# Multiple Choice Questions in Physiology

## with answers and explanatory comments

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# Introduction

Multiple-choice questions are being used increasingly in examinations at all levels, but they often test little more than factual recall. The main purpose of this booklet is to provide a selection of questions that also test reasoning power and ability to interpret data or perform simple calculations. Most of the questions were devised originally for examining preclinical medical students at University College London and they have been found to discriminate well among students of differing abilities as judged by other criteria.

We hope that teachers of physiology and their students will benefit from this booklet. Teachers may find the questions provide a useful source of ideas for creating their own questions, while students will gain experience of multiple-choice questions that test understanding as well as factual knowledge. Students may also find working through the booklet a useful form of revision as explanatory comments are provided for most of the answers; these are more detailed for points that students tend to find difficult.

*How to use the booklet*. The main topics covered are set out on the Contents page. Questions on the central nervous system and special senses are not included because these topics are taught and examined in a separate Neurosciences course at University College. Questions on applied and clinical physiology that are more suitable for 2nd year medical students are marked with an asterisk. Every question consists of a stem and five statements, each of which must be judged '**True**' or '**False**'. We suggest you answer all parts of the question before looking at the answers and explanations given on the opposite page.

*Test yourself*. You may like to compare your performance with that of our medical students. Give yourself a mark of +1 for each correct judgement, −1 for each incorrect judgement, and zero for any you left out. The score for each question can therefore vary from +5 to −5 marks. In tests consisting of 20 questions, the mean mark for University College students in examinations over a period of five years has been around +50 with a standard deviation of about 10 marks. There are of course other ways of setting and marking multiple-choice questions, and a useful discussion of these with references will be found in the booklet 'An Introduction and Guide to the Use of Multiple-Choice Questions in University Examinations' published by the University of London.

*Ambiguous questions*. It is extremely difficult to set questions that contain no ambiguities and for several years we have invited our examination candidates to qualify their answers to questions they find ambiguous by writing on the question paper. In fact this has necessitated very few adjustments to the marks awarded, but it has allowed us to refine some of our questions and it has undoubtedly helped to reduce the tension often induced by multiple-choice examinations. We would be pleased if users of this booklet would draw our attention to ambiguities in the questions included in it.

*Acknowledgements*. We thank the University of London for permission to publish some of our examination questions and Deana MacCormack for her skill and patience in typing this booklet.

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**Abbreviations**

*Units*

| | |
|---|---|
| g | gram |
| l | litre |
| m | metre |
| s | second |
| mol | mole |
| osmol | osmole |
| Pa | pascal (unit of pressure = 1 newton/$m^2$) |
| mm Hg | millimetre of mercury |
| | 1 mm Hg ≡ 133·3 Pa |

*Prefixes*

| | | |
|---|---|---|
| k | kilo | ($\times 10^3$) |
| m | milli | ($\times 10^{-3}$) |
| $\mu$ | micro | ($\times 10^{-6}$) |
| n | nano | ($\times 10^{-9}$) |

1 The following statements give reasons for including certain ingredients in physiological bathing solutions:

(a) The composition of a physiological bathing solution should be as close as possible to that of intracellular fluid.
(b) Nerve axons become inexcitable if they are bathed in a Na-free Ringer's solution.
(c) Spontaneous activity will occur in nerve fibres if the $Ca^{++}$ concentration in the bathing medium is too high.
(d) The membrane potential of a nerve axon is more sensitive to the concentration of potassium in the bathing medium than to the concentration of any other ion.
(e) If a bathing solution containing bicarbonate is bubbled with pure oxygen instead of 5% $CO_2$/95% $O_2$ mixture, its pH will be too low.

