United States Patent

Oses

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[54] PARABIOSIS ASSEMBLY

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[63] Continuation-in-part of Ser. No. 608,190, Jan. 9, 1967, abandoned.

[52] **U.S. Cl.** ..... **128/214 B,** 128/214.2
[51] **Int. Cl.** **A61m 05/00**
[58] **Field of Search** 128/214, 214.2

[56] **References Cited**

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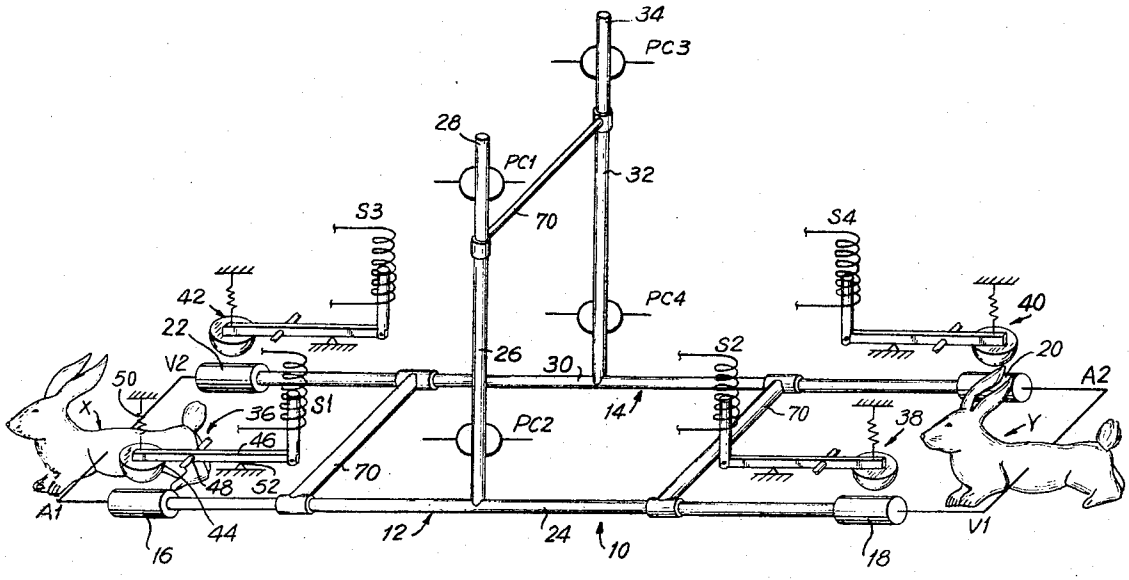
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[57] **ABSTRACT**

A parabiosis assembly for bringing about exchange of blood between a pair of beings. The arterial system of one being is interconnected with the venous system of the other being while the arterial system of this other being is interconnected with the venous system of the one being. The interconnecting structure provides for flow of a given quantity of blood from the arterial system to the venous system whereupon the cycle is repeated. The only force relied upon to move the blood between the beings is the pressure of the blood itself in the arterial systems, so that the use of pumps or other flow-producing devices is not required.

