COMMUNICATIONS

BLOOD VESSELS OF THE BULBAR CONJUNCTIVA IN MAN*†

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LARGELY owing to technical difficulties the role of the capillary in human disease is not known. Chambers (1948) stated that an adequate survey of the capillary bed for study of the variations in its functional activity required tissue in which the vessels could be traced from the arteriolar to the venular ends, and at the same time be exposed for observation with a minimum of trauma so as not to upset the normal activity of the functioning components of the bed. In man, the only available site which fulfils these requirements is the bulbar conjunctiva.

The topography of minute vessels was greatly clarified by Chambers and Zweifach (1944), who demonstrated the existence of a structural unit in the architecture and physiological activity of the capillary bed. These investigators found, in the mesentery of the dog and the meso-appendix of the rat, occasional vessels of capillary dimensions through which the blood was flowing more rapidly than through the capillaries adjacent to them. These vessels originated as branches or as prolongations of the terminal arterioles and could be traced through the vascular bed until they merged with similar channels to form the venules. These thoroughfare or central channels were frequently varicose along their proximal portions.

The capillaries were branches of the central channels. Along the proximal portion of a central channel the capillaries branched off more or less abruptly and carried the blood away from it. Along the distal portion they joined at increasingly acute angles in the direction of the flow within the channel. The junctional segments of the capillaries leaving the meta-arteriole were designated the pre-capillaries, and were encircled by contractile muscle cells, the pre-capillary sphincters. The muscle cells of the junctional segments along the remainder of the central channel progressively diminished until, at the venular portion, they were absent. The true capillaries were purely endothelial vessels which extended between the pre-capillaries and the capillaries which led into the venous channels. Capillaries were not branches only of the central channels. Along the length of a typical arteriole occasional capillary offshoots were seen.

Fig. 1 shows a diagrammatic representation of Chambers and Zweifach's concept of a structural unit.

The terminal and meta-arterioles were observed to undergo alternate constriction and dilatation (spontaneous vaso-motion). These phases occurred at irregular intervals of about 15 seconds to 3 minutes. The constriction was not so complete that the flow stopped, although the rate of flow was affected, being slower during the constrictor phase of vaso-motion. The pre-capillaries also exhibited vaso-motion in which the sphincters tended to close completely during the constrictor phase. Vaso-motion produced an intermittent flow in the true capillaries, and when the constrictor phase predominated the main bulk of the blood from the arterioles became restricted to the thorough-fare channels. The control of vaso-motion was considered to be under humoral and nervous influence.

Although Jacobj (1920) had described main channels in which the blood was flowing at all times in frogs, and Klemensiewicz (1923) observed that during ischaemia the side branches from these main channels were closed, Zweifach (1937, 1939) and Chambers and Zweifach (1944) were the first to demonstrate the widespread occurrence of arteriolar-venular channels of which the true capillaries were side branches, and the existence of a structural pattern in the minute vessels.
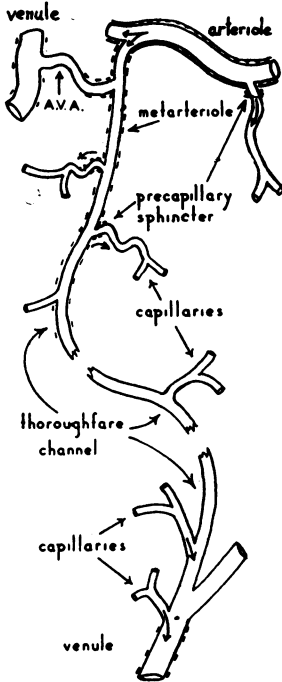

FIG. 1.—Diagram of functional unit of the capillary bed, with a meta-arteriolar-venular anastomosis (A-V-A) and a precapillary branching off directly from an arteriole (after Chambers and Zweifach, 1944).

The concept of a structural and functional unit in capillary organization was not accepted by all; Webb and Nicoll (1954) stated that in the bat's wing they were unable to distinguish thoroughfare channels and could not accept such specialized structures as part of the fundamental pattern of capillary organization. Lutz and Fulton (1954) observed that in the cheek pouch of the hamster there was a rich network of vein-to-vein anastomoses and many arteriolar inter-communications; thoroughfare channels were not obvious.

Modifying his earlier statements, Zweifach (1954) said that subsequent studies had indicated that a similar type of thoroughfare channel was present in tissue other than animal mesentery but to a modified extent.

