}{6l} = W =$ the strength of the beam.

17. When the beam is a cylinder, and its radius $= r$; $a = r$,
 and, by the property of the circle, $y = 2\sqrt{(r^2 - x^2)}$.

Therefore $\frac{2fyx^2\dot{x}}{la} = \frac{4fx^2\dot{x}\sqrt{(r^2 - x^2)}}{lr}$; and its fluent when
 $x = r$, and $p = 3.141 = 5$, &c. is $\frac{fpr^3}{4l} = W =$ the strength of a
 cylinder supported at one end; or, $\frac{fpr^3}{l} = W =$ the strength sup-
 ported at both ends.

18. From the preceding examples it appears, that when the
 length and the areas of the sections are the same, the transverse
 strengths of the beams will be nearly in the following propor-
 tion; viz.

The strength of a square beam being unity, or ..	1.000
The strength of the same beam when the force is } in the direction of the diagonal, will be }	0.7071
And that of a cylinder	0.846

It is not, however, to be expected that these proportions will
 perfectly agree with experiments, unless the material be homo-
 geneous. For this reason, timber is very unfit for the purpose
 of making experiments to establish a pure mechanical theory.

When

When a beam is compressed in the direction of its length, the deflexion is always in the direction of the diagonal, when the section is nearly square; this has been shown by the experiments of Girard, Lamandé, and Navier; and it is only a modification of the transverse strain, which confirms the general principles of the theory, and at the same time shows that a cylinder is the best form for an insulated post*.

19. When the neutral line divides the section into two parts, that are neither equal nor similar; assume the distances of the upper and lower sides of the beam from the neutral line, and find the force exerted on each side of the neutral line by art. 13. Make those forces equal to each other, and from this equation the distance of the neutral line from the upper side may be obtained; which being substituted for the assumed distance in the expression for the force of the part above the neutral line, will give half the strength of the beam.

In this manner the rule for the strength of a triangular beam has been found, which is inserted in the *Philosophical Magazine*, vol. xlvii. p. 22.†

20. As the cohesion of their parts not only serves to characterize different substances, but also to determine their relative value in the various uses to which they may be appropriated; I have endeavoured to collect from various sources, the best experiments on this important subject; and to present them in the form which appeared to me best adapted to render them capable of universal application.

For this purpose they are reduced to a common standard, from which, by a simple operation, they may be reduced to any kind of weights or measures.

I have adopted plate glass as a standard, because it is a substance tolerably uniform in its nature, its defects may be readily perceived, and it is not used where its strength need be calculated; and therefore, the strengths of different kinds of it will not be required. The experiments were made on the transverse strength, and the direct cohesion was calculated by art. 14. The pieces were loaded by letting sand run slowly into the scale till they broke. The results were regular, and the highest was taken.

* This remark extends only to the form of the section.

† The rule for the resistance to crushing (*Phil. Mag.* xlvii. 22) was an attempt to apply the principles which M. de Prony has used in his investigation of the push of the earth against retaining walls to the resistance to crushing—neglecting the effect of the cohesion in determining the angle of fracture. Since that time I have found that the angle of fracture will vary with the cohesion; therefore any rule where it is neglected can only be a rude approximation.—It may not be improper here to state, that in M. de Prony's investigation of the push of the earth, one very material element is omitted; viz. the friction against the back of the wall. The existence and effect of this friction may readily be seen from the results of Col. Pasley's experiments. "*Course of Military Instruction*," iii. 563.

Experiments on the direct cohesion of bodies require to be made with much care, in order to obtain correct results, particularly when they are brittle; and it is also very probable that the strength of bodies, to resist being torn asunder, is not exactly as their areas. For if the cohesion be as the area, it does not follow that the strain excited by a force tending to pull the body asunder should be in the same proportion. Indeed, Count Rumford's experiments led him to conclude that the strength is not in the simple proportion of the area*, and Perronet found that when a bar of iron was strained in the direction of its length, a very slight incision made with a file on one side, sometimes reduced its strength more than one-half; which could not have been the case had the strain been equally diffused over the section †.

