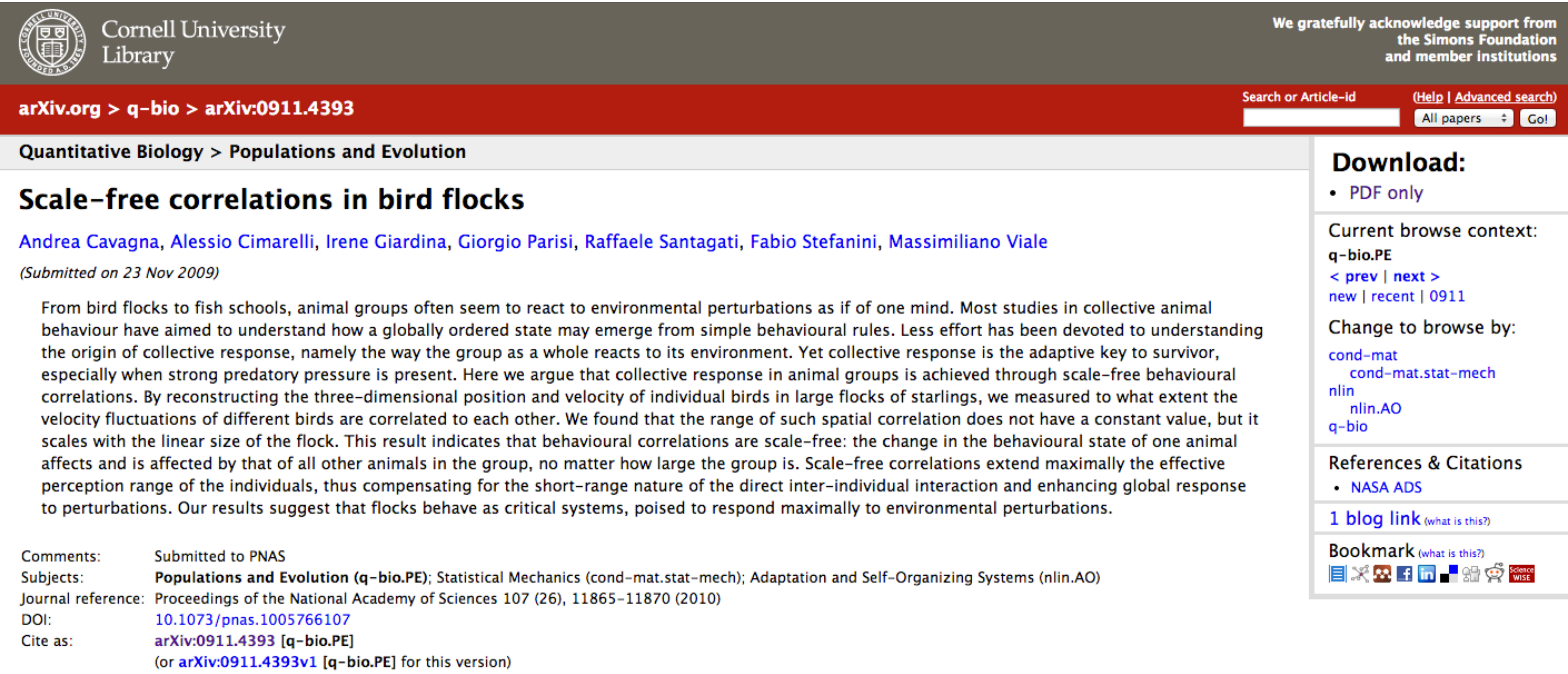
https://www.youtube.com/watch?v=MncUDWhPB_E

https://www.youtube.com/watch?v=oW3exmnm5AY

https://www.youtube.com/watch?v=XH-groCeKbE



Scale-free correlations in bird flocks

Andrea Cavagna, Alessio Cimarelli, Irene Giardina, Giorgio Parisi, Raffaele Santagati, Fabio Stefanini, Massimiliano Viale

(Submitted on 23 Nov 2009)

From bird flocks to fish schools, animal groups often seem to react to environmental perturbations as if of one mind. Most studies in collective animal behaviour have aimed to understand how a globally ordered state may emerge from simple behavioural rules. Less effort has been devoted to understanding the origin of collective response, namely the way the group as a whole reacts to its environment. Yet collective response is the adaptive key to survivor, especially when strong predatory pressure is present. Here we argue that collective response in animal groups is achieved through scale-free behavioural correlations. By reconstructing the three-dimensional position and velocity of individual birds in large flocks of starlings, we measured to what extent the velocity fluctuations of different birds are correlated to each other. We found that the range of such spatial correlation does not have a constant value, but it scales with the linear size of the flock. This result indicates that behavioural correlations are scale-free: the change in the behavioural state of one animal affects and is affected by that of all other animals in the group, no matter how large the group is. Scale-free correlations extend maximally the effective perception range of the individuals, thus compensating for the short-range nature of the direct inter-individual interaction and enhancing global response to perturbations. Our results suggest that flocks behave as critical systems, poised to respond maximally to environmental perturbations.

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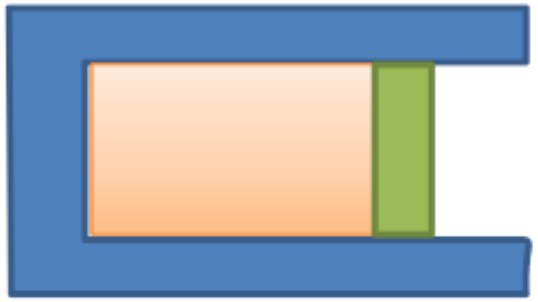
Demo

1. Where does the force come from?

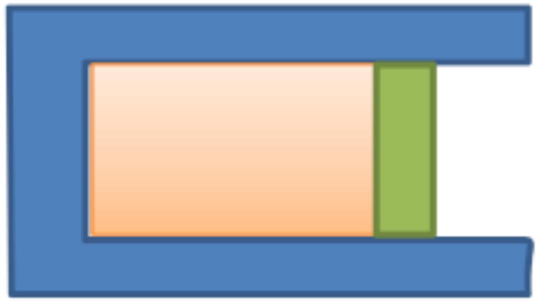
2. What microscopic properties (variables) of the air does it depend on?