2 The following are statements about the osmotic pressure of plasma:

(a) The *total* osmotic pressure of plasma is similar to that of 0·9% NaCl.
(b) The *total* osmotic pressure of plasma is similar to that of 0·9% glucose.
(c) The *total* osmotic pressure of the plasma is largely due to the contributions of Na + Cl ions.
(d) The *colloid* osmotic pressure of plasma is about 25 mm Hg.
(e) The *total* osmotic pressure of plasma opposes the ultrafiltration of fluid from the capillaries.

3 Glycerol penetrates the red cell membrane rather slowly. Which of the following will happen when red cells are suspended in a solution of 1 mol/l glycerol in water?

(a) The red cells will immediately undergo haemolysis.
(b) The red cells will shrink, becoming permanently crenated.
(c) The red cells will swell first and then shrink to become permanently crenated.
(d) The red cells will shrink first and then swell and haemolyse.
(e) No volume changes will take place.

4 The following are statements about human red blood cells:

(a) Red cells are rigid biconcave discs.
(b) Normally 10 to 20% of circulating red cells contain remnants of nuclear material.
(c) Following haemolysis, red cells release haemopoietin which stimulates the production of more red cells.
(d) Red cells contain carbonic anhydrase.
(e) Red cells make a major contribution to the buffering capacity of the blood.

1 (a) **False** It should resemble interstitial fluid.
(b) **True** Na is essential for the action potential.
(c) **False** Spontaneous activity will occur if $[Ca^{++}]$ is too *low*. See the answer to 97 (c).
(d) **True** This is because the resting potential depends mainly on the ratio of the K concentrations inside and outside the membrane.
(e) **False** Its pH will be too high.

$$pH = pK + \log_{10}\frac{[HCO_3^-]}{[CO_2]}$$

2 (a) **True** Red blood cells will neither swell nor shrink when placed in 0·9% NaCl which is often referred to as 'physiological' saline. Both have an osmolarity of about 300 mosmol/l.
(b) **False** The molecular weight of glucose is different from that of NaCl, so 0·9% glucose will have a different molarity. Even if the molarities of the two solutions were equal, the osmolarities would differ because NaCl dissociates in solution and exerts a higher osmotic pressure.
(c) **True**
(d) **True** The plasma proteins exert a very small fraction (about 1/200) of the total osmotic pressure of about 5000 mm Hg (1 mm Hg $\equiv$ 133·3 Pa).
(e) **False** It is only the colloid osmotic pressure that opposes the loss of fluid. Small particles like ions and glucose can diffuse across the capillaries and hence can exert no transmural osmotic pressure.

3 (a) **False** There are neither chemical nor physical factors that will cause *immediate* disruption of the membrane.
(b) **False**
(c) **False**
(d) **True** The osmotic gradient between the glycerol solution (1 osmol/l) and the cell contents (0·3 osmol/l) will initially cause water to leave the red blood cell. Glycerol penetrates slowly under the concentration gradient until the osmolarity of the cell contents exceeds that of the glycerol. Water will therefore re-enter the cell and eventually the swelling produced by the continual entry of glycerol and water will burst the cell membrane.
(e) **False**

4 (a) **False** They are not rigid, and indeed undergo considerable reversible deformation as they pass through capillaries. They only appear as biconcave discs when unstressed.
(b) **False** Normally there are 1 to 2% of reticulocytes. Much higher percentages occur when there is accelerated haemopoiesis.
(c) **False** The main source of haemopoietin is the kidney.
(d) **True**
(e) **True**

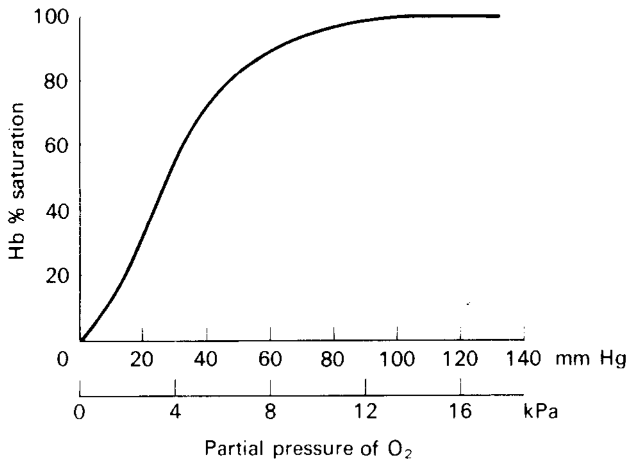
*5 A blood count in a woman aged 40 gave the following picture: Hb, 110 g/l, RBC, $3{\cdot}0 \times 10^{12}$/l; mean cell diameter, $8{\cdot}2\mu$m. The following are statements about the findings:

