No 7 ATMOSPHERIC PRESSURE and BREATHING

12 May 2008

1. Last time, we were talking about pressure. The force per unit area applied to something. We talked about stiletto heels and elephants.
2. We also looked at the various ways in which the body detects pressure. We have different kinds of sensors in the skin which tell us about different kinds of external pressures acting on us. We also have lots of internal sensors which tell us about changes in the internal pressures on the joints and other internal bits of our body.
3. Today I want to look at pressure in liquids, or fluids. Here, the rule is quite simple; the deeper you go in a liquid, the greater the pressure it exerts upon you.
4. Those who are interested in scuba diving know a lot about this and of the special precautions that have to be taken the deeper you go. Deep sea diving suits and submarines have to be very carefully designed so they do not squash when they are taken down into the depths.
5. We can look at this in a simplified way by envisaging a long cylinder filled with water. The further down in the cylinder one goes, the greater the pressure. We can, in fact, specify the pressure at any point in terms of the height of water above it.
6. So if we are at a depth of 10 cm, we can say the pressure is 10 cm of water per square centimetre; at 20 cm, we say it is 20 cm of water; at 20 metres we can say it is 20 metres and so on. In practice, different units are used to measure pressure but the principle is same; the deeper you go in a liquid, the higher the pressure.
7. One of the best examples of the effect of this increase in pressure with depth is illustrated by bubbles in a liquid. If you take a long glass and pour some fizzy water, or champagne, into it and look closely at the bubbles rising through it, you will see that each bubble gets bigger as it rises. You see the same thing in glass fish-tanks.
8. This is because the pressure on the bubble is getting lower as it rises. You can see it even more clearly if you take a thick or viscous liquid like olive oil in which the bubbles rise more slowly. Shake it up to trap some air and watch the bubbles getting bigger as they rise.

9. The relevance of this to us is that the atmosphere, the air that surrounds the earth, behaves as a very thin fluid. In a very real sense, the earth is enveloped in an ocean of air.

10. This ocean, the atmosphere, is a mixture of gases. Its composition is 78% nitrogen and 21% oxygen, that is 99% of the total, with the remaining 1% being made up of other gases. The carbon dioxide, which is causing so much worry makes up about 0.04%

11. But we are not swimming in this ocean or floating on it, we are crawling around on the bottom of it. We are more like crabs and lobsters while birds are like fish and aeroplanes are like submarines.

12. Just as in the water ocean, the higher we go in the air ocean, the atmosphere, the lower the pressure. When a lighter than air balloon is released at the earth's surface and rises through the atmosphere, it gets bigger as it goes up. If you could track one of those helium-filled balloons that small children let go and howl about, you would see it getting bigger as it goes up.

13. Eventually, we get to outer space where there is no air and no atmospheric pressure. People have to wear pressurised space suits to prevent themselves swelling up and bursting in a rather messy way.

14. Down here on the ground, we have the full weight of the atmosphere pressing down on us. This is what is called the atmospheric or air pressure.

15. It is specified in a variety of ways. In old imperial units, the standard or normal air pressure is about 15 lbs/sq inch or 1 kg/sq cm. Even though we do not notice it, the atmosphere exerts a pressure of 1 kg on every square centimetre.

16. Weather people, meteorologists, measure the air pressure in bars or millibars. The normal pressure of 1 kg/sq m is referred to as 1 bar or 1000 millibars. If you look at a weather map, you will see figures like 1024 or 1008 which refer to the air pressure in particular areas.

17. These small differences in pressure have important impacts on the weather. Air flows from areas of high pressure to areas of low pressure. The differences in pressure are not directly noticeable to human beings but the effects certainly are in the form of hurricanes and cyclones.

18. In a normal hurricane, the pressure drops to about 930 millibars at the eye but in the case of Katrina it went down to 902 millibars and in the case of Wilma in 2005 it dropped to 888 millibars.

19. One might ask why we do not feel this atmospheric pressure pushing down on a hand when we stick it out horizontally. This is because pressure in a fluid works in all directions. So provided the air can get all round it, the pressure on my hand is the same in all directions – up, down, and sideways

20. One way we can see this pressure in action would be to take, say, a biscuit box and attach an air pump to it so that we can extract some air and reduce the pressure inside the box. If we took all the air out, so there was zero pressure inside, and atmospheric pressure of 1 kilogram per sq cm outside, the box would completely flatten.

21. If this were the Royal Institution, there would be no problem in demonstrating this to you. But this year's teaching materials budget does not run to a vacuum pump and a biscuit box. But we can get the general idea from this plastic bottle. If I suck the air out, so that the pressure of the air inside is reduced, the bottle squashes.