3. Can we estimate the force in terms of microscopic properties?



The density of a gas is doubled, keeping the type and average speed of the atoms fixed. The force on the green object is multiplied by a factor of

A) ¼
B) ½
C) 1
D) 2
E) 4

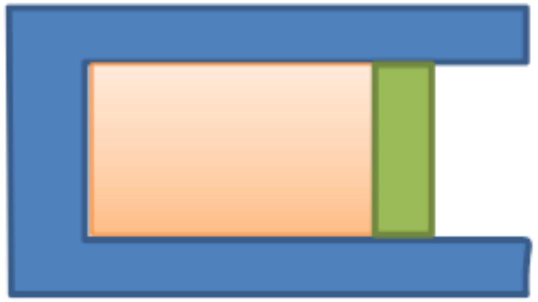


The density of a gas is doubled, keeping the type and average speed of the atoms fixed. The force on the green object is multiplied by a factor of

A) ¼
B) ½
C) 1
D) 2
E) 4

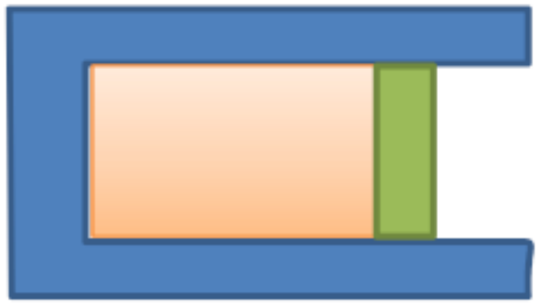
-Doubles # of collisions per time
-same average Δp per collision

F = dp/dt is doubled



The average speed of the gas atoms doubles, keeping the type and density fixed. The force on the green object is multiplied by a factor of

A) ¼
B) ½
C) 1
D) 2
E) 4

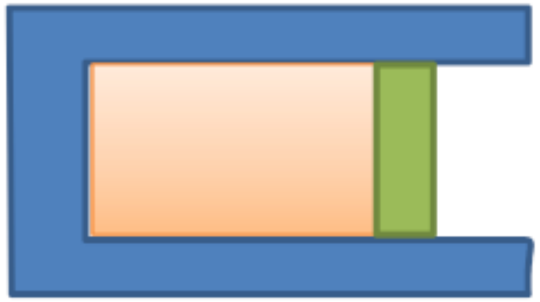


The average speed of the gas atoms doubles, keeping the type and density fixed. The force on the green object is multiplied by a factor of

A) ¼
B) ½
C) 1
D) 2
E) 4

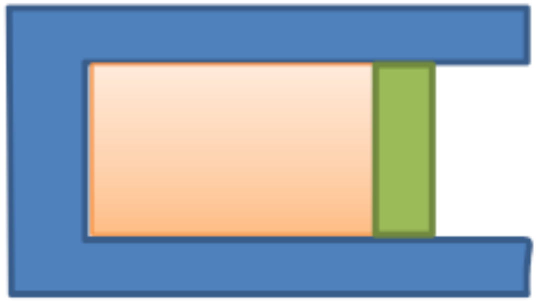
-Doubles # of collisions per time
-Doubles average Δp per collision

F = dp/dt is quadrupled



The gas is replaced by a new gas whose atoms are twice as heavy, keeping the average speed of the gas atoms and density fixed. The force on the green object is multiplied by a factor of

A) ¼
B) ½
C) 1
D) 2
E) 4

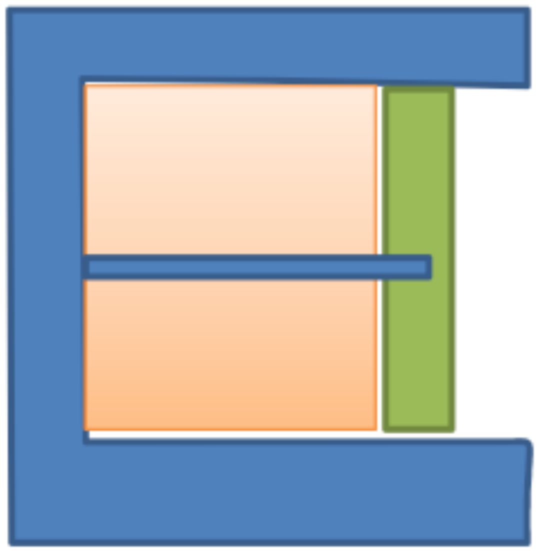


The gas is replaced by a new gas whose atoms are twice as heavy, keeping the average speed of the gas atoms and density fixed. The force on the green object is multiplied by a factor of

A) ¼
B) ½
C) 1
D) 2
E) 4

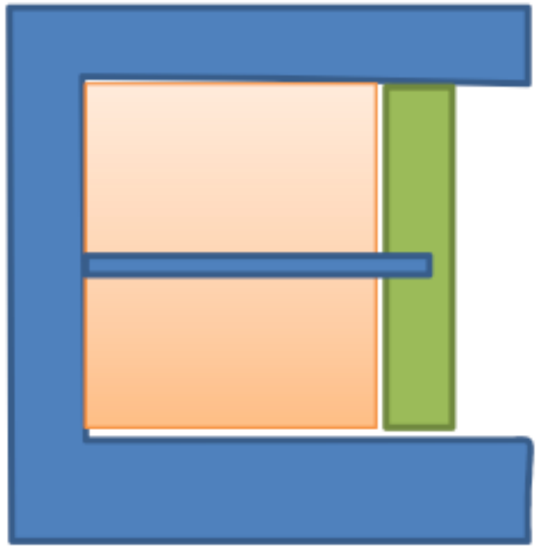
-Same # of collisions per time
-double average Δp per collision

F = dp/dt is doubled



The system above is a doubled version of the previous system, so the new green object has twice the area of the old one, while the density of atoms in the gas, the mass, and the average speed remain the same. The net force on the green object here is what multiple of the force on the old green object?