5 Claims, 2 Drawing Figures



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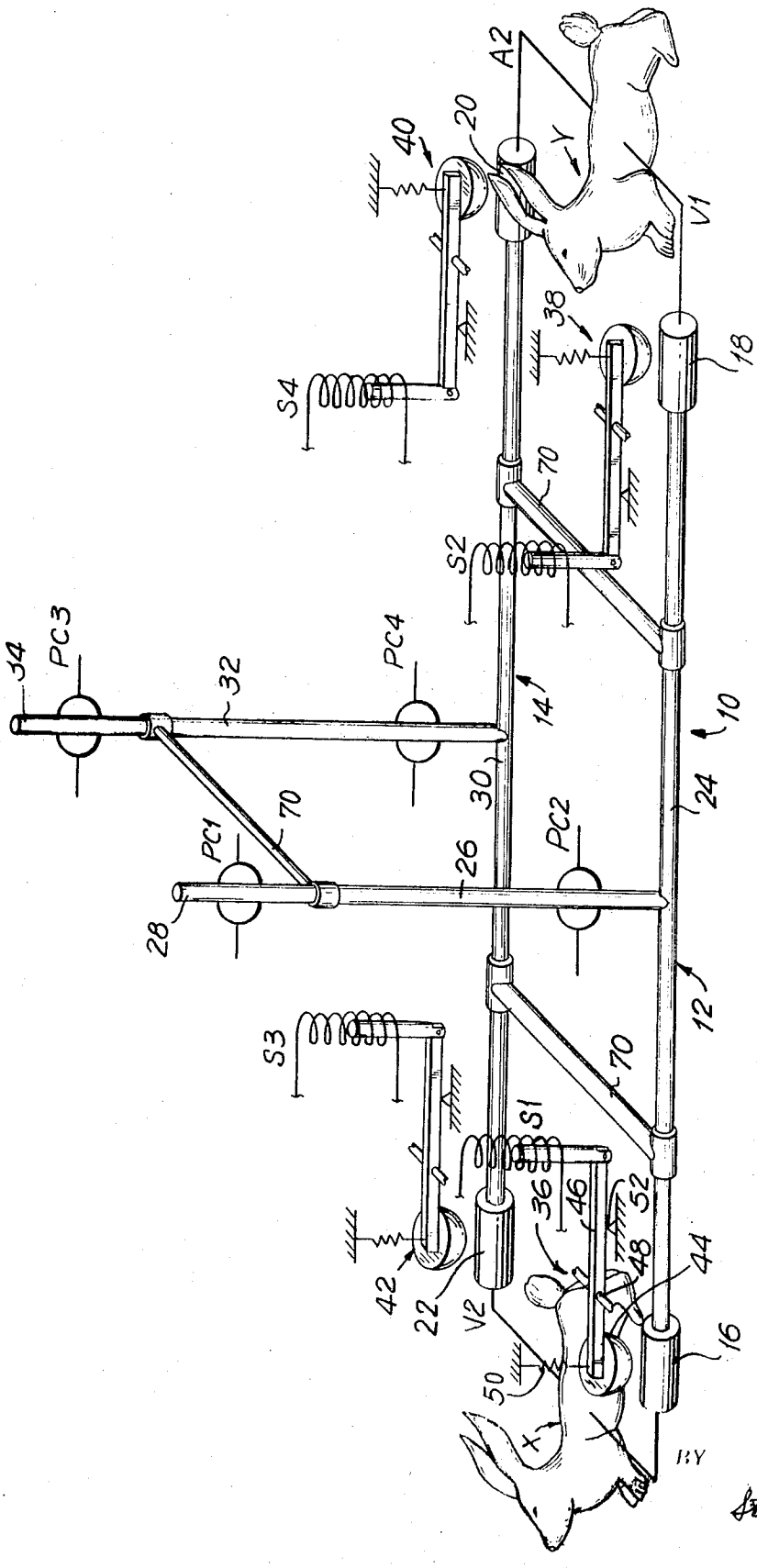