Hence I conclude, that the length being taken so that the deflexion ‡ does not sensibly affect the result, the cohesion calculated from the transverse strength, is as near or nearer the real cohesion than that obtained by pulling the body asunder.

Morveau very justly observes that the *maximum* cohesion of the metals ought not to enter into the calculations of the artist who employs them, as it is known that accidental imperfections always accelerate the rupture in a greater or less degree, and render it necessary to augment their dimensions; but it is not less true that their proportional tenacity being known, it would assist the artist in his choice, and furnish the valuable means of ascertaining the degree of purity, and the qualities which are imparted to them in the course of their manufacture§.

It will be seen from the following Tables, that the cohesive force of metals is much increased by wire-drawing, rolling, and hammering; and that the strength of woods of the same kind is extremely variable, depending on the nature of the soil, the situation, and the climate where they are grown.

A complete table ought to exhibit the limits of these variations, and might be made to contain much useful information for the planter and landed proprietor,—but not till experimentalists give better descriptions of the specimens they try, than they have hitherto done.

In the following tables the specific cohesion of plate glass is denoted by unity; and,

The cohesive force of a square inch is 9420 pounds avoirdup.

.. .. of a squ. millimetre is 6.62 kilogram. nearly.

.. .. of 25 squ. centim. is 16543.625 kilograms.

.. .. of a square ponce is 9906.26 Paris pounds.

Hence the specific cohesion of a substance multiplied by one of these numbers will give the cohesion in the corresponding weights and measures.

* Phil. Mag. x. 51.

† Œuvres de Gauthey, ii. 150.

‡ On the effect of the deflexion, see Phil. Mag. xlv. 191.

§ *Ann. de Chimie*, lxxi. 190.

TABLES OF THE COHESIVE FORCE OF SOLID BODIES.

TABLE I.—METALS.

(h) and (l) mark the highest and lowest result which Muschenbroëk obtained from each kind of iron.

Metals.	Specific Cohesion. Glass 1.	Cohesive Force of a square Inch in lbs. avoird.	Specific Gravity.	Hardness.	Authority.
STEEL.					
Razor temper.....	15.927	150,000	7.78	†	Muschenbroëk, Encyclo. Brit.
Soft	12.739	120,000	7.84	‡	art. <i>Strength</i> . Idem.
IRON.					
Wire	12.004	113,077	from 7.6 to 7.84	from 8 to 9.6	Sickingen, Ann. de Chimie xxv. 9.
German bar, mark } BR (h)	9.880	93,069			Muschenb. Intr. ad Phil. Nat. i. 426.
Swedish bar (h) } German bar, mark } L (h)	9.445	88,972			Idem.
Wire	9.119	85,900			Idem.
Bar	9.108	85,797			Buffon, Œuvres de Gauthey i.
Bar	8.964	84,443			Emerson, Mechanics, 115.
Liege bar (h)	8.794	82,859			Muschenb. Intr. ad Phil. Nat. i. 426.
Spanish bar	8.685	81,901			Idem.
Bar	8.581	80,853			Soufflot, Rondelet's L'Art de Bâtir, iv. 500.
Bar	8.492	80,000			Edin. Encyclo. art. <i>Bridge</i> , 544.
Oosement bar (h) ..	8.142	76,697			Muschenb. Intr. ad Phil. Nat. i. 426.
Cable	7.752	73,024			Annals of Phil. vii. 320.
German bar, mark } L (l)	7.382	69,538			Muschenb. Intr. ad Phil. Nat. i. 426.
German bar, common } Swedish bar, } Oosement bar } (l)	7.339	69,133			Idem.
Bar of best quality ..	7.296	68,728			Idem.
Liege bar (l)	7.006	66,000			Rumford, Phil. Mag. x. 51.
German bar, mark } BR (l)	6.621	62,369			Muschenb. Intr. ad Phil. Nat. i. 426.
Bar*	6.514	61,361			Idem.
Bar of good quality ..	6.480	61,041			Perronet, Œuv. de Gauthey, ii. 154.
Cable	5.839	55,000			Rumford, Phil. Mag. x. 51.
Bar, fine-grained	5.787	54,513			Annals of Phil. x. 311.
— medium fineness ..	5.306	49,982			Rondelet, L'Art de Bâtir, iv. 502.
— coarse-grained	3.618	34,081			Idem.
	2.172	20,460			Idem.
CAST IRON.					
French	7.470	70,367	7.907		Navier, Œuv. de Gauthey, ii. 150.
German	7.250	68,295			Muschenb. Intr. ad Phil. Nat. i. 417.
French, soft	6.754	63,622			Rondelet, L'Art de Bâtir, iv. 514.
English	5.520	52,000			Banks, Gregory's Mechan. i. 129.
French	5.412	50,981			Ex. i.
—	4.540	42,666			L'Ecole des Ponts, &c. Gaut. ii. 150.
English, soft	4.334	40,824			Gauthey, Œuvres ii. 150.
				§	Banks, Greg. Mech. i. 128. Ex. iii.