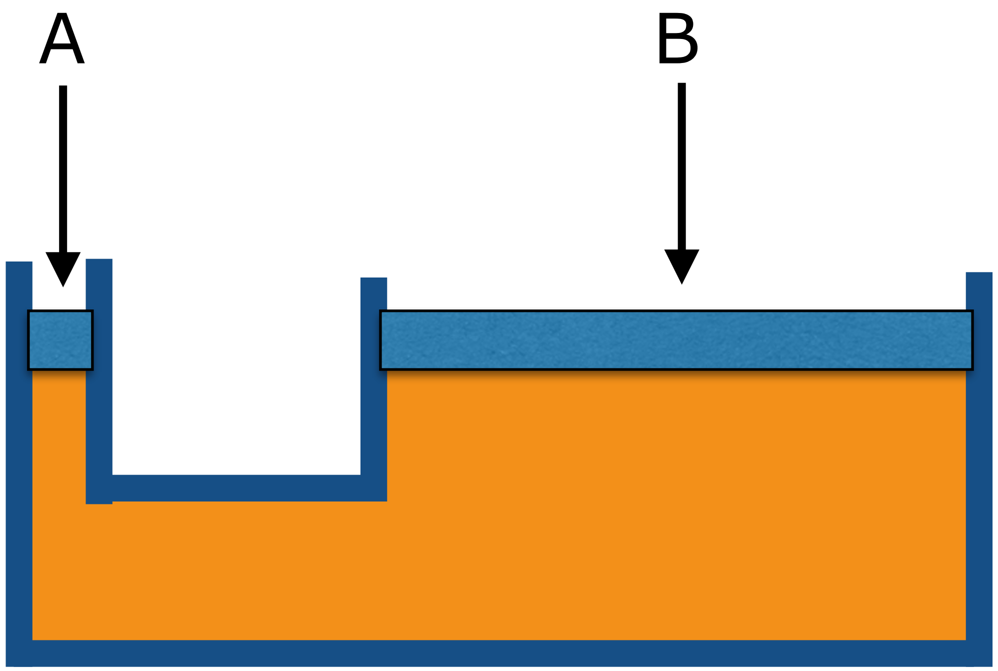
A) ¼
B) ½
C) 1
D) 2
E) 4



If we double the area of the green object, keeping the properties of the gas the same. The net force on the new green object is what multiple of the force on the old green object?

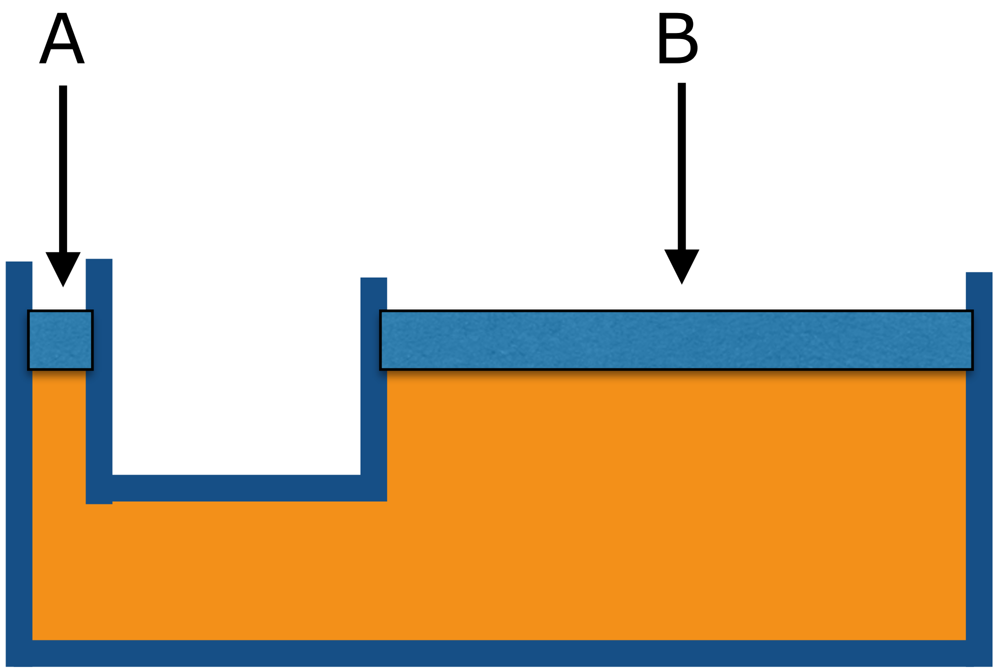
A) ¼
B) ½
C) 1
D) 2
E) 4

-Doubles # of collisions per time (since number of collisions per time on any fixed area stays the same)
-same average Δp per collision
F = dp/dt is doubled



A container of gas with uniform pressure has a large piston and a small piston attached to it. The forces A and B act on the pistons from the outside such that the system is in equilibrium. We can say that

A) The forces are the same
B) The force A is greater
C) The force B is greater
D) Any of the above are possible