The view now held is that the true capillary is a non-muscular and therefore probably non-contractile structure. Whatever the mechanisms involved, however, it is certain that the living organism can regulate the flow of blood

through its minute vessels.   Sanders, Ebert, and Florey (1940) suggested that alteration in the calibre of the capillaries could be produced by swelling of the endothelial cells which occurred both spontaneously and in response to sympathetic stimulation.   Chambers and Zweifach considered that these workers must have been observing the junctional segment of an abrupt offshoot from a larger vessel, since it closely resembled a contracted pre-capillary sphincter.

The majority of studies of the topography of the minute vessels have been carried out in animals.   It should not be taken for granted that the same vascular phenomena occur in man.

The objects of the present investigation were to determine the normal appearances of the minute vessels of the bulbar conjunctiva in man, and to establish whether or not there existed a structural or a functional pattern of architecture.

Clinical Material

Two series of normal healthy subjects were examined.   The first comprised sixty subjects (36 male, 24 female) aged between 9 and 76 years, in each of whom the left lateral bulbar conjunctiva was examined thoroughly on one occasion.   The purpose of this study was to acquire familiarity with the normal appearances of the conjunctival blood vessels and to be able to differentiate the various vascular elements.

For the second part of the investigation, eight normal, healthy, young subjects (3 male, 5 female) aged between 23 and 31 years were used.   In this group one area of bulbar conjunctiva was examined repeatedly over a period of not less than 2 months.

Each subject examined felt well and gave no previous history of eye disease: the erythrocyte sedimentation rate (Westergren) was less than 10 mm./hr, and the blood pressure was within the normal range for age as described by Master, Garfield, and Walters (1948).

Methods of Examination

The subject was seated at an ophthalmological slit-lamp table.   The chin was placed upon an adjustable rest and further stability for the head was provided by a forehead bar, also adjustable.   The subject's gaze was directed laterally to an object strategically placed to expose the maximum area of lateral bulbar conjunctiva compatible with comfort.   A tungsten filament lamp in a lamp-house was focused upon the exposed surface which was directly observed through a stereoscopic dissecting microscope, using paired ×5 or ×10 objective glasses and paired ×10 eyepieces.   This optical system therefore gave magnifications of fifty or one hundred diameters.   A piece of heat-resisting glass was introduced between the light-source and the conjunctiva in order to eliminate the effects of temperature changes on the minute blood vessels.

For the comfort and confidence of the subject a considerable working distance was necessary.   This imposed a limitation of the magnification which could be employed.   The use of a stereoscopic microscope was highly advantageous.   At the higher magnification several disadvantages were encountered.   The depth of field was reduced, and, as the eye is a globular structure, only a small area of

conjunctiva was seen clearly and sharply. The problem of the constant, slight involuntary movements of the eye became accentuated. The light source required to be much more intense to permit adequate observation and the subjective discomfort occasioned by such illumination therefore limited the magnification employed.

For photomicrography, a monocular system was employed with a 1·5″ objective and a ×10 eyepiece. A 35-mm. eyepiece camera was fitted to a tube carrying a monitoring angle eyepiece. With such an instrument it was possible to keep the area to be photographed under observation up to and during the actual moment of exposure. The illumination was augmented by an electronic flash unit with an output of 100 joules, placed 9″ from the eye. The duration of the electronic flash was about 0·001 of a second. Using a shutter speed of 0·02 of a second, the effective exposure time was the duration of the flash.

In the first part of the investigation, arterioles, capillaries, and venules were distinguished easily. A single examination however was insufficient to determine the vascular pattern for three reasons:

(1) Subjective discomfort made it impossible to observe the conjunctival vessels for more than 15 min. at a time.
(2) It seemed likely that some blood vessels might be open at one time and closed at another, and that one examination might not reveal the normal complete peripheral vascular anatomy.
(3) In many places the vascular pattern was too complex to be properly understood during one short observation.

In the second part of the investigation, an arteriole was selected at random at the time of initial examination and the region of distribution of its branches noted. Several photomicrographs were then obtained, each focused at a slightly different point within the area to be studied. In this way a series of photographs each in focus at a slightly different point was obtained. These sharply focused areas were then cut out from the photographic prints and pieced together as a mosaic to form a composite photomicrograph which formed the basic plan for all future observations. Upon it were marked the direction of blood flow and the appearance of any blood vessels not apparent at the time of photography. For clarity of reproduction, the course of the blood vessels was traced on paper and drawn with India ink. In all figures, arterioles are shown with stippled centres, venules as broad black lines, and capillaries as single black lines. The term arterio-venous anastomosis will be used to describe a vessel which conforms to the description given by Grant (1930); other wide vessels which run from the arterial to the venous side will be termed arterio-venous communications. When doubt arose as to the identity of a portion of an arterio-venous communication, it was represented as arteriolar up to the point where the last capillary branch was given off. The direction of the blood flow is indicated with arrowheads.

