The Atmosphere

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When you swoosh your hand through the air, if you happen to knock against a fixed and solid object like the book-case or the door, you are made aware of the fact that the space through which you intended to swoosh your hand is already occupied. The book-case is solid, and dense, and refuses to get out of the way unless you apply a far greater force than you are prepared to exert by knocking it with your hand. The same idea, less painfully learnt, holds for a blow applied to water, though if you bang your hand down hard and flat on the surface of the water, the resistance will be sufficient to cause your hand to sting, although some of the water does fly out of the way.

When you sweep your hand through the free air, you get a slight sensation of cooling, and feel a very feeble resistance. The air is just as much a material substance as the book-case or the water, but the mass of the stuff you have to throw out of the way is much less than the mass of water you were trying to replace, or the mass of the book-case which had to move as a whole if it moved at all.

We say that the air is much less dense than either the solid or liquid with which we have been dealing, and that the portion that we have tried to push, that is to which we have applied a force, is free to move.

Whether we are dealing with a solid, a liquid like the water, or gases like the air, we are dealing with swarms of molecules of the material, the size and mass of each of which is known ; I can give you three simple pictures of the molecular nature of solids, liquids and gases, which will help you to see the essential differences between them ; but, like most analogies, they are wrong if carried too far, and are merely to help you to see why the air gets out of the road and the book-case does not.

Take a solid first, a lump of iron if you like. All my molecules in the solid are like bees that have swarmed ; each bee is a molecular speck of the material, and all the bees hang together to make a compact mass. All the bees are in motion, but their motions are very restricted. If an analogy were to be more complete, the bees would be permitted to move backwards and forwards a little about their central position, but would not be permitted to swop places. A little bit of iron, enormously magnified, would be *somewhat* like that—we can smash up the swarm of bees, but it is much easier to move the swarm as a whole ; they are close together, and hang together ; they form a dense mass.

Take a liquid next. Let's tip all our bees into a large empty tank, and suppose that, their minds being made up to swarm, they continue to buzz and hover round the lower half of the tank. They are now much more widely separated than they were before, and have much greater freedom of movement, so that a bee that was at the bottom of the tank at one moment, a little later on might be flying round the upper layer half-way up. The number of bees per cubic foot is still considerable, so that the density of our mass distribution is still relatively big. If we magnified a drop of water enormously—far more than we can do it by any microscope—that is the effect we would notice. The bees would be the molecules of water, and they all tend to occupy the lower part of a vessel, and not to spread out completely to fill it. The molecules not only move about their mean positions, but also wander from place to place, but without increasing the total space they occupy.

Now let us pass to the gases, such as constitute our atmosphere. In the case of the solid, the molecules were represented as the swarm of bees, locked fairly tightly together. Then we placed that swarm in an empty tank, and sufficiently disturbed the bees so that they represented the molecules of a liquid ; the bees were stirred up, spread out to occupy a wider space, swopped places by movement of bees from place to place, but still had the swarming idea at the back of their minds, so that, during the period we were examining them, they occupied a larger but still definite volume. Now for the gas analogy : Let's do something really annoying to the bees, so as to get this idea of swarming right out of their minds. Let's kill the queen bee, for instance. Then, whether you run east, or west, or north, or south, whether you climb trees or rush into the cellar, you are likely to meet or be overtaken by bees. They spread out and occupy the space around them. If they were still in our otherwise empty tank, we would have to put the lid on it to prevent their escaping, and they would occupy the whole tank space, widely separated, and buzzing about. If we placed a second tank at their disposal they would spread out and occupy that also, and the mass of bees per cubic foot of space would become less.

Our atmosphere is mainly, nearly entirely, gas. The bees we call molecules are of different breeds. You can imagine it as made up of several different kinds of bees. One of the molecule types we call oxygen, one we call nitrogen, and there are about four times as many of our nitrogen bees present as the oxygen ones. Other molecules present, representing relatively very few bees per cubic foot, we call carbon dioxide and argon, neon, xrypton and zenon. But you would be just as unlikely to come across one of these strange molecules, particularly those of the so-called rare gases, as you would be to discover a different kind of bee from your ordinary domestic pets buzzing round your garden.

