

# DR. CLARENCE DENNIS AND THE DEVELOPMENT OF A HEART-LUNG MACHINE FOR OPEN HEART OPERATIONS

In the late nineteen thirties while Dr. Clarence Dennis was an instructor at the University of Minnesota, Dr. Owen Wagensteen and Dr. Maurice Vischer suggested that he undertake the development of an apparatus to perform the function of the heart and lungs. So began years of intense investigation by Dr. Clarence Dennis and his colleagues to develop a machine that would sustain life while the surgeon worked to repair a damaged heart. The search was marked by hope, failure, doubt, enlightenment, exhaustion and eventually, success. His work in the development of the heart-lung machine and cardiac research has eased pain and suffering and extended the lives of tens of thousands of men, women and children. To this day, it pays dividends of life. Along the way, Dr. Dennis also trained hundreds of surgeons.

The first known clinical operation involving open cardiomy with temporary takeover of the functions of both the heart and lungs by mechanical devices occurred at the University of Minnesota Hospital on April 1, 1951, after four years of experimental laboratory work with dogs. That first patient was lost by virtue of an unexpected complex congenital abnormality, and a second was lost two weeks later through human error in operation of the equipment. A month later the laboratory group moved to SUNY Downstate Medical Center.

In 1953, Dr. John H. Gibbon, who had been working on the problem for over a decade, had a successful repair by similar means but more elegant mechanical accomplishments; his sole success among seven attempts undertaken. On June 30, 1955, the group who had moved from Minnesota, under the leadership of Dr. Clarence Dennis, with participation from many Downstate staff who joined in the effort, were successful in the cure of a patient with a large interatrial septal defect, the second such success in the world and the first in New York State. In the meantime, superlative contributions to the field of cardiac surgery had been made by the workers who had remained at the University of Minnesota, including using the mother as an oxygenator to support repair of congenital intracardiac defects in infants and, along another line of approach, total body cooling, which made possible repair of the simpler cardiac defects without use of mechanical support. This poster is concerned with the apparatus first used at the University of Minnesota and the derivative of it used in the first successful case at Kings County Hospital.