When, after repeated observation, it seemed probable that all blood vessels normally open had been observed, adrenaline hydrochloride (1:1,000) was instilled into the conjunctival sac and the behaviour of each blood vessel noted. At a subsequent examination, the minimum concentration of adrenaline which produced a discernible change in the blood vessels (the adrenaline threshold) was determined. The concentrations used were 1:100,000, 1:50,000, 1:25,000, 1:10,000, and 1:5,000. In view of the rapidity with which dilute adrenaline

solutions lose constrictor activity, each solution was made up freshly from a stock solution of 1:1,000 strength immediately before instillation. Four drops of each solution were instilled proceeding from the weaker to the stronger solutions.

Blood Supply of the Conjunctiva

Three groups of blood vessels can be recognized. They are the posterior conjunctival vessels, or conjunctival vessels proper, the anterior conjunctival vessels, and the anterior ciliary vessels. From the lacrimal branch of the ophthalmic artery a peripheral arcade is derived. This arcade, situated at the upper border of the tarsus, supplies posterior conjunctival branches which pass upwards, bend round the conjunctival fornix, and descend to supply the bulbar conjunctiva, except for an area 4 mm. wide round the corneal rim. The peripheral arterial arcade of the lower lid is not always present; it is situated in front of the inferior palpebral muscle and has a similar distribution to that of the upper lid. The anterior ciliary vessels lie deep to the conjunctiva in the episcleral tissue; 4 mm. from the corneal rim they bend, pierce the sclera, and supply internal ocular structures. At this bend the anterior conjunctival vessels are given off; these supply the region round the corneal rim and send a few anastomotic twigs to join with the posterior conjunctival vessels.

The posterior conjunctival vessels are mobile and move with the conjunctiva when the eyelids are closed. The other vessels do not move with the conjunctiva (Wolff, 1948). The conjunctival veins accompany the arteries. The blood is returned to the ophthalmic vein by a series of channels similar in course to the arteries.

Another type of vessel is found in the bulbar conjunctiva, the aqueous vein. These vessels emerge from the deeper ocular structures some 2 mm. from the limbus and run centrifugally. They are filled partly with a clear fluid and partly with blood and are held to be exit channels for the aqueous humour (Ascher, 1942).

Microscopic Appearances

I. The posterior conjunctival vessels only were examined in detail. All types of minute vessel could be recognized. It was possible to identify arterioles, capillaries, and venules, both by their appearance and by the direction of blood flow within them. The walls of the blood vessels were not normally visible, but the width of the stream of circulating blood, in the absence of anaemia and haemodilution, provided a fairly accurate indication of the diameter of the vessel (Bloch, 1954).

Arterioles.—These vessels were usually straight or gently curved and light red in colour. At magnifications of up to one hundred diameters it was not possible to perceive blood flow in the main arteriolar trunks. This was due probably to the opaque muscular wall and to the rapid rate of blood flow. In the terminal arterioles the flow of blood could be appreciated.

The calibre of the arterioles was even and regular in 55 subjects (92 per cent.) and showed beading in five (8 per cent.). The occurrence of small dilatations at points of bifurcation was frequent. The average ratio of the diameters of the arterioles to the venules (a/v) in each subject was:

1:2	..	..	..	6 subjects (10 per cent.)
1:3	..	..	..	40 subjects (66·7 per cent.)
1:4	..	..	..	14 subjects (23·3 per cent.)

The a/v ratio of the conjunctival vessels did not seem to be related to the age of the patient or to the a/v ratio of the retinal vessels. Inter-arteriolar anastomoses were seen occasionally. Spontaneously recurring phases of constriction and relaxation ("spontaneous vaso-motion") were observed.

Capillaries.—The capillaries were seen as fine hair-like structures of diameter just large enough to allow the passage of single blood corpuscles. The blood flow in some capillaries was constant, in others intermittent. Their calibre was even and regular, their course straight or gently curved. Looping and coiling were rarely observed.

Venules.—The venules were dark red in colour and much more tortuous than the arterioles. The calibre of the venules was even and regular in 38 subjects (63·3 per cent.) and showed multiple local dilatations in 22 (36·6 per cent.). Veno-venous anastomoses in which the blood flow was often bi-directional were common.