FIG. 1

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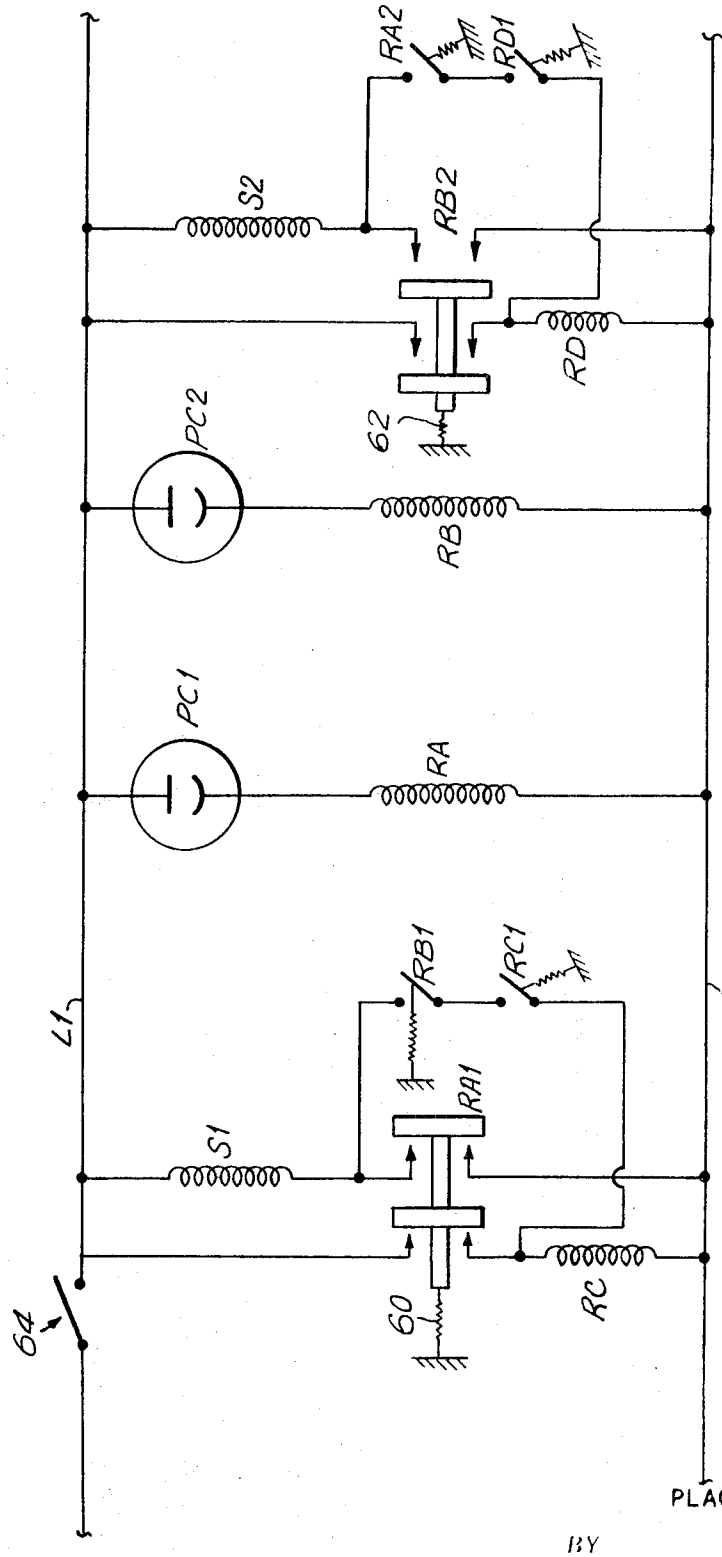


FIG. 2

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PARABIOSIS ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of abandoned application Ser. No. 608,190, filed Jan. 9, 1967 and entitled DEVICE FOR VOLUMETRICALLY REGULATING EXCHANGE OF BLOOD.

BACKGROUND OF THE INVENTION

The present invention relates to an assembly for permitting parabiosis, or in other words the mutual exchange of blood between a pair of beings.

While there are known assemblies for exchanging the blood between a pair of beings, such known assemblies are relatively complex and expensive. They invariably require flow-producing devices such as pumps, vacuum chambers, and the like to propel blood from one prospectus, or being, into the other. Because of the presence of these flow-producing devices and the requirement of controlling the latter the known assemblies are both complex and expensive.

Moreover, it is difficult to operate such known assemblies continuously for any desired length of time. Also, the known structures are difficult to manufacture and are difficult to sterilize. Great care must be exercised to maintain the highest degree of safety during operation of the known devices.

SUMMARY OF THE INVENTION

It is accordingly a primary object of the present invention to provide a parabiosis assembly which will avoid the above drawbacks.

In particular, it is an object of the invention to provide an assembly of this type which is simple and inexpensive to manufacture while at the same time being easily sterilized and capable of operation with absolute safety.

Furthermore, it is an object of the invention to provide a parabiosis assembly which can provide continuous operation according to which the two beings, whether human beings or animals, can be placed in parabiosis for hours, days, or weeks.