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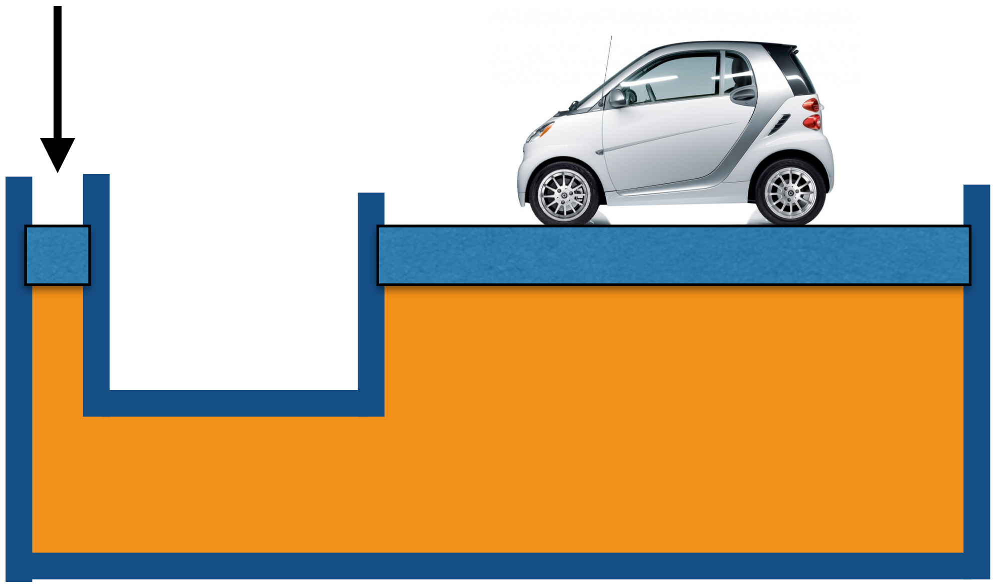
A) The forces are the same
B) The force A is greater
C) The force B is greater
D) Any of the above are possible

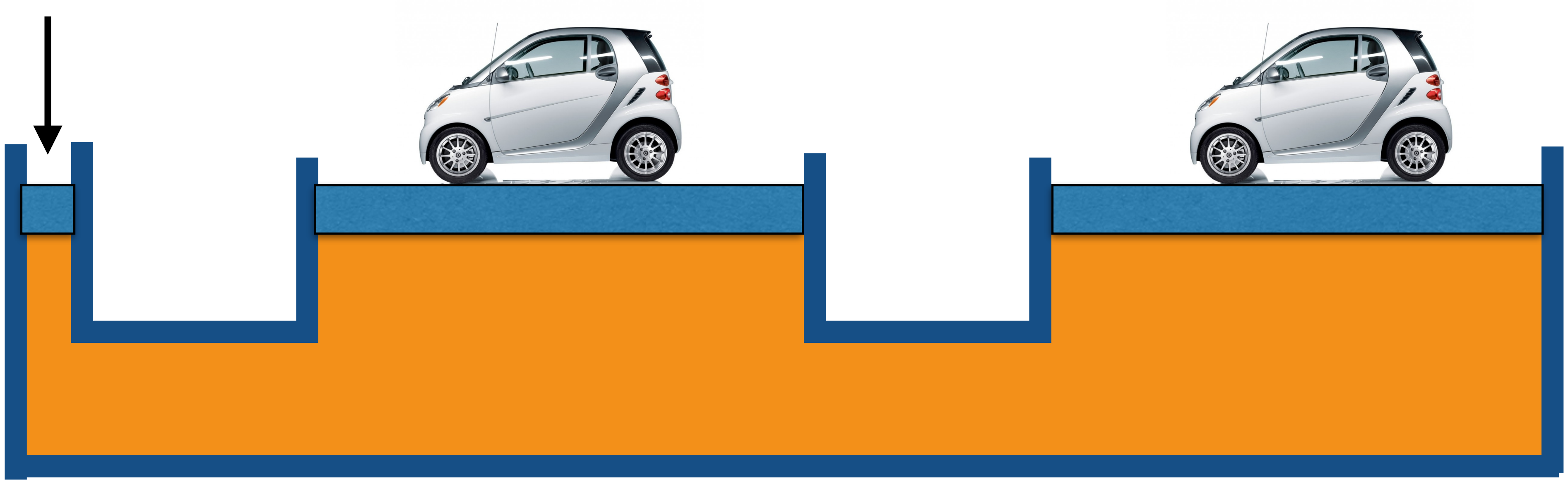
Pressure is the same throughout the gas. Force from gas on piston is pressure times area. This is greater for the right piston, so the force B must be larger.

Atomic picture: more gas molecules per unit time are collide with the right hand right hand piston.