(a) The blood picture is within normal limits.
(b) The findings are typical of iron deficiency anaemia.
(c) The findings are typical of vitamin $B_{12}$ deficiency.
(d) This blood would carry about 150 ml oxygen/l blood.
(e) The findings are typical of someone living at high altitude.

*6 Oxygen delivery to the tissues is usually reduced in the following conditions:

(a) Sickle cell anaemia.
(b) Reduced ventilation/perfusion ratio.
(c) Severe iron deficiency anaemia.
(d) Congestive cardiac failure.
(e) Emphysema.

7 The graph shows the relationship between the saturation of haemoglobin with oxygen and the partial pressure of oxygen.



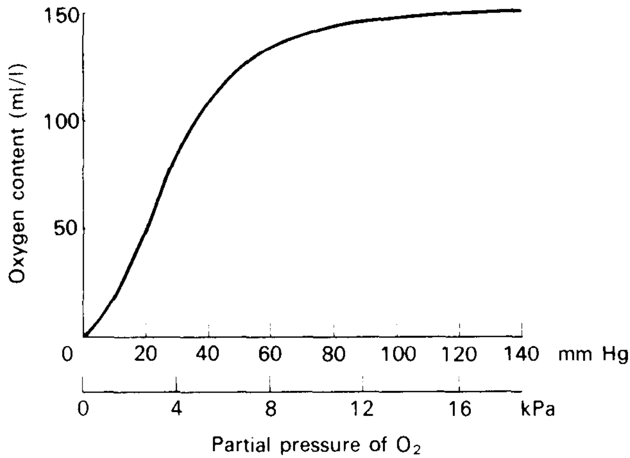

(a) A rise in pH will move the curve to the left.
(b) Anaemia will depress the curve.
(c) A fall in temperature will move the curve to the left.
(d) An increase in 2, 3, diphosphoglycerate in the red cells would shift the curve to the right.
(e) Foetal haemoglobin has a similar dissociation curve.

5 (a) **False** The Hb is lower, the RBC count lower and mean cell diameter larger than normal.
(b) **False** The woman is anaemic, but in iron deficiency anaemia red blood cells *are smaller than usual.*
(c) **True** Vitamin $B_{12}$ deficiency produces a megaloblastic anaemia which results in RBCs that are larger than normal.
(d) **True** Each 1 g of haemoglobin can carry 1·34 ml of oxygen at NTP.
(e) **False** *In acclimatization to high altitude the red cell count and haemoglobin* concentration would be higher than normal.

6 (a) **True** Sickled cells are more rigid than normal cells, and cannot therefore squeeze their way through narrow capillaries. (The abnormal Hb-S molecules form polymers when the oxygen tension is low, and the cell becomes sickle-shaped).
(b) **True** Blood leaving the lungs is likely to be less well oxygenated when the ventilation/perfusion ratio falls.
(c) **True**
(d) **True** The cardiac output is reduced and the peripheral resistance vessels are likely to be constricted. Both factors reduce oxygen delivery to the tissues.
(e) **True** As in (b) the blood is likely to be incompletely oxygenated when it leaves the lungs.