A particular object of the present invention is to provide an assembly of this type which does not require the use of any pumps, vacuum chambers, or other types of flow-producing devices.

According to the invention a first interconnecting means interconnects the arterial system of one being with the venous system of the other being while a second interconnecting means interconnects the arterial system of the other being with the venous system of the one being. Each interconnecting means receives a given quantity of blood from an arterial system before delivering it to the venous system, this receiving of a quantity of blood from an arterial system and delivering the latter quantity to the venous system forming one cycle of operations. These cycles are carried out repeatedly and continuously without interruption. According to the invention the blood is propelled only with the pressure in the arterial system so that the use of pumps or other flow-producing devices is not required, thus enabling the entire assembly to be maintained simple and easy to manufacture as well as easy to sterilize while being capable of operation with absolute safety. Moreover, this assembly can be maintained in continuous operation, with two individuals remaining in parabiosis for hours, days, or even weeks.

BRIEF DESCRIPTION OF DRAWINGS

The invention is schematically illustrated in the accompanying drawings which form part of this application and in which:

FIG. 1 is a schematic representation of a parabiosis assembly of the invention shown operatively connected with a pair of beings in the form of animals in the illustrated example, although it is to be understood that these animals could as well be human beings; and

FIG. 2 is an illustration of the electrical circuitry forming the control means of the illustrated invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIG. 1, a pair of beings X and Y are schematically represented as being placed in parabiosis with the assembly **10** of the present invention. In the illustrated example the pair of beings X and Y may be dogs, rabbits, or the like, although they could as well be human beings. The parabiosis assembly **10** of the invention includes an interconnecting means **12** connected to the arterial system of being X and to the venous system of being Y, as well as an interconnecting means **14** connected to the arterial system of being Y and to the venous system of being X.

The pair of interconnecting means **12** and **14** are identical except for their interconnections with the pair of beings. Thus, the interconnecting means **12** includes a needle or catheter A1 connected in a known way with the arterial system of being X, while the interconnecting means **14** includes a needle or catheter A2 connected with the arterial system of being Y. The interconnecting means **12** includes a needle or catheter V1 connected with the venous system of being Y, while the interconnecting means **14** includes a needle or catheter V2 connected with the venous system of being X. These needles respectively communicate with flexible tubular members **16**, **18**, **20**, and **22** as illustrated in FIG. **1**, these flexible tubular members forming parts of valve means which are capable of being opened and closed in a manner described below.

The pair of resilient flexible tubular portions **16** and **18** respectively form extensions of a pair of opposed open ends of a horizontal branch **24** of an inverted T-shaped tube which has a vertical branch **26** communicating with the horizontal branch **24** between the ends thereof which respectively communicate with the flexible tubular extensions **16** and **18**. The top end **28** of the vertical branch **26** of the inverted T-tube is closed. In the same way the interconnecting means **14** includes a horizontal tubular branch **30** having opposed open ends communicating with the flexible tubular portions **20** and **22** which form extensions of the horizontal branch **30**. This branch **30** communicates with a vertical branch **32** which is closed at its top end **34**, so that the interconnecting means **14** is identical with the interconnecting means **10**. This tubular structure which forms the pair of inverted T-tubes is transparent and may be made of glass or a suitable transparent plastic.

The four valve means **36**, **38**, **40**, and **42** are all identical so that only the valve means **36** will be described in detail. This valve means **36** includes a valve operating member **44** which is substantially rigid and has the configuration of part of a sphere. It is carried by a lever **46** supported for swinging movement intermediate its ends by a pivot **48**. A spring **50** acts on the lever **46** to urge the valve means **36** to its open position. At the side of the pivot **48** opposite from the spherical closure member **44** a solenoid S1 acts on the lever **46** to swing the latter in a counterclockwise direction away from a stop **52**, as viewed in FIG. **1**, in order to close the valve means **36** when the solenoid S1 is energized. When the solenoid S1 is unenergized the spring **50** acts to open the valve means **36**. The remaining valve means include the solenoids S2, S4, and S3, respectively, which operate in the same way in opposition to springs which act to urge the several valve means to their open positions, respectively.