A



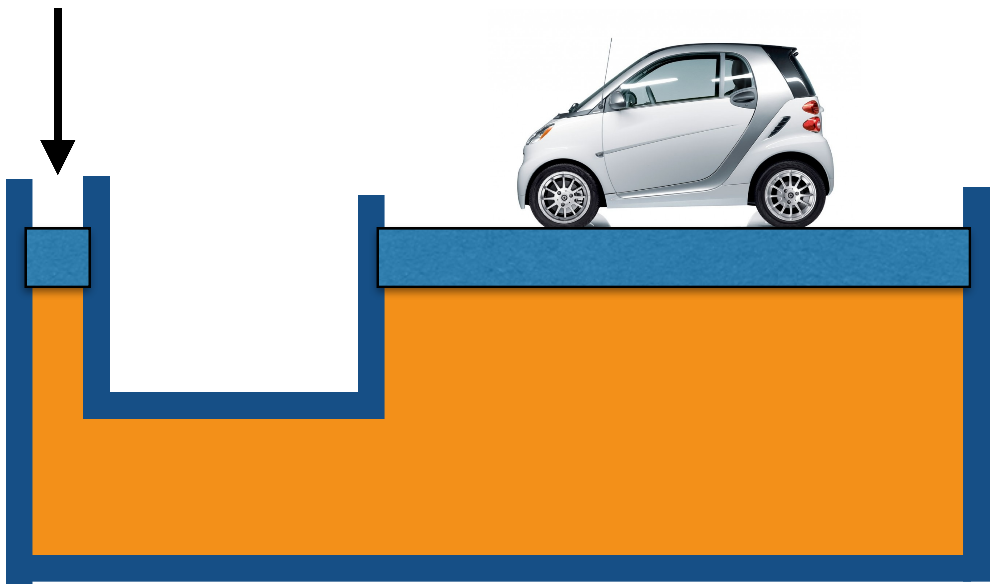
B



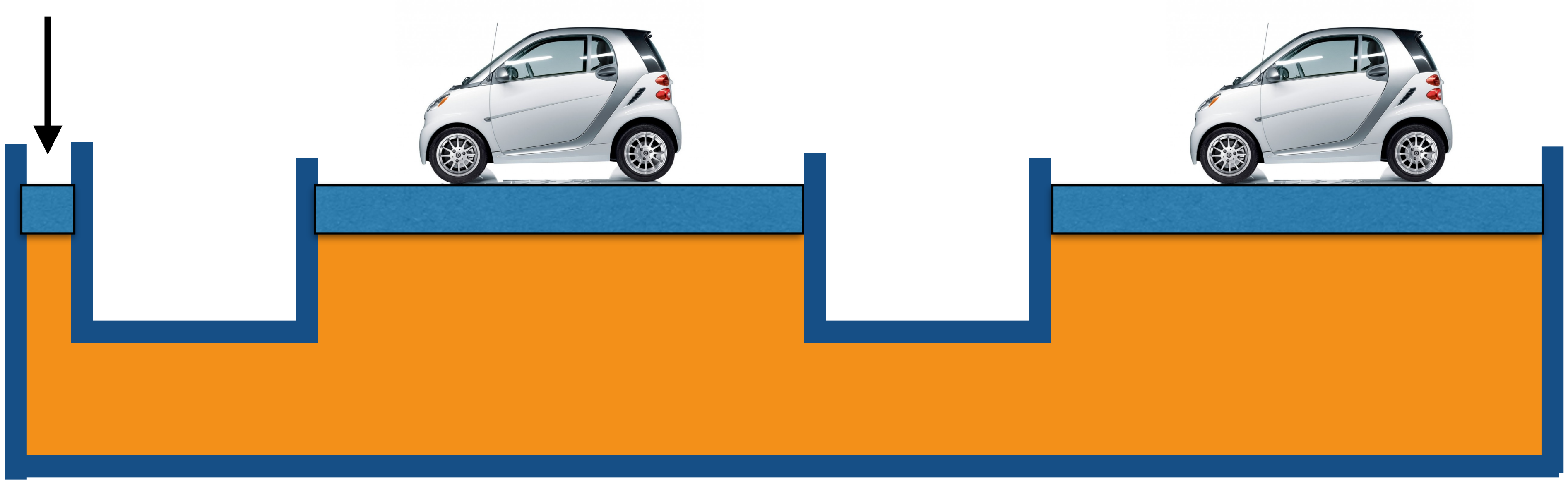
The force on the left piston indicated but the arrow is

A) greater in situation A
B) greater in situation B
C) the same in A and B

A



B



The force on the left piston indicated but the arrow is

A) greater in situation A
B) greater in situation B
C) the same in A and B

The force has doubled, but the area has doubled, so the pressure acting on both cars in the same in both situations. Thus, the pressure in B is the same as A, so the force is the same.

NEW
EXPERIMENTS
PHYSICO-MECHANICAL,

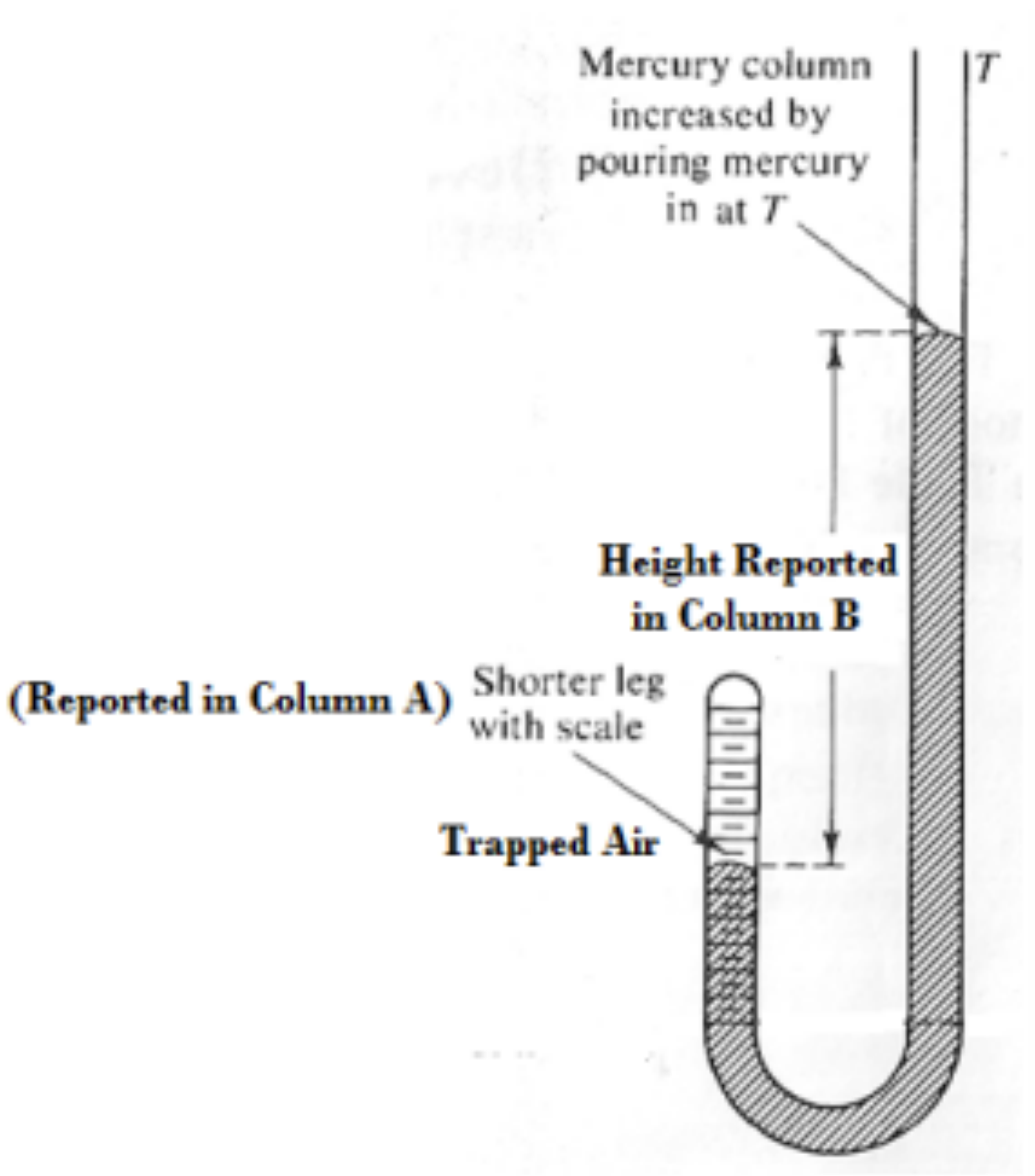
Touching
The Spring of the Air, and its Effects,
(Made, for the moſt part, in a New
Pneumatical Engine)
Written by way of Letter
To the Right Honorable *CHARLES* Lord
Vicount of *DUNGARVAN*,
Eldeſt Son to the Earl of *CORKE.*

