CLAIMS

1. A photosynthetic reactor (1) suitable for the culture of photosynthetic organisms, notably of algae, comprising :

- at least one photosynthetic reaction pipe (2) in which the liquid culture medium circulates and which is provided with several substantially horizontal reaction sections (23) at least partly made in a material transparent to light radiation, said reaction pipe (2) having a low end (21) positioned in the low portion of the reactor (1) and a high end (22) positioned in the high portion of the reactor (1) above the low end (21), and said reaction sections (23) are successively connected in series so that the reaction pipe (2) has the shape of a continuous conduit between its low end (21) and its high end (22);
- at least one return pipe (3) ensuring the fluidic connection between the low end (21) and the high end (22) of the reaction pipe (2);
- at least one circulation means (4) for circulating the liquid culture medium;
- at least one gas injection means (5) positioned in the low portion of the reactor (1) and allowing gas to be injected into the reactor (1); and
- at least one exhaust means (6) positioned in the high portion of the reactor (1) and allowing the gas injected into the reactor (1) to escape;

characterized in that the circulation means (4) is positioned in the return pipe (3) and the gas injection means (5) is positioned in the lowest reaction section (23) of the reaction pipe (2) or upstream from said lowest reaction section (23) with respect to the direction of the circulation of the gas, so that the gas injected through the gas injection means (5) moves up to as far as the exhaust means (6) by circulating in the reaction pipe (2), in a direction of circulation from the low end (21) to as far as the high end (22) of the reaction pipe (2), so that the injected gas and the liquid culture medium establish gas/liquid two-phase flow in the substantially horizontal reaction sections (23) and the gas/liquid transfer does not occur inside any vertical column but along said substantially horizontal reaction sections (23).

2. The reactor (1) according to claim 1, comprising at least one liquid injection means (7) allowing injection of the liquid into the reactor (1), the exhaust means (6) being conformed so as to allow the excess liquid volume in the reactor (1) to escape at the same time as the escape of the injected gas.

3. The reactor (1) according to any of claims 1 or 2, wherein the circulation means (4) is positioned in the return pipe (3) in order to circulate the liquid culture medium in the reaction pipe (2) of the low end (21) up to the high end (22) of said reaction pipe (2), in the same direction of circulation as the injected gas.

~~4. The reactor (1) according to any of claims 1 or 2, wherein the circulation means (4) is positioned in the returned pipe (3) in order to circulate the liquid culture medium in the reaction pipe (2) of the high end (22) to as far as the low end (21) of said reaction pipe (2) in a direction of circulation opposite to the direction of circulation of the injected gas.~~

~~5.~~4. The reactor (1) according to any of claims 3 or 4, wherein the gas injection means (5) is positioned in the low portion of the reactor (1), between the circulation means (4) and the low end (21) of the reaction pipe (2).

~~6.~~5. The reactor (1) according to claim 5, wherein the return pipe (3) has a difference in height (39) located between the circulation means (4) and the gas injection means (5), said difference in height (39) forming a difference in levels between the circulation means (4) and the gas injection means (5) in order to avoid that the gas injected by the injection means moves towards the circulation means (4).

~~7.~~6. The reactor (1) according to any of the preceding claims, wherein the circulation means (4) is a mechanical propulsion means positioned in the return pipe (3).

~~8.~~7. The reactor (1) according to claim 7, wherein the circulation means (4) comprises a propeller (40) driven into rotation by a motor (41) and wherein the return pipe (3) has a housing (35) with a widened cross-section, inside which said propeller (40) is mobile in rotation.

~~9.~~8. The reactor (1) according to claim 8, wherein the housing (35) is positioned between a divergence area (36) and a convergence area (37) of the circulation of the liquid culture medium.

~~10.~~9. The reactor (1) according to any of the preceding claims, wherein the return pipe (3) has in the high portion a widened area (32) and wherein the exhaust means (6) is positioned in said widened area (32) of the return pipe (3).

~~11.~~10. The reactor (1) according to any of the preceding claims, wherein the exhaust means (6) is positioned upstream from the means (4) for circulating the liquid culture medium with respect to the direction of circulation of the gas, in order to avoid that the gas circulates through said circulation means (4) and is detrimental to its operation.