The molecules are tiny little things, so that if we formed a line of them up on parade, it would take nearly a hundred million of them to give an inch frontage ; so that if it were possible for us to pack a cube of edge one inch with these molecules all touching, we would have a cubic inch of very solid solid, containing a hundred million, multiplied by a hundred million, multiplied by a hundred million molecules. If you put down a 1 and then twenty-four noughts after that, you have the total number of molecules that would occupy the cubic inch, *if* all could be jammed up tightly. That will give you an idea of the extremely tiny things these, our bee molecules, really are.

You will be relieved to hear, however, that our atmosphere, being gas, represents the bees in their buzziest and most widely separated condition ; so that there are, in our atmosphere here below, not nearly so many molecules per cubic inch as the one and twenty-four noughts after it. In fact, there are only about one-two thousand five hundredth $\left(\frac{1}{2500}\right)$ of that number, which means that if you write a 4 and put only twenty noughts after it, you have about the number of tiny, widely separated, rapid-moving molecular bees in every cubic inch of air.

Now bees have weight. A dead bee drops to the ground, unless something gets in the way. Also, every one of our molecules of gas has weight, and would drop to the ground if " dead ", that is if it ceased moving about with high velocity or being bumped by other molecules. So that the molecules are drawn down to the ground, and are much more crowded together there than at higher levels. This is possibly the meaning of the famous old saying : " The higher the fewer ".

When, in response to my first invitation, you swooshed your hand through the air, it met very little resistance ; the number of oxygen, nitrogen and our other molecular " bees " that you had to push out of the way, although vast, was few compared to those you would have been pushing if you had been hitting at a liquid or at a solid, and as you would expect, meeting fewer molecules per cubic inch the higher you go in the air, the less resistance again to pushing them out of the way.

You may think that the resistance to your hand being swung through the air is so slight that it is not worth while considering, but when we want to push these molecules out of the road rapidly, and when we push the larger numbers per second, that we must push when we move more rapidly, it is important ; hence, stream-lined cars, and engines of trains. Some of you may have had the experience of moving through the air at forty miles or more without a wind-screen in front of you. The force opposing your motion is quite appreciable. For that reason aeroplanes moving with high velocity, now several hundreds of miles an hour, meet much less resistance if they climb up to places where the molecules are fewer, and shells from long-range guns, passing twenty and more miles up, meet with much less resistance than those travelling in the lower and denser atmosphere.

To leave our bees for a moment, they being animals that you seldom meet in sufficient numbers to obstruct your passages, imagine yourself in a great hurry to catch your bus, tram, train, or whatever you do catch, and running blindly down a sparsely crowded street. You are not going to attempt to dodge anyone ; if they get in your way, you bump them out of it, and continue.

This would slow you down ; you would make better pace if no one was about, and you had an uninterrupted run. Now imagine the same street crowded, and you carrying out the same performance. You would have to work very much harder to go the same distance at the same speed, and, being only a weak little thing, you would find that, strain as you might, you bumped so many people that you could not struggle along beyond a limiting speed. Clear most of the obstructing people out of the way and you simply bound ahead.

It's the same idea with the aeroplane or the shell from the gun : if they go up some six miles or more, they are in the less crowded streets of what is called the stratosphere, the molecules—call them people or bees now, as you will—being fewer per cubic inch. That is one of the reasons why high speed transport of the future will undoubtedly be through the stratosphere. The molecules are small compared with the aeroplane, certainly, but there are such vast numbers to be pushed away.

Here we are, then, squashed under a pressure of some fifteen pounds weight per square inch, under and surrounded by countless, but calculable, myriads of molecules of oxygen and nitrogen, and still vast swarms, but relatively fewer, of the other gases naturally present, or city impurities, that go to make our atmosphere. They are darting about at an average velocity of a thousand miles an hour, and if we don't like such rough treatment, we can go to the top of a mountain, and up into the stratosphere some 30,000 feet up ; but if we find that the vulgar molecular horde is still too numerous, we must betake ourselves into outer space, where molecules are relatively select and rare objects.