Considering the interconnecting means **12**, during flow of blood from the arterial system of being X to the venous system of being Y the valve means **38** will initially be closed by energizing the solenoid S2 while the valve means **36** will initially be open with the solenoid S1 unenergized. The result is that blood will flow, solely under the pressure of the blood in the arterial system of being X into the interconnecting means **12** and up the vertical branch **26**, air being compressed in the vertical branch between the blood and the top closed end **28** of the vertical branch, but of course this air cannot enter into the systems of the beings, as will be apparent from the description below.

In order to detect when the blood in the vertical branch **26** has reached a given elevation, a photocell PC1 is provided at a

selected elevation along the vertical branch 26. As long as the blood has not reached the elevation of the photocell PC1 the photocell is energized. However, when the blood reaches the elevation of this photocell PC1 the energizing thereof is interrupted. This photocell forms part of a control means which includes the solenoid S1 so as to energize the latter and close the valve 36 when the blood reaches the elevation of the photocell PC1. At the same time the control means acts to deenergize the solenoid S2 of the control means so as to open the valve 38, and now the blood will flow by gravity back down the vertical branch 26 and into the venous system of being Y. This operation will continue until the blood in the vertical branch 26 reaches a lower elevation determined by the position of a lower photocell PC2 along the vertical branch 26, as indicated in FIG. 1. When the blood flows below the elevation of the lower photocell PC2 of the control means, this latter photocell becomes energized to bring about energizing of the solenoid S2 and deenergizing of the solenoid S1, so that now the above cycle of operations are repeated and blood flow into the venous system of being Y is terminated while blood flow out of the arterial system of being X again starts until the blood reaches the elevation of photocell PC1.

FIG. 2 illustrates the electrical circuitry of the control means. The structure is connected between the lines L1 and L2. Between the lines the photocell PC1 is connected in series with a relay coil RA, and this coil will become energized when there is no blood at the elevation of the photocell PC1. In the same way the lower photocell PC2 is connected in series with a relay coil RB which becomes energized only when there is no blood at the elevation of the lower photocell PC2. The solenoid S1 is controlled by the relay switch RA1 which is normally closed by the spring 60 and which is maintained open in opposition to the spring 60 whenever the coil RA is energized. When the switch RA1 closes a circuit to a second relay coil RC is closed to energize this coil and close a normally open relay switch RC1 in opposition to a spring which urges this latter switch to its open position. The circuit includes also a switch RB1 which is normally closed and which is controlled by the relay coil RB so as to be opened in opposition to a spring urging this switch RB1 to its closed position whenever the coil RB is energized.

The solenoid S2 is controlled by a switch RB2 which is urged to its normally open position by a spring 62 and which is closed in opposition to this spring whenever the coil RB is energized. At the same time a switch will close to energize a fourth relay coil RD which will bring about closing of a normally open switch RD1. In series with the switch RD1 is a switch RA2 which is normally open and which is maintained closed whenever the coil RA is energized.

FIG. 2 also illustrates a master switch 64 which is closed whenever the entire system is set into operation and which is opened when the assembly is to have its operation terminated.

The above-described structure operates in the following manner:

In order to begin the operations both of the identical interconnecting means 12 and 14 are properly sterilized. This operation is easy to carry out because of the simplicity of the assembly. The insides of the tubes, including the flexible tubular extensions, which may be polyethylene, for example, the needles, and other connections, are coated with a suitable substance such as silicone to prevent the blood from clotting, agglutinating, or the like. The blood of the prospecti may or may not be rendered incoaguable by administering substances such as heparin, dicoumarol, etc., as needed. Both of the interconnecting means are then purged with physiological solutions such as saline, blood, or the like, so that when the exchange of blood begins there will be no free air inside the system. Of course, the air compressed in the upper part of the vertical branches of the inverted T-tubes will not enter into the systems of the prospecti so that this air is not free air in the true sense since it cannot flow down beyond the lower photocell PC2.

The prospecti X and Y are then connected into the system by the usual means, so that the arterial system of being X is connected to the inlet end of the horizontal branch 24 while the venous system of the being Y is connected to the outlet end of the horizontal branch 24.