† Kirwan, Elem. Miner ii. 155.

* This is the mean result of thirty-three experiments.

‡ Calculated from experiments on the transverse strength, by arts. 14 and 15.

§ Yielded to the file without difficulty.

TABLE I—(continued.)

Metals.	Specific Cohesion. Glass l.	Co. Force of a sq. inch in lbs av. r.	Specific Gravity.	Hardness.	Authority.
CAST IRON.					
French gray	4.000	37,680			Rondelet, L'Art de Bâtir, iv. 514.
Gray, of Cruzot, } 2d fusion	3.257	30,680			Ramus, Gauthey, ii. 150,
Gray, of Cruzot, } 1st fusion †	3.202	30,162			Ramus, Gauthey, ib. §
COPPER.					
Wire	6.606	61,228			Sickingen, Ann. de Chimie, xxv. 9.
Cast, Barbary	2.596	22,570	8.182		Muschenb. Intr. ad Phil. Nat. i. 417.
—, Japan	2.52	20,272	8.726	8†	Idem.
PLATINUM.					
Wire	5.995	56,473	20.847	8	Morveau, Ann. de Chimie, xxv. 8.
Wire	5.625	52,987			Sickingen, Ann. de Chim. xxv. 9.
SILVER.					
Wire	4.090	38,257			Sickingen, Ann. de Chim. xxv. 9.
Cast	4.342	40,902	11.091	7	Muschenb. Intr. ad Phil. Nat. i. 417.
GOLD.					
Wire	3.279	30,888			Sickingen, Ann. de Chim. xxv. 9.
Cast	2.171	20,450	19.238	6†	Muschenb. Intr. ad Phil. Nat. i. 417.
TIN.					
Wire	0.7568	7,129			Morveau, Ann. de Chim. lxxi. 194.
Cast, English block . .	0.706	6,650			Muschenb. Intr. ad Phil. Nat. i. 417.
—, idem	0.565	5,322	7.295	6†	Idem.
—, Banca	0.3906	3,679	7.2165		Idem.
—, Malacca	0.342	3,211	6.1276		Idem.
BISMUTH.					
Cast	0.845	3,250	9.810		Muschenb. Intr. ad Phil. Nat. i. 417.
—	0.3193	3,008	9.926	7	Idem, i. 454.
ZINC.					
Wire	2.394	22,551			Morveau, Ann. de Chim. lxxi. 194.
Patent sheet	1.762	16,616			By my trial.
Cast, Goslar, from to . .	0.3118	2,937	7.215	6†	Muschenb. Intr. ad Phil. Nat. i. 417.
	0.2855	2,689			
LEAD.					
Milled	0.3533	3,328	11.407		By my trial.
Wire	0.334	3,146	11.348		Muschenb. Intr. ad Phil. Nat. i. 452.
Wire	0.274	2,581	11.282	5	Idem.
Wire	0.2704	2,547			Morveau, Ann. de Chim. lxxi. 194.
Cast, English	0.094	885	11.479		Muschenb. Intr. ad Phil. Nat. i. 452.
Antimony, cast . . .	0.1126	1,060	4.500	6†	Muschenb. Intr. ad Phil. Nat. i. 417.