Arterio-Venous Anastomoses.—In all the subjects examined, dilated arterio-venous communications could be seen. These vessels were often tortuous. At this stage it was not possible to be certain of the exact nature of these vessels.

Aqueous Veins.—These vessels were observed in fifteen of the subjects examined. As the aqueous veins passed laterally they were joined by conjunctival venules. A striking feature was the maintenance of the separate identities of the streams in the parent vessel for a considerable distance (Fig. 2).
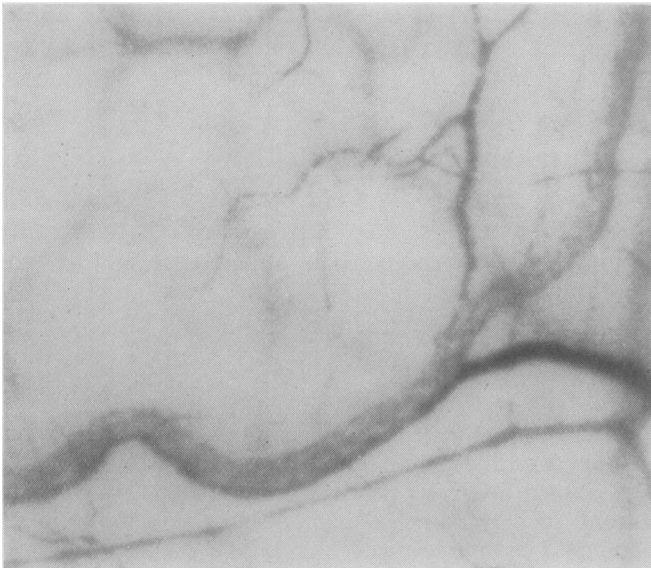

FIG. 2.—Aqueous vein joined by a venule; the blood maintains its own identity in the parent vessel ($\times 70$).

II. The minute vessels in the area of the conjunctiva examined and their response to the local instillation of adrenaline will be described separately in each subject examined. Each figure is oriented in the position in which it was seen.

Subject 1, male, aged 31 years (Fig. 3).—An arteriole ran alongside and then crossed its accompanying venule. A smaller arteriole was given off and this in turn gave several capillary branches (C). Both the arterioles exhibited spontaneous vaso-motion. All the capillaries represented in the figure were seen at each examination. The only variation which occurred was in the direction of blood flow in the capillary marked F, which was sometimes in one direction and sometimes in another. The calibre of the arterioles and venules was regular. The small cluster of capillaries (mid-left in the figure) were slightly wider in diameter than the other capillaries.

When adrenaline hydrochloride (1:1,000) was instilled into the conjunctival sac, there was immediate constriction of the arterioles and venules. The rate of blood flow was markedly reduced; in the small arteriole flow was extremely slow. Blood flow stopped completely in all the capillaries except in the vessel marked D, where it continued but at such a reduced rate as to be hardly perceptible. The presumptive true capillaries did not empty. The reaction of the blood vessels to adrenaline was repeated on five separate occasions with an identical pattern of response.

The adrenaline threshold was 1:5,000. No pattern of structural architecture was found in this area of conjunctiva.
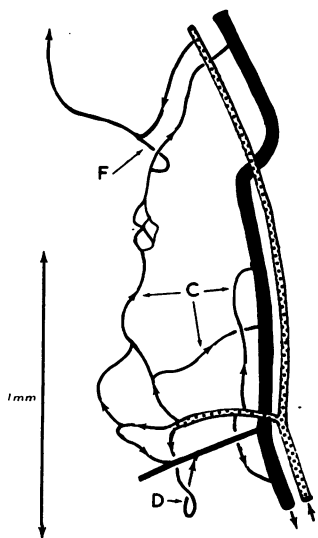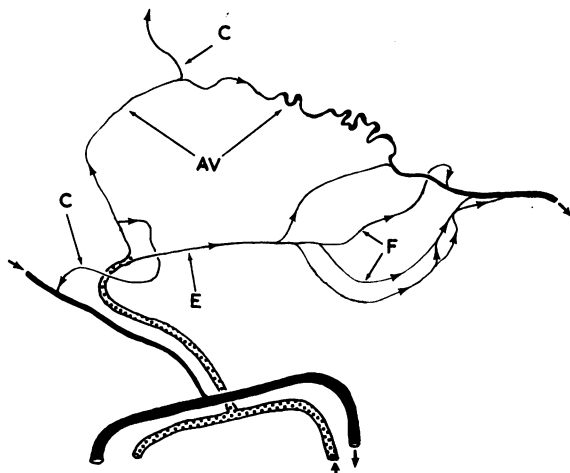

FIG. 3.—Subject 1 (1-mm. scale shown).   FIG. 4.—Subject 2 (Scale as Fig. 3).