~~12.~~11. The reactor (1) according to any of the preceding claims, comprising at least one cleaning body (10) conformed for circulating inside the reaction (2) and return (3) pipes and for passing through the means (4) for circulating the liquid culture medium.

~~13.~~12. The reactor (1) according to claim 12, wherein the cleaning body (10) is conformed so as to at least partly let through the gas circulating inside the reaction pipe (2) while being adapted so as to be driven by the circulation of the liquid culture medium.

~~14.~~13. The reactor (1) according to claim 13, wherein the cleaning body (10) is made in the form of a brush comprising an assembly of bristles, hairs, strands or equivalents, or in the form of a hollow sphere in elastomeric material, at least one portion of the surface of which is pierced with holes.

~~15.~~14. The reactor (1) according to any of the preceding claims comprising:

- a short-circuit pipe (90) positioned in parallel on the return pipe (3) and connecting two connection points (91, 92) provided on the reactor (1), including a first connection point (91) positioned on the reaction pipe (2) and a second connection point (92) positioned on the return pipe (3) or on the reaction pipe (2);
- two valves (93, 94) positioned on either side of said first connection point (91) with one of the valves (94) positioned on the short-circuit pipe (90); and

- two valves (95, 96) positioned on either side of said second connection point (92) with one of the valves (96) positioned on the short-circuit pipe (90);

so that by handling the valves (93, 94, 95, 96) it is possible to isolate the portion of the reactor (1) located between the first (91) and the second (92) connection points on the side of the reaction pipe (2) and the gas/liquid culture medium mixture circulates in the short-circuit pipe (90) and in the non-isolated portion of the reactor (1) located between the first (91) and second (92) connection points on the side of the return pipe (3).

~~16. An assembly of photosynthetic reactors (1A; 1B) adapted for cultivating photosynthetic microorganisms comprising at least two reactors (1A; 1B) according to any of claims 1 to 15, i.e. a first (1A) and a second (1B) reactors, and comprising at least one connection pipe (71, 72) ensuring a fluidic connection between the first reactor (1A) and the second reactor (1B) and at least one valve (77, 78) positioned on said connection pipe (71, 72).~~

~~17. The assembly according to claim 16, comprising two connection pipes (71, 72) between both reactors (1A, 1B), each provided with at least one valve (77, 78), including:~~

~~- a first connection pipe (71) connecting an inlet point (73) positioned on the first reactor (1A) upstream from the circulation means (4) of said first reactor to an outlet point (74) positioned on the second reactor (1B) downstream from the circulation means (4) of said second reactor (1B); and~~

~~- a second connection pipe (72) connecting an inlet point (75) positioned on the second reactor (1B) upstream from the circulation means (4) of said second reactor (1B) to an outlet point (76) positioned on the first reactor (1A) downstream from the circulation means (4) of said first reactor (1A).~~

~~18. The assembly according to any of claims 16 or 17, comprising a pump interposed on either one of the connection pipes (71, 72).~~

~~19. The method for cultivating photosynthetic microorganisms, notably algae, using a reactor (1) according to any of claims 1 to 15 and comprising the following steps:~~

~~– Injecting a liquid culture medium into the reactor (1) according to a controlled flow rate;~~

~~– Injecting a gas into the reactor (1) according to a controlled flow rate with the gas injection means (5);~~

~~– circulating the liquid culture medium with the circulation means (4);~~

~~– controlling the circulation means (4) and the gas injection means (5) in order to establish in the reaction section (23) gas/liquid two-phase flow conditions of the laminated flow or slug flow or elongated bubble flow type.~~

~~20. The method according to claim 19, wherein the control step comprises a step for controlling the circulation rate of the liquid in the reaction pipe (2) between about 0.1 and 0.2 m/s in order to establish two-phase flow conditions of the laminated flow type.~~

~~21. The method according to claim 19, wherein the control step comprises a step for controlling the circulation rate of the liquid in the reaction pipe (2) between about 0.2 and 1 m/s in order to establish two-phase flow conditions of the slug or elongated bubble flow type.~~

~~22. The method according to any of claims 19 to 21, wherein the control step comprises a step for controlling the circulation rate of the gas between about 0.5 and 0.8 m/s.~~

~~23. The method according to any of claims 19 to 22, wherein the circulation means (4) comprises a propeller (40) driven into rotation by a motor (41) and wherein the speed of rotation of the propeller is less than about 100 revolutions per minute.~~