§ In the operation of casting, the surface of the iron always becomes much harder, and is more tenacious than the internal parts; hence, the strength of a small specimen is always greater than that of a large one. Those of M. Ramus, however, are unexceptionable in this respect, as the area of the section at the place of fracture was above nine square inches.

N. B. When the specific gravity is not referred to a separate authority, it is to be considered that of the specimen of which the cohesive force is given.

† Kirwan's Miner. vol. ii.

|| Thomson's Chemistry, vol. i.

TABLE II—ALLOYS.

Alloy of		Specific Cohesion. Glass 1.	Cohesion of square inch. in lbs. avoird.	Specific Gravity.	Authority.
Parts.	Parts.				
Gold	2 Silver	1	2.972	28,000	Musch. Encyclop. Brit. art.
Gold	5 Copper	1	5.307	50,000	Idem. [Strength.
Silver	5 Copper	1	5.148	48,500	Idem.
Silver	4 Tin	1	4.352	41,000	Idem.
Brass			4.870	45,882	Muschenb., Colson, i. 242.
Copper	10 Tin	1	3.407	32,093	Musch. Intr. ad Phil. Nat.
Copper	8 Tin	1	3.831	36,088	Idem. [i. 428.
Copper	6 Tin	1	4.687	44,071	Idem.
Copper	4 Tin	1	3.794	35,739	Idem.
Copper	2 Tin	1	0.108	1,017	Idem.
Copper	1 Tin	1	0.077	725	Idem.
Tin, English, 10	Lead	1	0.733	6,904	Musch. Intr. ad Phil. Nat.
Tin, ———, 8	Lead	1	0.841	7,922	Idem. [i. 438.
Tin, ———, 6	Lead	1	0.849	7,997	Idem.
Tin, ———, 4	Lead	1	1.126	10,607	Idem.
Tin, ———, 2	Lead	1	0.793	7,470	Idem.
Tin, ———, 1	Lead	1	0.751	7,074	Idem.
Tin, Banca, 10	Antimony ..	1	1.187	11,181	7.359 Musch. Intr. ad Phil. Nat.
Tin, ———, 8	Antimony ..	1	1.049	9,881	7.276 Idem. [i. 442.
Tin, ———, 6	Antimony ..	1	1.341	12,632	7.228 Idem.
Tin, ———, 4	Antimony ..	1	1.431	13,450	7.192 Idem.
Tin, ———, 2	Antimony ..	1	1.277	12,029	7.105 Idem.
Tin, ———, 1	Antimony ..	1	0.338	3,184	7.060 Idem.
Tin, ———, 10	Bismuth	1	1.347	12,688	7.576 Musch. Intr. ad Phil. Nat.
Tin, ———, 4	Bismuth	1	1.772	16,692	7.613 Idem. [i. 443.
Tin, ———, 2	Bismuth	1	1.488	14,017	8.076 Idem.
Tin, ———, 1	Bismuth	1	1.276	12,020	8.146 Idem.
Tin, ———, 1	Bismuth	2	1.063	10,013	8.58 Idem.
Tin, ———, 1	Bismuth	4	0.836	7,875	9.009 Idem.
Tin, ———, 1	Bismuth	10	0.411	3,971	9.439 Idem.
Tin, ———, 10	Zinc Indian, 1	1	1.371	12,914	7.288 Musch. Intr. ad Phil. Nat.
Tin, ———, 2	Zinc	1	1.595	15,025	7.000 Idem. [i. 444.
Tin, ———, 1	Zinc	1	1.682	15,844	7.321 Idem.
Tin, ———, 1	Zinc	2	1.701	16,023	7.100 Idem.
Tin, ———, 1	Zinc	10	0.602	5,671	7.130 Idem.
Tin, English, 1	Zinc, Goslar 1	1	0.958	9,024	Musch. Intr. ad Phil. Nat.
Tin, ———, 2	Zinc	1	1.164	10,964	Idem. [i. 446.
Tin, ———, 4	Zinc	1	1.089	10,258	Idem.
Tin, ———, 8	Zinc	1	1.126	10,607	Idem.
Tin, ———, 1	Antimony ..	1	0.154	1,450	7.000 Musch. Intr. ad Phil. Nat.
Tin, ———, 3	Antimony ..	2	0.338	3,184	Idem. [i. 448.
Tin, ———, 4	Antimony ..	1	1.202	11,323	Idem.
Lead, Scotch, 1	Bismuth	1	0.777	7,319	10.931 Musch. Intr. ad Phil. Nat.
Lead, ———, 2	Bismuth	1	0.620	5,840	11.090 Idem. [i. 454.
Lead, ———, 10	Bismuth	1	0.300	2,826	10.827 Idem.