22. And, of course, when I allow it to happen, the air rushes back in, the pressure equalises on the inside and the outside and the bottle springs back to its normal shape.

23. But so much for weather and the atmosphere in general. I now want to move on to the question of breathing.

24. We know that air is absolutely vital to our survival. Breathing it in and out is the most important thing we do. We are naturally adapted to doing it properly, efficiently and effortlessly. We start to do it within moments of being born; we continue to do it whether we are stupid or clever. We do it in our sleep. The only time we stop doing it is when we are dead.

25. What happens when we breathe is that the air is taken in through our nose or mouth, down through the pharynx, the throat, to the trachea, the windpipe, and into the bronchi which lead into the lungs.

26. The bronchi divide into smaller bronchioles which lead into tiny little air sacs called alveoli – a single one is called an alveolus. There are about 300 million of them in the lungs. The lungs are like sponges, filled with tiny little air-spaces.

27. Although we are adapted to breathing a mixture of nitrogen and oxygen, it is the oxygen that is the active constituent. When the air is drawn into the alveoli, what is known as a gas-exchange takes place. The red cells in the blood surrounding the alveoli absorb oxygen from the air and give up the carbon dioxide they have accumulated in their way round the body.

28. The oxygen-enriched blood goes from the lungs to the left chamber of the heart and is pumped round the body. On its way, it gives up oxygen to the various organs and tissues that use it. It also picks up the carbon dioxide that organs and tissues produce as a waste product.

29. The veins return the blood to the right side of the heart where it is pumped back into the lungs and the cycle begins again. It is this replenishment of the oxygen in the blood and the disposal of the waste carbon dioxide that enables the body to keep functioning.

30. The reason we feel breathless when we are up a high mountain is that our lungs are adapted to working at normal atmospheric pressure. When we go up a mountain, the pressure drops and this reduces the effectiveness of the gas exchange in the alveoli. The oxygen content of the blood drops and we suffer shortness of breath, headaches, nausea and the rest.

31. Our normal breathing rate is around 15-16 times a minute and it can go up to around 80 in vigorous exercise. Depending on our level of activity, we take about 25 000 breaths per day. That is about 9 million breaths per year.

32. But we do not breathe in the same way all the time. Our breathing changes depending on what we are doing. The gentle flow in and out which happens when we are relaxed or sleeping is called tidal breathing. When we are exercising and the body needs more oxygen, our breathing rate becomes more rapid.

33. There are also times when we have to do something special with our breathing. If you are playing Brunnhilde in Wagner, the final scene demands that you leap on a horse and jump into the flames while bellowing about what a wonderful fellow Siegfried was. This requires some tricks of breathing that do not come automatically. The same is true of playing wind instruments and various other kinds of activities.

34. Moreover, because breathing is absolutely essential to life, the body has a variety of ways in which it can improvise an inflow and outflow of air if the various muscles and other bits of the body involved in breathing are damaged or are not working properly.

35. In the extreme case of being trapped under rubble after an earthquake, with the chest completely immobilised, people are sometimes able to survive by instinctively using various shoulder and stomach muscles to expand and contract the lungs.

36. So although breathing comes completely naturally, we are able to interfere with the way we do it in a wide variety of ways. And many of us do.

37. If we are getting every breath even slightly wrong, so that the gas-exchange in our lungs is not happening quite as it should, the cumulative effect over days and months and years can be quite big. And the fact that we are repeating the breathing process about 9 million times a year means any bad breathing habits we develop can become pretty deeply engrained.

38. One of the very insidious ways we can develop serious breathing problems is when we get into the habit of breathing faster or deeper than we need. It is a risk if we get drawn into "breathing exercises".

39. One of the effects of such over-breathing is that it increases the amount of carbon dioxide expelled with each breath. Technically, this is known as hyperventilation. We often think of hyperventilation as a kind of panicky gasping but it does not need to be particularly dramatic to cause quite serious problems.

40. Since carbon dioxide makes the blood acidic, over-breathing, by reducing the amount in the blood makes it more alkaline. This is known as alkalosis and can lead to hand trembling, numbness or tingling in the face or extremities, dizziness and so forth. In severe cases it can also lead anxiety and tension – the classic "fight or flight" symptoms.[1]

41. So it is important that we breathe in the way nature intended. This is also why improving the way people are breathing can sometimes have quite dramatic effects on their general health and well-being.

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[1] Lum (1981) p3

42. Breathing was very much a concern of Alexander's and it was as a teacher of proper breathing that he originally made his name.

43. So next time I am going to look at the basic mechanics of ordinary breathing.