7 (a) **True**
(b) **False** Look again at the ordinate! It is *percentage* saturation of haemoglobin, not oxygen content of the blood.
(c) **True**
(d) **True** This occurs for example in acclimatization and in anaemia, and assists in unloading oxygen in the tissues.
(e) **False** It is displaced to the left, thereby facilitating oxygen transfer from mother to foetus. Foetal Hb is less affected by 2,3,DPG than adult Hb.

8 This diagram shows how the oxygen content of a sample of blood varied with the $PO_2$ of the gas with which it was in equilibrium at a $PCO_2$ of 40 mm Hg (5·3 kPa).




(a) The sigmoid shape of the curve is due to the fact that red blood cells vary in their affinity for oxygen.
(b) This sample of blood must have had a haemoglobin concentration of about 150 g/l.
(c) The haemoglobin is almost fully saturated at a $PO_2$ of 100 mm Hg (13·3 kPa).
(d) If the $PO_2$ had been raised to higher values, the curve would have become horizontal when the $PO_2$ exceeded 150 mm Hg (20 kPa).
(e) If the $PCO_2$ of the sample is increased, the oxygen content would be greater at a given $PO_2$.

9 The following are statements about the viscosity of blood:
(a) Viscosity of the blood increases as the haematocrit increases.
(b) The viscosity of blood flowing through small tubes (e.g. arterioles) is lower than in large tubes (e.g. the aorta).
(c) The viscosity is less at 25°C than at 37°C.
(d) Viscosity of the blood usually increases in acclimatised mountaineers.
(e) It is decreased in people with iron-deficiency.

10 Blood clotting is delayed or prevented *in vitro* when:
(a) Blood is placed in polythene tubes (compared with glass tubes).
(b) The temperature of the blood is increased from room temperature to 37°C.
(c) Sodium citrate is added to the blood.
(d) Dicoumarol is added to the blood.
(e) When heparin is added to the blood.

8 (a) **False** It is due to the binding properties of the haemoglobin molecule for oxygen.
(b) **False** 1 g haemoglobin can combine with 1·34 ml of oxygen at NTP.
(c) **True**
(d) **False** The curve (i.e. the oxygen content) would continue to rise slightly as more oxygen is dissolved in physical solution.
(e) **False** It's the other way around (Bohr effect).

9 (a) **True** Remember that the haematocrit is the fraction of red cells in the blood sample.
(b) **True** A surprising fact with a complicated explanation.
(c) **False** Viscosity always increases with a fall in temperature.
(d) **True** In acclimatization the haematocrit rises.
(e) **True** Iron-deficiency leads to anaemia and hence to a lower haematocrit.

10 (a) **True** The non-wettable surface delays surface activation of the initial sequences of blood clotting.
(b) **False** The optimum temperature for the enzymes involved is around 37°C.
(c) **True** It binds the calcium ions that are essential for clotting.
(d) **False** Dicoumarol is a competitive antagonist of vitamin K which is required for prothrombin synthesis. Dicoumarol added to the blood *in vitro* therefore has no effect on blood clotting as prothrombin is already present. *In vivo* it needs to be taken for a few days before any effects are seen.
(e) **True** Heparin is an effective anticoagulant both *in vitro* and *in vivo* and probably acts as an anti-thrombin.

11 It is often difficult to find suitable blood for transfusion to patients who have had:
(a) A previous transfusion of Rh+ blood.
(b) Horse serum injections (e.g. anti-tetanus serum).
(c) Many previous transfusions.
(d) Syphilis or jaundice.
(e) No previous transfusion.

12 If Rh+ blood is transfused into an Rh− woman who has not previously been transfused, then:
(a) Anti-Rh antibodies will be produced by the woman.
(b) The bloods are incompatible so red cell agglutination and death may follow.
(c) In a subsequent pregnancy the foetus could be threatened by haemolytic disease.
(d) There is no immediate or long term effect as 70% of the Rh+ population are heterozygous.
(e) Provided anti-D antibody is given before the next pregnancy no harm will be done.