TABLE III.—WOODS.

Woods.	Specimen Cohesion. Class I.	Cohesion of a square inch, in lbs. avoird.	Specific Gravity,	Authority.
Lance-wood	2·621	24,596	1·022	Layman, Nich. Journal, xxxv. 54.
Locust-tree	2·185	20,582		Muschenb. Intr. ad Phil. Nat. i. 415.
Jujube (Ziziphus) ..	2·008	18,915		Idem, i. 414.
Ash (Fraxinus) ..				
Red, seasoned ..	1·899	17,892	0·812	Layman, Nich. Journal, xxxv. 54.
Ash	1·804	17,000		Barlow, Rees's Cyclop. art. <i>Strength</i> .
White, seasoned ..	1·509	14,220	0·685	Layman, Nich. Journal, xxxv. 54.
Ash	1·274	12,000		Muschenb. Ency. Brit., art. <i>Strength</i> .
Oak (Quercus) ..				
Oak	1·891	17,820		Emerson's Mechanics, 114. Ed. 1773.
—, highest result ..	1·861	17,532		Banks, Gregory's Mechan. i. 127.
—, ..	1·836	17,300		Muschenb. Ency. Brit., art. <i>Strength</i> .
Dry, cut 4 years ..	1·707	16,079		Duhamel, Transport du Bois, p. 212.
Provence, season.*	1·559	14,685	1·164	Idem, 434.
English, seasoned,†	1·509	14,220	0·880	Layman, Nich. Jour. xxxv. 54.
Oak	1·481	13,951		Rondelet, L'Art de Bâtir, iv. 65.
French, season.†	1·450	13,659		Duhamel, Trans. du Bois, 213.
Provence, season.‡	1·444	13,602	0·828	Idem, 423.
Provence, season. young	1·565	12,839	0·771	Idem, 230.
Oak, dry	1·274	12,000		Muller, Pract. Fortification, 76.
Baltic, seasoned ..	1·211	11,412	0·675	Layman, Nich. Jour. xxxv. 54.
Oak, lowest result ..	1·146	10,840		Banks, Gregory's Mech. i. 127.
—, ..	1·107	10,428		Belidor, Scien. des Ingen. 319. Ed. 1813.
English,	1·085	10,224		Beaufoy, Ann. Phil. ix. 286. Ex. No. 4.
Oak,	1·076	10,136		Belidor, Scien. des Ing. 321. Ed. 1813.
French, unseason.‡	1·060	9,985	1·068	Buffon, Mém. de l'Acad. Paris, 1741, [329.
White American, seasoned ..	1·009	9,504		Layman, Nich. Jour. xxxv. 54.
Oak,	1·009	9,504		Barlow, Rees's Cyclo. art. <i>Strength</i> .
French, unseason.†	0·960	9,043		Buffon§, Mém. de l'Acad. Paris, 1741, [328.
Oak	0·955	9,000	0·774	Barlow, Rees's Cyclop. art. <i>Strength</i> .
English	0·936	8,820		Beaufoy, Ann. of Phil. ix. 297. Ex. 10.
Dantzic	0·818	7,704		Idem, 233. Ex. 19.
Beech (Fagus sylvaticus) ..	1·880	17,709		Muschenb. Intro. ad Phil. Nat. i. 415.
Arbutus, from ..	1·845	17,379		
—, to ..	0·814	7,667		Idem, 414.
Orange (Aurantium) ..	1·764	16,616		Idem.
—, to ..	1·629	15,345		
Bay (Laurus) ..	1·547	14,572		
—, to ..	1·085	10,220		Idem.