The operator will initially manually maintain the switch RA1 open while closing the master switch 64. Initially there will be no blood in the vertical branch 26 so that both of the photocells PC1 and PC2 are energized, thus energizing both of the coils RA and RB. The energizing of the coil RA maintains the switch RA1 open in opposition to the spring 60, and thus the solenoid S1 is unenergized and the valve 36 is in its open position. At the same time the energizing of the lower photocell PC2 energizes the coil RB so as to close the normally open switch RB2. The result is that the solenoid S2 becomes energized and the valve 38 is closed. The energizing of the coil RB also opens the normally closed switch RB1, but this has no effect on the solenoid S1 since the coil RC is unenergized and the switch RC1 is in its normally open position. The closing of the switch RB2 energizes the coil RD so as to close the normally open switch RD1 and at this time since the coil RA is energized the normally open switch RA2 is also closed, so that the branch of the circuit which includes the coil RD and the switches RD1 and RA2 is also closed.

The result is that the blood will flow into the interconnecting means 12 up the branch 26 until it reaches the elevation of the lower photocell PC2 so that the coil RB will become unenergized. At this time the switch RB2 will assume its normally open position, but the solenoid S2 will remain energized because of the closed switches RD1 and RA2. The blood continues to rise up the branch 26 until it reaches the elevation of the upper photocell PC1. Then this photocell is interrupted by the blood so that the coil RA becomes deenergized.

This operation terminates the initial phase of each cycle when blood is received from the arterial system. The deenergizing of the coil RA permits the switch RA1 to assume its normally closed position, thus energizing the solenoid S1 and closing the valve 36. At the same time the switch RA2 will assume its normally open position, thus deenergizing the solenoid S2 and permitting the valve 38 to assume its open position. The closing of the switch RA1 energizes the coil RC so as to close the switch RC1, and the normally closed switch RB1 is already in its closed position because the coil RB is unenergized as long as the blood is at the elevation of the lower photocell PC2 or higher. Therefore, when the blood flows down below the photocell PC1 into the venous system of the being Y, under influence of gravity, as well as the pressure of the air compressed at the top of the branch 26, the photocell PC1 will again become energized to energize the coil RA, thus opening the normally closed switch RA1, but the solenoid S1 will remain energized because of the closed switches RC1 and RB1.

Now the second phase of each cycle will continue with the blood flowing downwardly out of the branch 26 along the horizontal branch 24 through the open valve 38 into the venous system of the other being Y.

As soon as the blood reaches the elevation of the lower photocell PC2 so as to then flow slightly below the latter this photocell will become energized so as to energize the coil RB. The result is that the switch RB2 is closed in opposition to the spring 62 thus energizing the solenoid S2 so as to close the valve 38 and thus terminate this cycle. At the same time the normally closed switch RB1 is opened, so that the energizing of the solenoid S1 terminates and the valve 36 assumes its open position, thus initiating the next cycle, and in this way these cycles are continuously carried out without interruption from one cycle to the next.

It is apparent that at each cycle a given quantity of blood is delivered from the arterial system of one being into the venous system of the other being.

The interconnecting means 14 operates precisely in the same way as the interconnecting means 12 and simultaneously with the latter, the only difference being that the blood flows

from the arterial system of being Y into the venous system of being X. The various photocells, solenoids, valves, and the electrical circuitry form a pair of control means, one for the interconnecting means **12** and the other for the interconnecting means **14**. Each control means provides for the interconnecting means to which it is operatively connected a cycle of operations according to which first a quantity of blood is received from an arterial system and then the quantity of blood is delivered to a venous system before again being received from the arterial system during the next cycle. Furthermore, it is to be noted that the pair of interconnecting means **12** and **14** and the pair of control means respectively connected operatively thereto are completely independent of each other so that the operating cycles during which blood flows from the arterial system of one being to the venous system of the other take place completely independently of and without any relation whatsoever to the operating cycles during which the flow of blood takes place from the arterial system of this other being back to the one being.