13 A man of blood group A has 2 children. Plasma from the blood of one of them agglutinates his red cells while that from the other does not.
(a) Father *must* be heterozygous group A.
(b) Children *must* have had different mothers.
(c) 'Agglutinating' child *could* be group O.
(d) Mother of 'agglutinating' child *must* be group O.
(e) 'Non-agglutinating' child *could* be group AB.

14 The following are statements about the autonomic nerve supply to the heart:
(a) In the normal animal there is a background level of sympathetic 'tone' to the heart.
(b) Increased sympathetic activity decreases the rate of firing of the pacemaker cells.
(c) Sympathetic stimulation shifts the curve relating stroke work (ordinate) to diastolic volume of the heart (abscissa) to the right.
(d) Sympathetic stimulation increases the rate of coronary blood flow.
(e) Stimulation of the vagus nerve slows the heart rate.

11 (a) **False** If the recipient were Rh +ve, a Rh +ve transfusion would not provoke antibody formation. If the recipient were Rh −ve, a previous Rh +ve transfusion would have provoked antibody production but Rh −ve blood is readily available, so there is no problem.
(b) **False** This could make subsequent injections of horse serum dangerous but has no effect on blood group antigen/antibody reactions.
(c) **True** Each transfusion increases the possibility of antibody formation because of subgroup incompatibility.
(d) **False** People who have had syphilis or jaundice should not be used as *donors*.
(e) **False** But in every case recipient and donor blood should be directly cross-matched even if apparently compatible.

12 (a) **True** These will be mostly anti-D.
(b) **False** There are no naturally occurring anti-Rh antibodies.
(c) **True** After the transfusion anti-Rh+ antibodies would be formed; they may cross the placental barrier and if the foetus were Rh +ve react with foetal red blood cells.
(d) **False** Irrelevant.
(e) **False** Anti-D antibody cannot be used in this situation. It can be used immediately after childbirth to prevent a Rh −ve mother from forming anti-D antibodies to cells from a Rh +ve foetus that could have passed into her circulation at parturition. The donated antibodies are destroyed within a few weeks and so will not threaten future foetuses.

13 (a) **True** The A gene is dominant, so if he were *homozygous* group A, his children would be group A or AB, and neither plasma would agglutinate his cells.
(b) **False** The mother could for example be group AB. The non-agglutinating child could be group AA and the agglutinating child, BO.
(c) **True** Or the child could be group B with B gene inherited from the mother and O from the father.
(d) **False** See answer to b.
(e) **True**

14 (a) **True**
(b) **False** It increases heart rate.
(c) **False** The curve is shifted upwards and to the left (greater stroke work at given fibre length).
(d) **True**
(e) **True**

15 An infusion of noradrenaline is given to a human subject at a sufficient rate to produce a rise in systolic BP of 20 mmHg (2·7kPa). The consequences are likely to be:
(a) An increase in diastolic blood pressure.
(b) Decreased firing in the baroreceptor nerves.
(c) A reflex bradycardia (slowing of the heart).
(d) A generalized decrease in sympathetic nerve discharge.
(e) A decrease in [FFA] (free fatty acid concentration).

16 Cardiac output is decreased:
(a) During stimulation of efferent fibres in the vagus nerve.
(b) As a consequence of decreased pressure in the carotid sinus.
(c) By increasing the end-diastolic volume of the heart.
(d) On cutting the sympathetic nerves to the heart.
(e) On standing up.

17 The consequences of arteriolar vasoconstriction in an organ are likely to be:
(a) A reduction in blood flow through the organ.
(b) An increase in capillary pressure in the vascular bed.
(c) A decrease in the arterio-venous oxygen difference (i.e. difference in oxygen concentration in blood entering and leaving the organ).
(d) An increase in the partial pressure of $CO_2$ in blood leaving the organ.
(e) A decrease in the rate of lymph flow from the organ.