* Its colour brown; and it was hard and large-veined.

† This specimen lay six months in water after it was cut, and was afterwards dried. When the trial was made it had been cut four years.

‡ Middle-aged timber, fine-veined, light and pliant.

§ To find the distance between the supports, in Buffon's experiments, I deducted one-twelfth of the length of the piece, according to the notice he has given in the beginning of his memoir; the two results given are the highest and lowest from the eight-foot lengths.

TABLE

TABLE III.—(continued.)

Woods.	Specific Cohesion. Class I.	Cohesion of a square inch. in lbs. avoird.	Specific Gravity.	Authority.
TEAK (<i>Tectona grandis</i>).				
Java, seasoned, . . . †	1.509	14,220	0.697	Layman, Nich. Journ. xxxv. 54.
Pegu, seasoned, . . . †	1.400	13,194	0.619	Idem.
Malabar, seasoned, †	1.295	13,140	0.688	Idem.
Alder (Bet. <i>Alnus</i>)	1.506	14,186		Muschenb. Intr. ad Phil. Nat. i. 414.
Mulberry (<i>Morus</i>)	1.492	13,054		} Idem.
	1.221	11,501		
Elm (<i>Ulmus</i>) . . .	1.432	13,489		Idem.
Firs (<i>Pinus</i>).				
Pitch pine, †	1.398	13,176		Layman, Nich. Journ. xxxv. 54.
Fir †	1.380	13,000		Barlow, Rees's Cyclop. art. <i>Strength</i> .
Fir (strongest) . . . †	1.318	12,420		Banks, Gregory's Mech. i. 127.
Pitch pine, †	1.284	12,096		Beaufoy, Ann. of Phil. ix. 304, 305.
Pine (Pin du Nord), †	1.264	11,913		Duhamel, Transport du Bois, 460.
Larch (<i>Pinus Larix</i>), †	1.177	11,093	0.636	By my trials. †
Fir, strong red, . . . †	1.172	11,040		Muller, Pract. Fortification, 76.
Fir, Memel, season . . †	1.154	10,876		By my trial.
Fir, Russian †	1.062	10,608	0.459	Layman, Nich. Journ. xxxv. 54.
Fir †	1.061	10,000		Barlow, Rees's Cyclop. art. <i>Strength</i> .
Fir †	1.039	9,792		Idem.
Fir, Riga †	0.963	9,072		Beaufoy, Ann. of Phil. ix. 290, 291.
Fir, American †	0.942	8,874	0.416	Layman, Nich. Journ. xxxv. 54.
Fir †	0.903	8,506		Muschenb. Intr. ad Phil. Nat. i. 414.
—, yellow deal . . . †	0.900	8,478	0.472	Layman, Nich. Journ. xxxv. 54.
Fir, weakest †	0.879	8,280		Banks, Gregory's Mech. i. 127.
Larch, Scotch, seasoned †	0.837	7,888	0.496	Layman, Nich. Journ. xxxv. 54.
Pitch pine †	0.830	7,818		Muschenb. Intro. ad Phil. Nat. i. 414.
Larch, Scotch, very dry, . . . †	0.745	7,020	0.470	By my trial, very young wood, the lateral cohesion between the annual rings was 1760 lbs. per inch superfi.
Fir, Scotch (<i>P. sylvestris</i>) †	0.711	6,600	0.550	By my trials, it was seasoned.
Fir, white deal . . . †	0.455	4,290	0.498	By my trials, very dry.
Sissor, of Bengal . . †	1.395	13,140	0.889	Layman, Nich. Journ. xxxv. 54.
Saul, of Bengal . . . †	1.375	12,960	0.962	Idem.
Plum, (<i>Prunus</i>) . . . †	1.357	12,782		} Muschenb. Intr. ad Phil. Nat. i. 415.
— to . . . †	1.205	11,351		
Willow (<i>Salix</i>) . . . †	1.357	12,782		Idem.
Willow, dry †	0.8098	7,628		Duhamel, Trans. du Bois, 419.