Subject 2, female, aged 25 years (Fig. 4).—An arteriole gave off a smaller arteriolar branch; both vessels exhibited spontaneous vaso-motion. The vessel marked AV showed tortuosity and irregularity of calibre towards the venous end of its course. Blood flow was more rapid in this vessel than in the capillaries. In the vessel marked E the flow was intermittent, while in those marked C it was constant. All the capillaries were even in calibre and all the vessels shown were seen at each examination.

When adrenaline hydrochloride was instilled, the arterioles and venules were markedly constricted. Blood flow continued within them but at a markedly reduced rate. A

reduced rate of flow was also observed in the vessel AV. Vessel E disappeared imme-diately after the adrenaline was applied but 3 minutes later reopened to allow a spurt of blood to enter and pass through the various branches to the venous outflow. The process of admission of small quantities of blood into the vessel E continued and was observed for 10 minutes, during which the time between each period of flow gradually diminished and the duration of flow increased. The blood passing along this vessel did not take quite the same course on every occasion but never did one of the branches convey all the blood; the capillaries marked F were always employed. The capillaries marked C disappeared from view.

It could be suggested that the vessel AV was a thoroughfare channel (although it was of larger calibre than the capillaries), that the vessels C, E, and F were true capillaries, and that the pre-capillary sphincter at the junction between E and AV was particularly active in vasomotion. The adrenaline threshold was 1:25,000.

Subject 3, female, aged 30 years (Fig. 5).—An arteriole divided to give two equal-sized branches. After giving off several capillary branches, the upper arteriole in the figure passed straight into a venule. All the vessels were even in calibre and were seen at each examination. The upper arteriolar branch was very active in vaso-motion and was obviously an arterio-venous communication of considerable size.

After instillation of adrenaline hydrochloride, the arterioles and venules were greatly reduced in calibre and blood flow stopped in all the vessels except in the upper arteriole and the vessel AV, where it was maintained at a reduced rate. Forward flow in the lower arteriolar branch ceased, although a slight to-and-fro motion was just discernible. The majority of the capillaries (C) ceased to be apparent.

Blood entering from the arteriole therefore passed through a dilated arterio-venous communication straight to a venule. The architectural pattern and the response to adrenaline indicated that this vessel was more in the nature of a thoroughfare channel than a true arterio-venous anastomosis; it closely resembled the vessel described in Subject 2. The adrenaline threshold was 1:25,000.
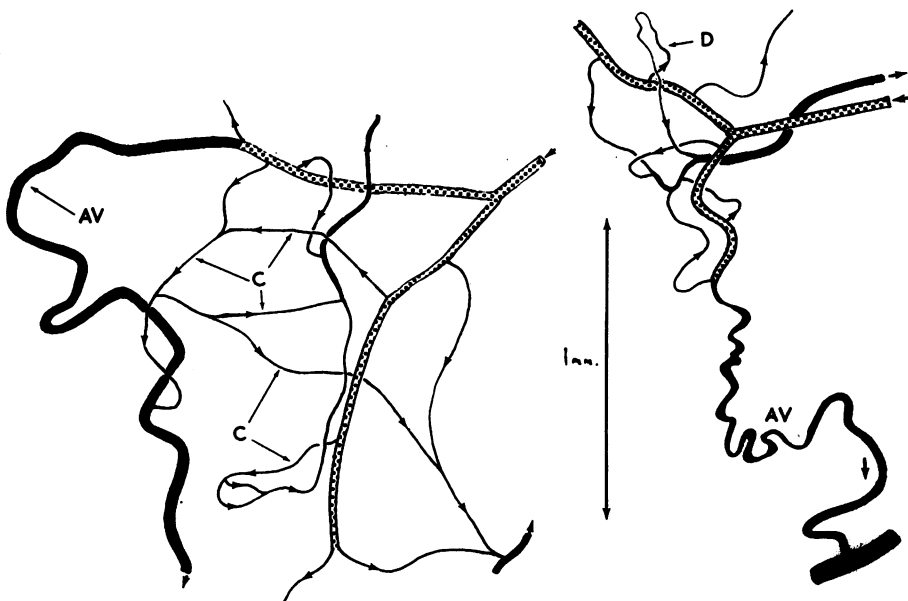

FIG. 5.—Subject 3 (Scale as Fig. 3).   FIG. 6.—Subject 4 (1-mm. scale shown).