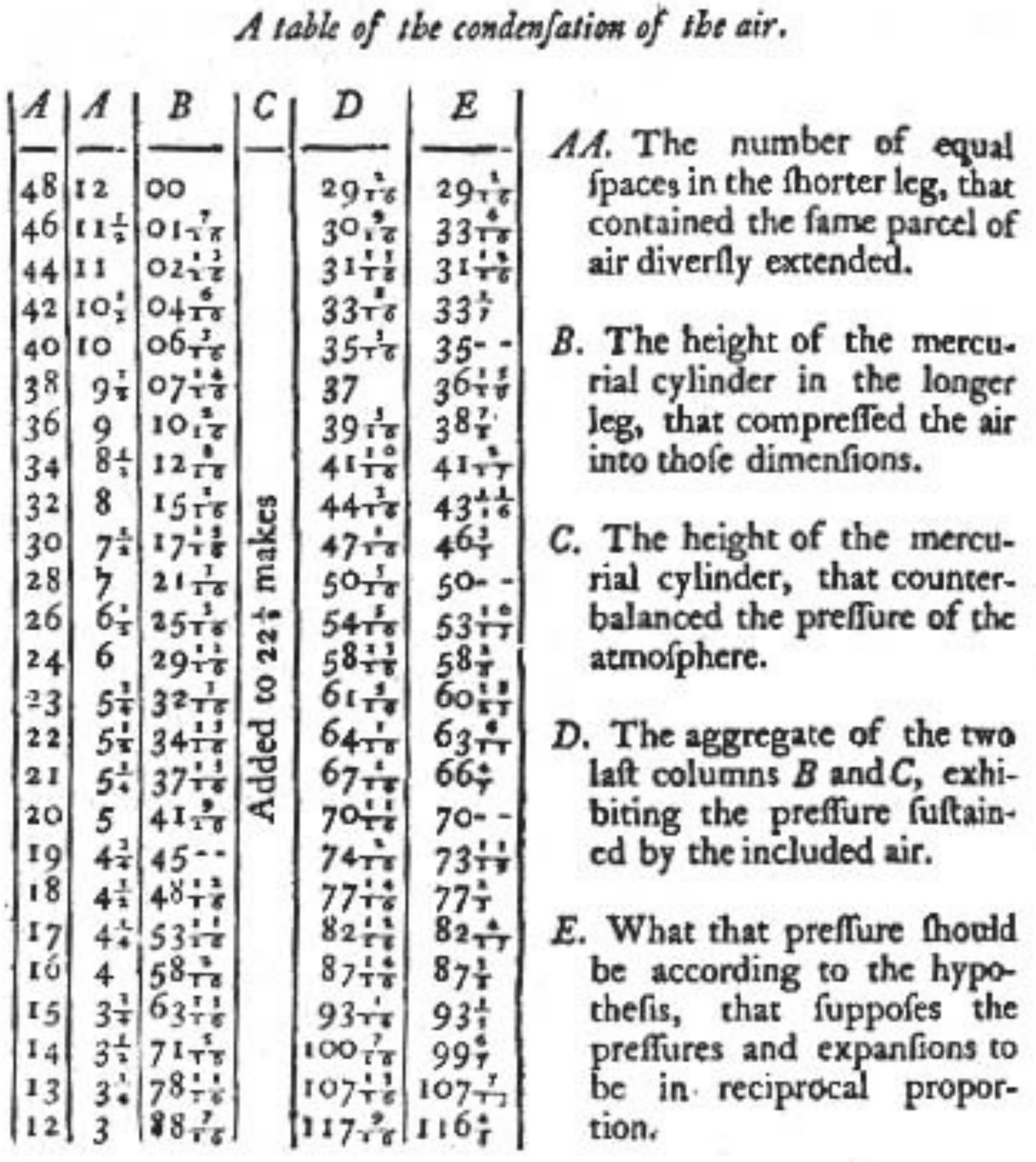
By the Honorable *Robert Boyle* Eſq;

OXFORD: Printed by *H. Hall*, Printer to the Univerſity,
for *Tho: Robinſon.* 1662.

Boyle's Law - 1662 from *New Experiments: Physico-Mechanical, Touching the Spring of Air*.

Boyle's Law - 1662 from *New Experiments: Physico-Mechanical, Touching the Spring of Air*.





A table of the condenſation of the air.