18 The following are statements about the exchange of substances between blood and the interstitial fluid:
(a) $O_2$ and $CO_2$ pass easily across capillary walls.
(b) The exchange of non lipid-soluble substances across capillary walls requires the presence of water-filled pores in the endothelial lining.
(c) Movement of a substance from blood to interstitial fluid will occur only if there is a favourable concentration gradient.
(d) Exchange diffusion provides an enormously greater turnover of water between the blood and the interstitial space than filtration and reabsorption along the lines envisaged by Starling.
(e) Exchange of substances between blood and interstitial fluid also occurs across the walls of venules.

15 (a) **True**
(b) **False** An *increased* firing results from the rise in blood pressure.
(c) **True** A consequence of the increased baroreceptor discharge; vagal slowing of the heart overrides any direct cardioaccelerator action of noradrenaline.
(d) **True** This is another reflex consequence of (b).
(e) **False** A *rise* in [FFA] is brought by activation of $\beta$ receptors. Noradrenaline acts mainly on $\alpha$ receptors.

16 (a) **True** Heart rate drops and hence cardiac output falls.
(b) **False** There is a reflex increase in cardiac output (and peripheral resistance).
(c) **False** It is increased by the Starling relationship except in the failing heart.
(d) **True** The heart rate and stroke volume decrease because of the abolition of sympathetic tone.
(e) **True** Cardiac output drops when you stand up due to pooling of blood and remains lower in spite of compensatory reflex adjustments.

17 (a) **True** Flow is given by P/R. The vascular resistance of the organ, R, is increased by arteriolar constriction, but P, the driving pressure, will not be increased much by vasoconstriction in a single organ. Flow will therefore decrease.
(b) **False**
(c) **False** If the blood flow falls, *more* oxygen will be extracted during the passage of blood through the capillary.
(d) **True**
(e) **True** There will be diminished filtration if capillary transmural pressure is reduced.

18 (a) **True** These gases are lipid soluble and can therefore easily penetrate cell membranes.
(b) **True** However such pores do not have to have a permanent existence.
(c) **False** Diffusion occurs in both directions but *net* movement by diffusion can only occur *down* a concentration gradient. Note also that movement can take place *against* a concentration gradient by ultrafiltration or by active transport.
(d) **True**
(e) **True** Total surface area of venules approaches that of capillaries and filtration coefficients can be higher.

19 The following are important variables in circulatory physiology: cardiac output, CO; total peripheral resistance, TPR; mean arterial blood pressure, BP; stroke volume, SV; heart rate, HR. Are the following relationships true or not?
(a) BP = CO × TPR
(b) CO = BP/TPR
(c) CO = SV × HR
(d) HR = BP/(SV × TPR)
(e) TPR = BP × SV × HR

20 The diagram shows a tube in which there is a narrow region, B, where the diameter is half that at A and C:


(a) The resistance to flow (per unit length of tube) will be eight times greater at B than at A.
(b) The velocity of flow will be four times greater at B than at A.
(c) The lateral (side-wall) pressure at B will be greater that at A.
(d) The pressure drop along the narrow section will be inversely proportional to its length.
(e) The tangential stress in the wall of the tube will be less at B than at A.

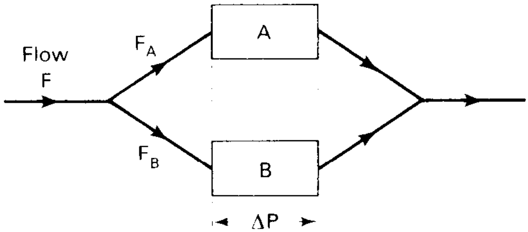
21 The following are statements about veins:
(a) Kinetic energy accounts for a much higher proportion of the total energy of blood flowing in the inferior vena cava than it does in the aorta.
(b) Sub-atmospheric pressures are never found in blood vessels outside the thoracic cavity.
(c) If the transmural pressure at a point A in a blood vessel is greater than that at point B, then the direction of blood flow in the vessel must be from A to B.
(d) The pressure in the veins of the foot will be lower when a person is walking than it will be when he is standing still.
(e) About two thirds of all the blood in the body is found in the systemic veins.