Subject 4, female, aged 26 years (Fig. 6).—The striking feature in the area of conjunctiva studied in this subject was the existence of a large tortuous arterio-venous communication of irregular calibre in which the flow of blood was constant. All the other blood vessels represented in the diagram were of even calibre, and each was seen at every examination. The arterioles exhibited spontaneous vaso-motion which was especially well marked in the upper arteriole in the figure.

After instillation of adrenaline, blood flow continued in the tortuous vessel AV and in the vessel D, but at a greatly reduced speed: in the latter it was just perceptible. The capillaries remained visible although the blood flow within them ceased. The vessel AV was very similar to the vessels described in Subjects 2 and 3.

The adrenaline threshold was 1:5,000.

Subject 5, female, aged 26 years (Fig. 7).—Another broad arterio-venous communication (AV) was seen in which the blood flow was constant. Spontaneous vaso-motion was obvious in the arterioles. The calibre of all vessels was even. All the vessels represented were seen at each examination.

The response to adrenaline was the same as in Subject 4, in that the flow of blood continued at a reduced rate in the arterio-venous communication but ceased in the capillaries.
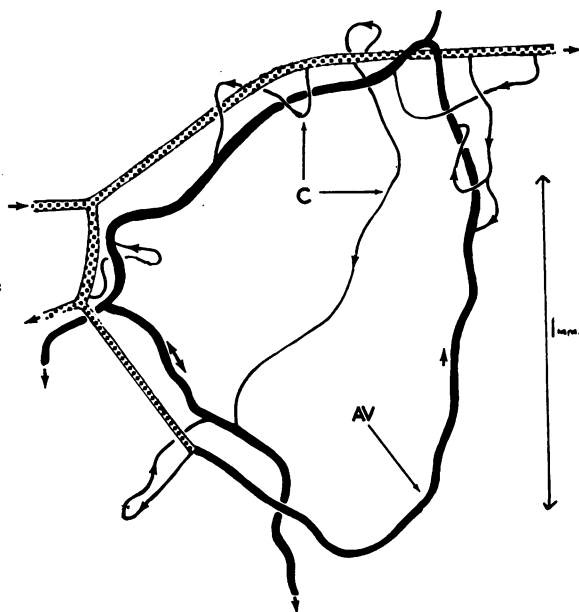
The adrenaline threshold was 1:10,000.

FIG. 7.—Subject 5 (1-mm. scale shown).

Subject 6, female, aged 23 years (Fig. 8 overleaf).—The area of conjunctiva studied in the next three subjects showed a much more complicated vascular arrangement than those described previously. In the present subject there were three small arterioles all of equal diameter in the area under study. All the blood vessels observed were seen at each examination. The flow of blood was constant and rapid in the two vessels AV. These vessels, larger in diameter than the capillaries, were further examples of arterio-venous communications. Both communications showed calibre variation and tortuosity. The blood flow in the majority of the capillaries was intermittent, spurts of blood passing through them with short periods of invisibility between.
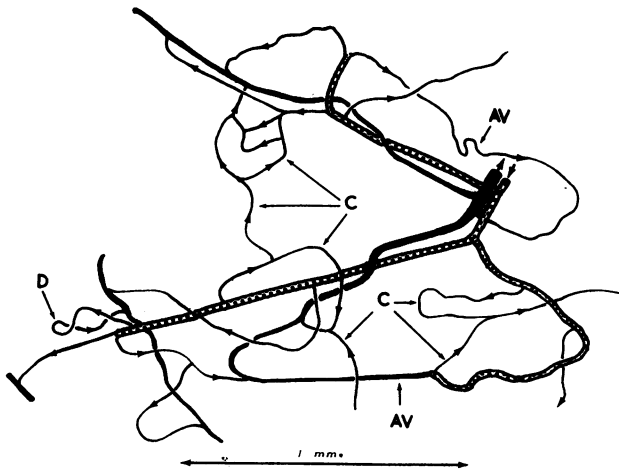
FIG. 8.—Subject 6 (1-mm. scale shown).

After instillation of adrenaline the flow of blood ceased in all the capillaries although they remained visible. In the vessels marked AV, blood flow continued but at a reduced rate. In vessel D the flow continued, but so slowly as to be hardly perceptible. The two tortuous vessels AV resembled the arterio-venous communications described previously, and the small vessel D was similar to the vessel similarly lettered in Fig. 1.

The adrenaline threshold was 1:25,000.