A	A	B	C	D	E
48	12	00	Added to $22\frac{1}{8}$ makes	$29\frac{2}{16}$	$29\frac{2}{16}$
46	$11\frac{1}{2}$	$01\frac{7}{16}$		$30\frac{9}{16}$	$33\frac{6}{16}$
44	11	$02\frac{13}{16}$		$31\frac{15}{16}$	$31\frac{12}{16}$
42	$10\frac{1}{2}$	$04\frac{6}{16}$		$33\frac{8}{16}$	$33\frac{1}{7}$
40	10	$06\frac{3}{16}$		$35\frac{5}{16}$	35- -
38	$9\frac{1}{2}$	$07\frac{14}{16}$		37	$36\frac{15}{19}$
36	9	$10\frac{2}{16}$		$39\frac{5}{16}$	$38\frac{7}{8}$
34	$8\frac{1}{2}$	$12\frac{8}{16}$		$41\frac{10}{16}$	$41\frac{2}{17}$
32	8	$15\frac{1}{16}$		$44\frac{3}{16}$	$43\frac{11}{16}$
30	$7\frac{1}{2}$	$17\frac{15}{16}$		$47\frac{1}{16}$	$46\frac{3}{5}$
28	7	$21\frac{3}{16}$		$50\frac{5}{16}$	50- -
26	$6\frac{1}{2}$	$25\frac{3}{16}$		$54\frac{5}{16}$	$53\frac{10}{13}$
24	6	$29\frac{11}{16}$		$58\frac{13}{16}$	$58\frac{2}{8}$
23	$5\frac{3}{4}$	$32\frac{3}{16}$		$61\frac{5}{16}$	$60\frac{18}{23}$
22	$5\frac{1}{2}$	$34\frac{15}{16}$		$64\frac{1}{16}$	$63\frac{6}{11}$
21	$5\frac{1}{4}$	$37\frac{15}{16}$		$67\frac{1}{16}$	$66\frac{4}{7}$
20	5	$41\frac{9}{16}$		$70\frac{11}{16}$	70- -
19	$4\frac{3}{4}$	45- -		$74\frac{2}{16}$	$73\frac{11}{19}$
18	$4\frac{1}{2}$	$48\frac{12}{16}$		$77\frac{14}{16}$	$77\frac{2}{3}$
17	$4\frac{1}{4}$	$53\frac{11}{16}$		$82\frac{12}{16}$	$82\frac{4}{17}$
16	4	$58\frac{2}{16}$		$87\frac{14}{16}$	$87\frac{3}{8}$
15	$3\frac{3}{4}$	$63\frac{15}{16}$		$93\frac{1}{16}$	$93\frac{1}{5}$
14	$3\frac{1}{2}$	$71\frac{5}{16}$		$100\frac{7}{16}$	$99\frac{6}{7}$
13	$3\frac{1}{4}$	$78\frac{11}{16}$		$107\frac{13}{16}$	$107\frac{7}{13}$
12	3	$88\frac{7}{16}$		$117\frac{9}{16}$	$116\frac{4}{8}$

AA. The number of equal ſpaces in the ſhorter leg, that contained the ſame parcel of air diverſly extended.

B. The height of the mercurial cylinder in the longer leg, that compreſſed the air into thoſe dimenſions.

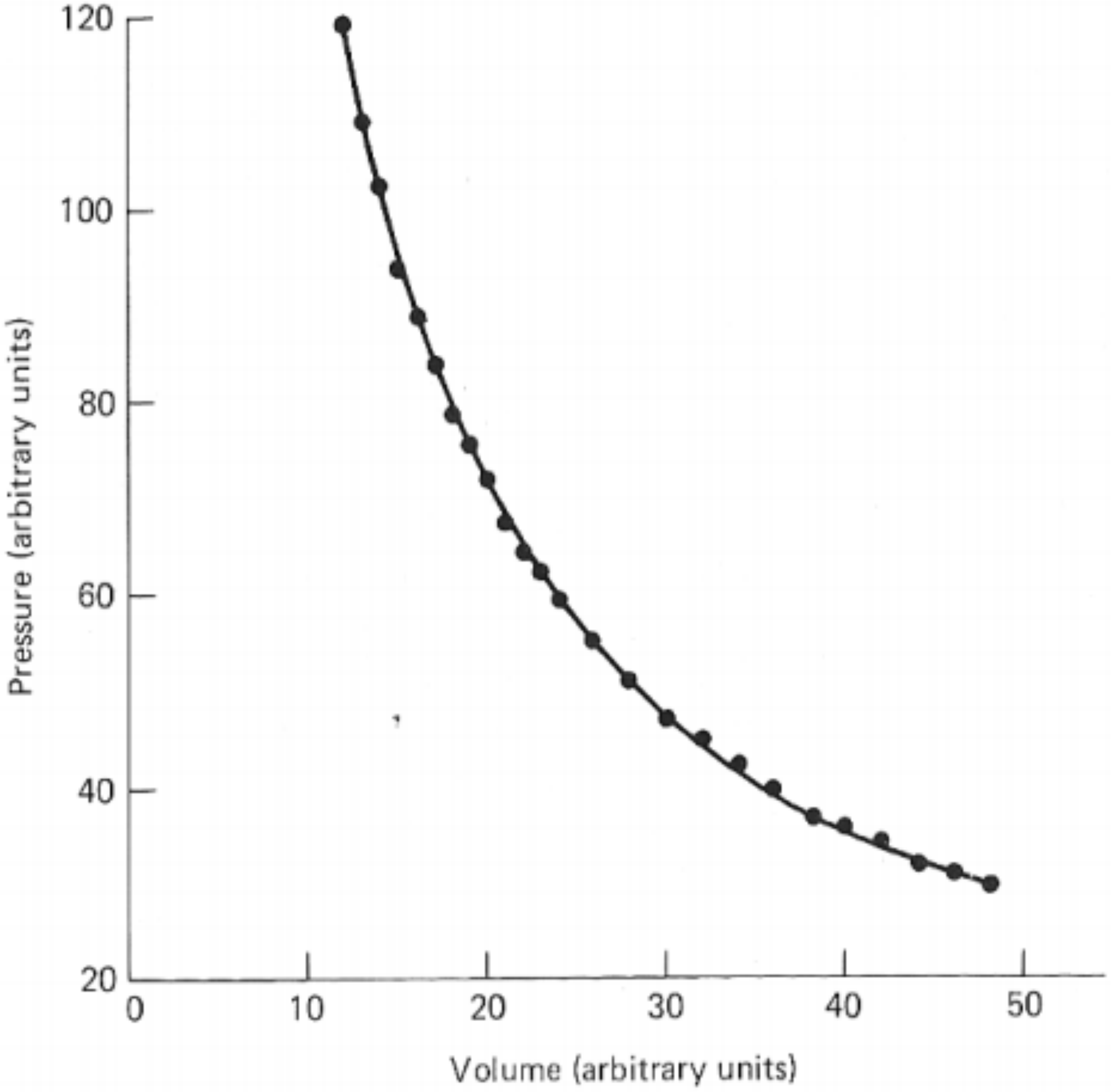
C. The height of the mercurial cylinder, that counterbalanced the preſſure of the atmoſphere.