† The specimen was taken from the middle between the centre and sapwood, about three feet from the root;—the diameter of the tree was nearly 18 inches, and the wood from which the specimen was taken had been cut into two-inch planks about six months. The wood was tough, hard, and weighed $39\frac{3}{4}$ pounds per cube foot;—the distance of the annual rings was about an eighth of an inch, and the wood appeared silky when planed. It was grown upon the Duke of Athol's estate at Blair, in Scotland; and the experiments were made at the desire of William Atkinson, Esq. Architect to the Ordnance, &c.

TABLE

TABLE III.—(continued.)

Woods.	Specific Cohesion. Glass l.	Cohesion of a square inch: in lbs. avoird.	Specific Gravity.	Authority.
MAHOGANY (Swietenia).				
Spanish,.....‡	1·283	12,186	0·753	Layman, Nich. Journ. xxxv. 54.
Citron (Citreum) ..	1·357	12,782		Muschenb. Intro. ad Phil. Nat. i. 414.
to..	0·868	8,176		Idem.
CHESNUT, Sweet, (Fagus castanea.)				
100 years in use +	1·291	12,168	0·877	Layman, Nich. Journ. xxxv. 54.
Jasmine (Jasminum) ..	1·276	12,020		Muschenb. Intro. ad Phil. Nat. i. 414.
to..	1·248	11,756		
Pomegranate (Punica) ..	1·221	11,501	}	Idem.
to..	0·882	8,308		
Tamarisk (Tamariscus) ..	1·194	11,247		Idem.
to..	0·732	6,895	}	
MAPLE (Acer).				
Norway‡	1·123	10,584	0·793	Layman, Nich. Journ. xxxv. 54.
Elder (Sambucus) ..	1·086	10,230		Muschenb. Intro. ad Phil. Nat. i. 415.
Lemon (Limon) ..	1·004	9,457		Idem. 414.
Quince (Cydonia) ..	0·841	8,822	}	Idem.
to..	0·624	5,878		
Cypress (Cupressus) ..	0·732	6,895		Idem.
to..	0·542	5,105	}	Idem.
Poplar (Pop. alba) ..	0·705	6,641		Idem.
to..	0·488	4,596		
Poplar (P. nigra) lateral cohesion of the annual rings ..‡	0·189	1,782	0·421	By my trials—the specimen very dry.
Cedar	0·528	4,973		Muschenb. Intro. ad Phil. Nat. i. 414.

‡ Those to which this mark is added were calculated from experiments on the transverse strength.

TABLE IV.—MISCELLANEOUS SUBSTANCES.