Subject 7, male, aged 28 years (Fig. 9).—Two large, wide arterio-venous communications (AV) were readily apparent. These vessels did not vary in calibre and blood flow was continuous within them. The arterioles showed spontaneous vaso-motion. A network of capillaries was observed, some of which were apparent at one examination and not at another.

When adrenaline was instilled, blood flow continued but at a reduced rate in both arterio-venous communications, but it ceased in the capillaries; some capillaries disappeared from view but the majority remained visible.

The adrenaline threshold was 1:25,000.

Subject 8, male, aged 26 years (Fig. 10). In this, the most complicated region examined, four arterioles supplied blood to the area. Each showed spontaneous vaso-motion. An arterio-venous communication (AV) was seen in which the blood flow was rapid and constant. In the small area (right centre in Fig. 10), there were many capillaries in which the blood flowed sometimes in one direction and sometimes in another. The calibre of all the blood vessels was even.

After instillation of adrenaline, the blood flow continued only in the vessel AV and in those marked D, but in the latter it was extremely slow. In the rest of the vessels blood flow ceased; in some places the capillaries disappeared and in others they remained visible.

The adrenaline threshold was 1:25,000.

Discussion

It is now well established that blood can circulate through the tissues by two routes, either through the capillaries or through arterio-venous anastomoses. Although arterio-venous anastomoses were described in various organs by some of the older anatomists, little attention was directed towards
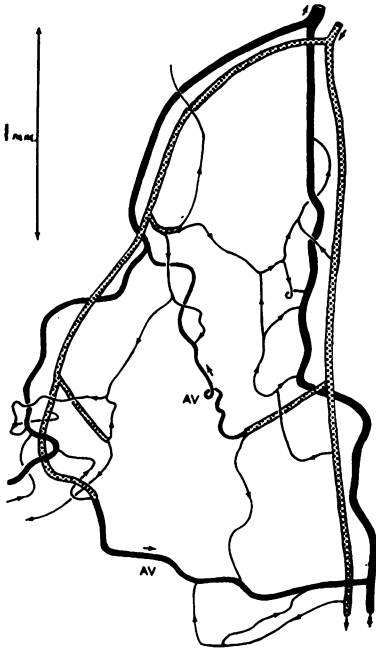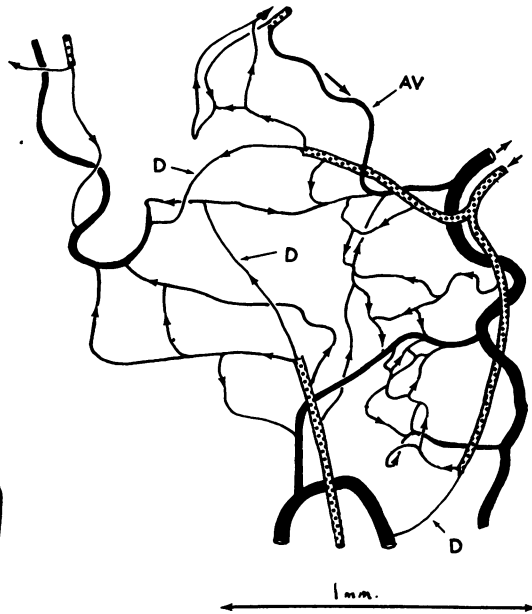
FIG. 9.—Subject 7 (1-mm. scale shown).   FIG. 10.—Subject 8 (1-mm. scale shown).

these structures until Grant (1930) and Grant and Bland (1931) demonstrated direct communications between the arteries and the veins in the rabbit ear and in human skin.   These vessels were shown to be active in contraction and dilatation.   Grant (1930) described muscular vessels, 20–70μ in diameter, which were closed at ordinary room temperature; when the temperature rose or fell below a certain critical level they opened.   They were constricted by adrenaline and dilated by mechanical stimulation, histamine, and acetylcholine.   The illustrations in Grant's article showed clearly that the arterio-venous anastomoses were capable of complete closure.   Clark (1938) stated that these vessels behaved in much the same way as the arteries and arterioles but were decidedly more active.   Clara (1939) listed as sites of occurrence of arterio-venous anastomoses, the nose, ear, glomus coccygeum, ovary, submandibular salivary gland, kidney, stomach, small intestine, mesentery, lymph nodes, and brain.