It is to be noted in particular that there are no pumps or other flow-producing devices with the structure of the invention. The blood is propelled solely by the pressure of the blood in the arterial systems of the beings.

Suitable bracing members **70** interconnect and hold the pair of interconnecting means **12** and **14** at a given position relative to each other where they are properly aligned, and the assembly may be placed on any suitable table or the like between the pair of beings X and Y.

Thus, the above-described assembly of the invention permits continuous operation and two individuals or other beings may be placed in parabiosis for hours, days, weeks, etc. The apparatus is easy to manufacture and easy to sterilize and also is absolutely safe to operate.

What is claimed is:

1. In an assembly for exchanging blood between a pair of beings, first interconnecting means for interconnecting the arterial system of one being with the venous system of the other being and for directing blood from said one being only under the pressure of the blood in said one being to the venous system of said other being, second interconnecting means for interconnecting the arterial system of said other being with the venous system of said one being and for directing the blood from the arterial system of said other being only under the pressure of the blood of said other being to the venous system of said one being, each of said interconnecting means consisting only of tubing into and out of which blood can freely flow, whereby the flow of blood between said beings takes place without requiring the use of pumps or other flow-producing devices, and a pair of control means respectively connected with said first and second interconnecting means for cyclically controlling the flow of blood through each interconnecting means according to cycles during each of which a quantity of blood is first received in each interconnecting means from an arterial system and then delivered to a venous system before a quantity of blood is again received from the arterial system during the next cycle, and each control means and interconnecting means to which it is operatively connected being completely independent of and having no timed relation with respect to the other control means and interconnecting means to which said other control means is operatively connected, so that the flow of blood from the arterial system of one being to the venous system of the other being takes place independently of but without any synchronization simultaneously with the flow of blood from the arterial system of said other being to said one being, whereby over a period of time the total quantity of blood transferred from one being to the other may be different from the total quantity of blood transferred from the other being to said one being.

2. The combination of claim **1** and wherein each of said interconnecting means includes a tube of inverted T configuration having a horizontal branch provided with opposed inlet and outlet ends and a vertical branch extending upwardly from said horizontal branch and situated between the ends thereof, said inlet end of said horizontal branch of said first interconnecting means communicating with the arterial system of said one being and said outlet end of said horizontal branch of said first interconnecting means communicating with the venous system of said other being, said inlet end of said horizontal branch of said second interconnecting means communicating with the arterial system of said other being and said outlet end of said horizontal branch of said second interconnecting means communicating with the venous system of said one being, said pair of control means including four valve means respectively connected operatively with the two inlet ends and the two outlet ends of said horizontal branches for opening and closing the same, and each control means coacting with each interconnecting means for closing the valve means at its outlet end and simultaneously opening the valve means at its inlet end until the blood rises to a given elevation in the vertical branch whereupon said control means closes the valve means at the inlet end of said interconnecting means and opens the valve means at the outlet end of said horizontal branch until the blood in said vertical branch reaches a given lower elevation whereupon a cycle ends and a new cycle begins with closing of the valve means at the outlet end and opening of the valve means at the inlet end until the blood again reaches said upper elevation in said vertical branch.

3. The combination of claim **2** and wherein said vertical branches each has a closed top end so that air is compressed in each vertical branch by the blood rising in the latter.

4. The combination of claim **2** and wherein each valve means includes a flexible resilient tubular portion forming an extension of the horizontal branch and a closure member having the configuration of at least part of a sphere and displaced into engagement with said flexible tubular portion for closing the latter in order to close the valve means while being displaced away from said flexible tubular member for opening the valve means.

5. The combination of claim **2** and wherein a pair of photocells are operatively connected with each vertical branch at said upper and lower elevations, said control means including in addition to said photocells solenoids operatively connected with said valve means for respectively operating the latter, and an electrical circuit interconnecting said photocells with said solenoids for actuating the latter to open and close said valve means to bring about the cyclical flow of blood first from an arterial system into the vertical branch up to said upper elevation and then out of the vertical branch into the interconnected venous system while terminating the flow of blood from the arterial system until the blood in the vertical branch reaches said lower elevation, whereupon the cycle is repeated.

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