D. The aggregate of the two laſt columns *B* and *C*, exhibiting the preſſure ſuſtained by the included air.

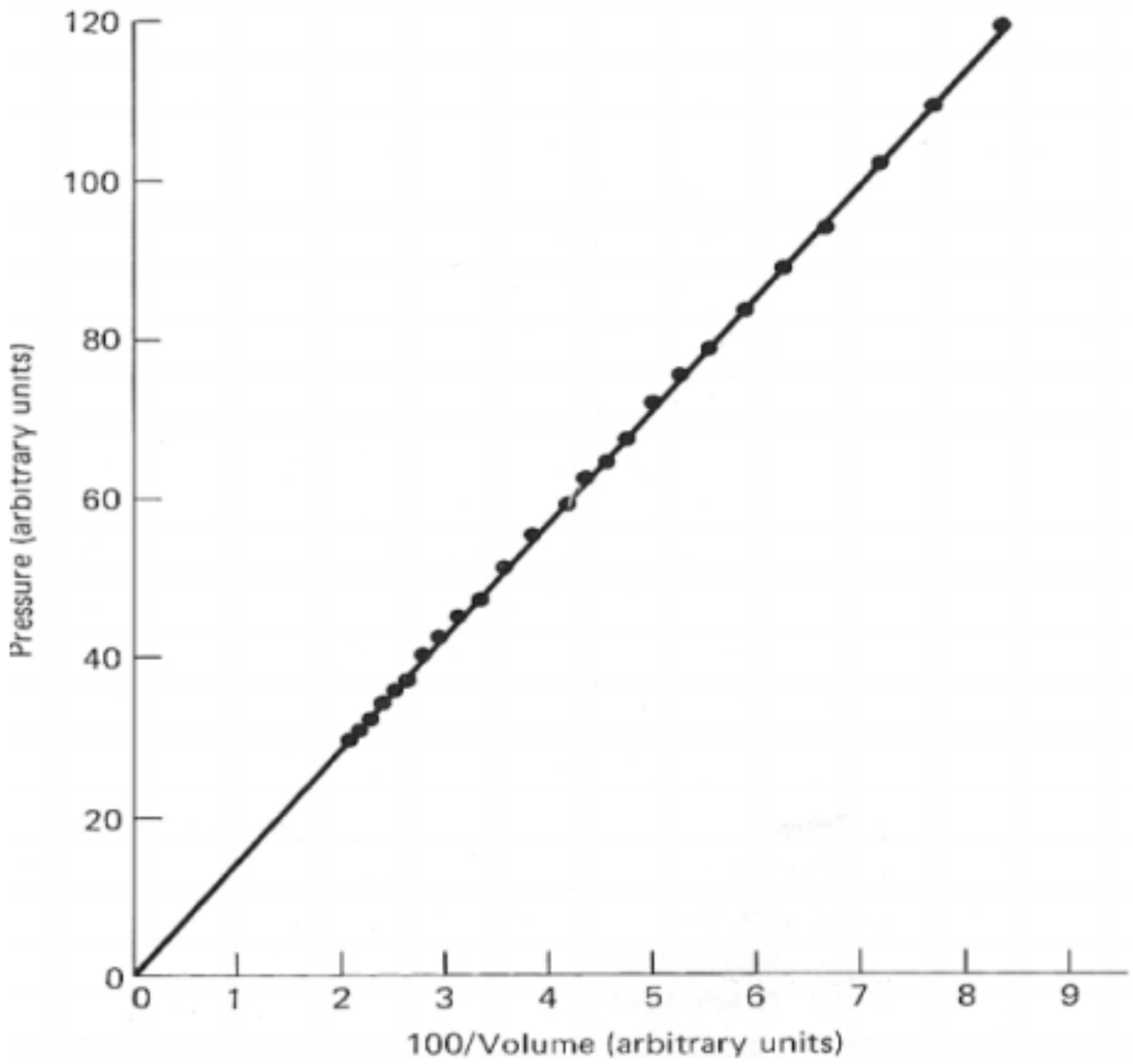
E. What that preſſure ſhould be according to the hypotheſis, that ſuppoſes the preſſures and expanſions to be in reciprocal proportion.

Boyle's Law - 1662 from *New Experiments: Physico-Mechanical, Touching the Spring of Air*.

P vs. V



P vs. $\dfrac{1}{V}$



A container with a partition in the middle is filled halfway with an ideal monatomic gas. If the partition is removed instantaneously so that the gas is allowed to fill the box, the final temperature of the gas will be

A) Lower than the original temperature
B) The same as the original temperature
C) Higher than the original temperature

A container with a partition in the middle is filled halfway with an ideal monatomic gas. If the partition is removed instantaneously so that the gas is allowed to fill the box, the final temperature of the gas will be

A) Lower than the original temperature
B) The same as the original temperature
C) Higher than the original temperature

Energy is conserved, so the total energy of the gas is the same before and after. For an ideal gas, we can ignore interactions between the molecules (which might be associated with potential energy) so all the energy is kinetic energy. Thus, kinetic energy is the same after the expansion. Temperature is translational kinetic energy per atom, and the number of atoms doesn't change, so the translational kinetic energy per atom stays the same.

Roughly: nothing that would make the gas molecules slow down, so their average translational kinetic energy stays the same.