19 (a) **True** This can be considered as a haemodynamic equivalent of Ohm's law.
(b) **True**
(c) **True**
(d) **True**
(e) **False**

20 (a) **False** Resistance is proportional to 1/radius$^4$, so if the radius is halved resistance will increase by a factor of 16.
(b) **True** Velocity × cross-sectional area must be the same at A and B, and the area decreases by a factor of 4.
(c) **False** If velocity (V) is greater at B than at A, the kinetic energy of the moving fluid ($\frac{1}{2}mV^2$) will also be greater. As the total energy of fluid (kinetic + pressure energy) cannot be greater at B than at A, pressure energy at B (and therefore side wall pressure) must be less than at A.
(d) **False** The pressure difference will be proportional to length (Poiseuille's Law).
(e) **True** The Laplace relation predicts this.

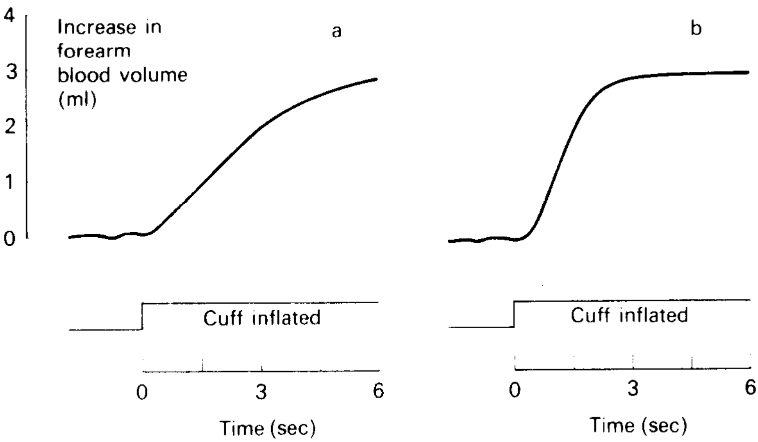
21 (a) **True** The flow (ml/min) in both vessels is about the same, so is their cross-sectional area; therefore mean velocity and kinetic energy will be similar. However pressure energy is nearly 100 times greater in the aorta than in the inferior vena cava.
(b) **False** They occur in cranial sinuses, where rigid walls prevent vessels collapsing due to sub-atmospheric pressure.
(c) **False** *Transmural* pressure gradients have nothing to do with blood flow *along* tubes.
(d) **True** Due to muscle pumping and the presence of valves.
(e) **True**

22 A and B represent two vascular beds (e.g. skin and muscle of upper limb) which are supplied with blood from the same artery (e.g. brachial). F denotes blood flow and R resistance to blood flow. Suppose the pressure drop, $\Delta P$, across the vascular beds remains constant:




(a) The flow through A is given by: $F_A = \Delta P/R_A$
(b) The total flow is given by: $F = F_A + F_B = \Delta P/(R_A + R_B)$
(c) An increase in $R_B$ will lead to a reduction in $F_B$.
(d) An increase in $R_B$ will lead to an increase in $F_A$.
(e) The combined resistance, R, of the two vascular beds is given by: $R = 1/R_A + 1/R_B$.

23 Diagrams a and b are records obtained by venous occlusion plethysmography on the human forearm taken before and during (or just after) an experimental intervention:




(a) Recording b could have been taken after cooling the forearm.
(b) Recording b could have been taken during fainting.
(c) Recording b could have been taken immediately after exercising the forearm.
(d) Recording b could have been taken after administration of a $\beta$-adrenergic antagonist.
(e) Recording b could have been taken by raising the occlusion cuff pressure to 60 mm Hg instead of the 40 mm Hg used in the control record a (to 8 kPa from 5·3kPa).