Substances.	Specific Cohesion, Glass I.	Cohesion of a square inch in lbs. avoird.	Specific Gravity.	Authority.
Hemp fibres } glued together }	9.766	92,000		Rumford, Phil. Mag. x.
Paper strips } glued together }	3.134	30,000		Idem.
Ivory	1.765	16,626		Muschenb. Intro. ad Phil. Nat. i. 463.
Slate, Welsh, (clay slate) †	1.353	12,800		By my trials.
Plate-glass	1.000	9,420	2.455	By my trials.
Marble (white) †	0.955	9,000		Robison, Gregory's Mech. i. 129.
Horn of an ox . . .	0.951	8,949		Muschenb. Intro. ad Phil. Nat. i. 463.
Whalebone	0.814	7,657		Idem.
Bone of an ox . . .	0.559	5,263		Idem.
Hard stone† of Givry	0.230	2,166	2.357	Gauthey, Roz. Journ. de Physiq. iv. 413.
Portland stone, (compact lime- stone),	0.083	784		By my trials.
Soft stone* of Givry,	0.041	385	2.071	Gauthey, Roz. Journ. de Physiq. iv. 313.
Brick from	0.031	300		} Coulomb, Young's Nat. Phil. ii. 174.
— to	0.030	280		
Brick from Dork- ing,	0.029	275		} By my trial,—colour deep-brick red, brittle.
Stone, homogene- ous white, of a fine grain	0.022	207		
Plaster of Paris . .	0.0077	72		Rondelet, L'Art de Bâtir, i. 314.
Mortar of sand and lime, 16 years made . . .	0.0054	50		Idem.

In our inquiries respecting the laws which regulate the phænomena of nature, we must always exclude certain circumstances which are not necessary, nor do not always accompany the phænomena.

This principle of exclusion is one of the most prominent fea-

† This stone was hard, of a red colour, and the beds distinctly marked.

* This stone was white, rather soft, and the beds not distinctly marked. These numbers were calculated from experiments on the transverse strength, because the experiments which Gauthey made on the suspending strength are so extremely irregular. He appears to have been aware of the principal cause, which was owing to his mode of fixing the pieces. The results of Gauthey's experiments on the suspending strength of stones have been, by mistake, copied as experiments on crushing, by Professor Robison, in his article *Strength of Materials*, Encyclo. Brit. See 4th edition, p. 759. This mistake has been copied by some other writers from the article above mentioned, and among others by the writer of the article *Strength*, Rees's Cyclopædia.

Gauthey's experiments on crushing are much more numerous and regular. See Rozier's Journal de Physique, iv. 406.

tures

tures of Bacon's method of reasoning*; and has been the guide of Newton in his noble discoveries.

In the resistance of solids, we must consider them homogeneous—that they may be extended and compressed in equal degrees by equal forces and proportionally by proportional forces, at least till it is shown by unexceptionable experiments on homogeneous bodies, that these principles are not consistent with the phenomena.

The effect of the deflexion should not be excluded in a perfect theory; but it has been omitted in calculating the preceding tables to save calculation, as it doubles the labour, while the corrections from introducing are too trifling to sensibly affect the result. Besides, such niceties are not needed for practical purposes, where simplicity is much more esteemed.

Timber is not homogeneous; and therefore it is not a proper material to verify the theory. I have found the transverse strengths of two pieces, of the same size, cut from the side of each other, to be as 9 to 12. Duhamel found pieces of the same size, and from the same zone, to be as 57 to 66 †;—these different results were caused by varying the position of the annual rings. The difference of specimens, from the same tree, both in weight and cohesive force, has been shown by Buffon ‡. Now when such differences are found in the same tree, is it wonderful that experiments, made in different countries, on wood of different ages, seasoned by different methods, and grown on different soils, should differ from one another?—Is it not rather to be wondered at, that they should agree so nearly as they do? Yet, how often has the correctness of these experiments been called in question where it was almost impossible that the writers could be mistaken!

LXXI. *Some further Observations on the Use of the Colchicum autumnale in Gout.* By Sir E. HOME, Bart., V.P.R.S. §

I LAID before the Society, some experiments and observations in favour of this medicine acting upon the gout through the medium of the circulation, and not by its effects directly upon the stomach and intestinal canal.

The object of the present paper is to show that the infusion throws down a deposit, the separation of which does not appear to diminish the specific effects upon the gout, and renders those upon the stomach and intestines milder than when the deposit is taken along with the infusion.

* Nov. Organ. lib. ii. Aph. 18. † Transport du Bois, p. 460 and 470.

‡ Mem. de l'Acad. Scien. Paris, 1741, p. 328—332.

§ From the Transactions of the Royal Society, 1817, part ii.