Prinzmetal, Simkin, Bergman, and Krüger (1947), by means of a technique involving the intra-arterial injection of glass spheres of known diameter, considered that they demonstrated the existence of arterio-venous anastomoses in the normal human heart *post mortem*.   If glass spheres of diameter many times greater than the average diameter of the capillaries could be recovered from the venous circulation of an organ after their intra-arterial injection, then the spheres must have travelled through channels which by-passed the capillaries.   With this technique, Prinzmetal, Ornitz, Simkin,

and Bergman (1948) and Simkin, Bergman, Silver, and Prinzmetal (1948) were able to demonstrate the existence of arterio-venous anastomoses in the liver, spleen, and lungs of living animals and in human kidneys *post mortem*. Simkin and others (1948) considered that there was evidence of a universal distribution of arterio-venous anastomoses which had a poorly understood role in the regulation and control of the circulation. The technique of intra-arterial injection of glass spheres can be criticized on the grounds that there is no way of telling the structure of the arterio-venous channel through which they may have passed. While the morphology of arterio-venous anastomoses may vary in different tissues, it is important that some definition of what constitutes such a vessel be established. It could be suggested that an arterio-venous anastomosis be required to fulfil Grant's description; certainly the term ought not to be applied indiscriminately to any dilated channel joining an artery to a vein.

Chambers and Zweifach (1944) stressed that the central channels of the capillary bed which they described were not strictly comparable with the arterio-venous anastomoses. Typically the arterio-venous anastomosis is a short muscular vessel which serves to shunt blood from an artery to the corresponding vein.

The most striking feature of the minute vessels of the bulbar conjunctiva was the existence of many arterio-venous communications, frequently tortuous, uneven in calibre, and much wider in diameter than the capillaries. These vessels were always open, even after the local application of adrenaline. Each arterio-venous communication gave off capillary branches in its proximal portion and received similar branches in its distal segment. There was often a considerable length of vessel in between which neither gave nor received branches. This disposition of the capillaries around a central arterio-venous communication was similar to that described by Chambers and Zweifach in the mesentery of animals, although the central channel in the conjunctiva was wider. Functionally they provided a mechanism whereby rather large quantities of blood could be delivered into the veins when the capillaries themselves were closed. By their behaviour they resembled a thoroughfare channel. This conclusion is in accord with the findings of Grafflin and Corddry (1953).

Regarding the architecture of the conjunctival vascular bed, Lee and Holze (1950) interpreted their findings in the conjunctival vessels as being generally in accord with those described by Chambers and Zweifach (1944) in the mesentery of animals. Grafflin and Bagley (1953) and Grafflin and Corddry (1953), however, stated that the vascular patterns exhibited endless variety, at times to the point of apparent randomness and suggested no definite plan of organization interpretable in terms of structural units. Nevertheless, by their acceptance of the arterio-venous communications as functionally similar to the thoroughfare channels, they did in fact accept some pattern of structural arrangement.

From the observations recorded in the present study, it is suggested that the arterio-venous communications present in the bulbar conjunctiva are more similar to the central or thoroughfare channels than to arterio-venous anastomoses. It is suggested that a structural pattern of architecture of the minute blood vessels exists in the bulbar conjunctiva of man, but only to a limited degree, and is certainly not as complete as that previously described in the mesentery of animals.

No true arterio-venous anastomoses were seen. The demonstration of arterio-venous communications of diameter considerably larger than the capillaries, but not justifying the name arterio-venous anastomoses, casts doubt upon the validity of experiments in which glass spheres were used to show the existence of vascular shunts.

It is obviously of fundamental importance to define what constitutes an arterio-venous anastomosis. It is suggested that the name be reserved for a short muscular vessel having an activity as great or greater than that of the arteries and arterioles, and capable of complete closure in response to topical adrenaline.

With regard to the sensitivity of the minute vessels to adrenaline, Lee and Holze (1950) stated that the adrenaline threshold in the conjunctival vessels was between 1:20,000 and 1:50,000 in a series of 51 normal subjects. In the present series, the adrenaline threshold ranged from 1:5,000 to 1:25,000.

Summary

(1) The minute blood vessels in the bulbar conjunctiva were studied in two groups of normal subjects. The appearance of the various vascular structures is described.

(2) The most striking feature of these blood vessels is the frequent occurrence of arterio-venous communications, larger in diameter than the capillaries, and frequently tortuous in course and irregular in calibre. These vessels resemble the thoroughfare channels previously described in the mesentery of animals.

(3) A structural pattern of architecture of the minute vessels exists, but to a limited degree, and is certainly not as complete as described in the mesentery of animals.

(4) No arterio-venous anastomoses were seen. The need for structural definition of arterio-venous anastomoses is stressed.

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