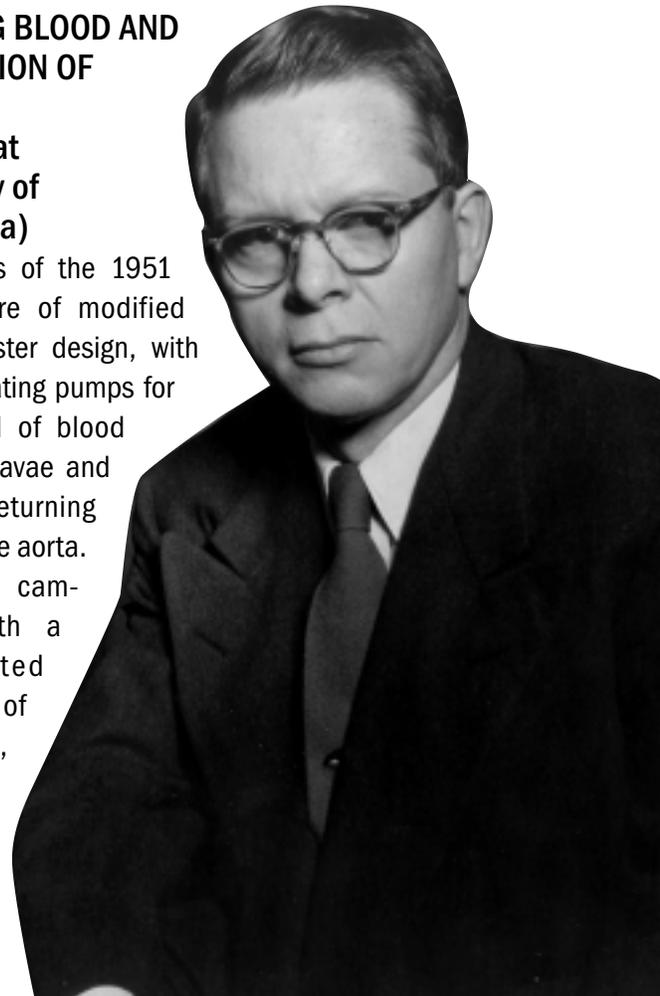
## OXYGENATION OF BLOOD

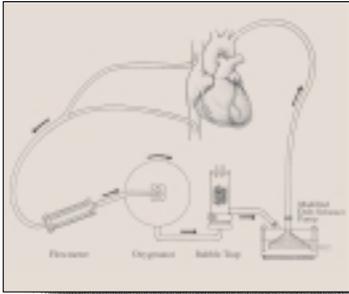
In both the 1951 and the 1955 cases, the oxygenator consisted of a series of stainless steel 18 by 18 mesh screen discs each 38 cm in diameter (later 50 cm) mounted on a horizontal axle rotating at 54 revolutions per minute (later as low as 12). Blood was filmed on a central solid plate and was collected by dropping a distance of about 1 cm from the solid rim of each disc for return to the subject. In each case, a cover fully enclosed this assembly so that the preferred oxygenating atmosphere consisted of oxygen supplemented with 3 to 5 percent carbon dioxide as indicated by continuing determinations of the arterial blood. In the canine model, Dr. Gibbon's finding had been confirmed that turbulence optimizes oxygen uptake by blood in extracorporeal films. The aims of a turbulent and ever-thinning layer of blood were maximally served in this manner rather than by the fixed filming surface which Dr. Gibbon adopted, for the blood film became progressively thinner as the blood spread toward the periphery of the revolving discs. In the dog, each disc raised the blood oxygen from 45 to 90 percent saturation at a flow of 550 ml of blood per minute.

## PUMPING BLOOD AND REGULATION OF FLOW

### (Pattern at University of Minnesota)

The pumps of the 1951 model were of modified Dale-Schuster design, with two alternating pumps for withdrawal of blood from the cavae and two for returning blood to the aorta. They were cam-driven with a complicated system of solenoids, rate-varying and stroke-length





controls, all fed by a tam-  
bour-operated leveling  
sensor in a small reservoir  
at the bottom of the oxy-  
genator. This was capped  
with an emergency  
instantaneous arrest acti-  
vated by dropping the  
blood level of the reser-  
voir below the specified  
level.

### UNIVERSITY OF MIN- NESOTA CLINICAL TRIALS

The first open-heart case  
with machine-supported  
circulation and oxygena-  
tion was performed on  
April 1, 1951, at the  
University Hospital of the  
University of Minnesota.  
This was apparently the  
first occasion for such an  
attempt to be made any-  
where. The patient was a  
4-year old child with a  
known inter-atrial septal  
defect who was previously  
operated upon with hope  
of repair by closed tech-  
nique. The size of the  
defect appeared to pre-  
clude any such attempt at  
that prior time. The surgi-  
cal team was still wary of  
cardiac catheterization,  
which was not generally  
accepted at that time,

and thus the effort was made to assist with the equipment  
which had been developed. The apparatus worked in satisfac-  
tory fashion, but the nature of the lesion was not at all clear  
after the right atrium had been opened. The patient was nicely  
supported by the equipment. Finally, the apparent offending  
defect was sutured. When an attempt was made to take the  
patient off perfusion, the patient's heart could not maintain  
the circulation, and the patient expired. Post-mortem exami-  
nation revealed that the lesion was not the simple secundum  
type of defect but rather an atrioventricular canal, a complicat-

ed set of anomalies, the first cure for which did not occur until  
several years later at the Mayo Clinic, using a variation of the  
Dr. Gibbon machine.

### THE 'DOWNSTATE' PUMPING SYSTEM

The pumps of the 1955 model were self-activated variations of  
the Dale-Schuster principle. Gravity was the only driving force  
of blood from the patient through the oxygenator. This required  
placement of the pumps on the floor, at which level gravity  
filled the 'ventricle' (or occasionally 2 "ventricles"). On the floor  
of the pumping chamber was a soft rubber diaphragm. This  
flexible floor of the pump, in turn, was activated by compressed  
air, introduced into or allowed to escape from the compart-  
ment below the diaphragm by a mercury switch on a lever and  
solenoid circuit which in turn was activated by changes in the  
level of the center of the diaphragm. By this means, the pump  
governed output by controlling pulse rate with little effect on  
stroke volume. The 1955 case required by one pump, but in  
larger, later cases, two pumps were often used with the second  
"ventricle" activated from the master mercury switch alternat-  
ing through an electrical relay.

### BIOGRAPHY

Dr. Dennis was born on June 16, 1909 in St. Paul, Minnesota  
where he attended elementary and high school. His father was  
a noted surgeon. He attended Harvard College where he grad-  
uated cum laude and Phi Beta Kappa in 1931. He received is  
M.D. Degree from Johns Hopkins in 1935, and earned a  
Masters Degree in Physiology and a Ph.D. Degree in Surgery  
from the University of Minnesota in 1940. Dr. Dennis' research  
into the development of a heart-lung machine began at the  
University of Minnesota in the late nineteen thirties where he  
started as an intern in 1935. By 1947, he had become a full  
Professor of Surgery at the University of Minnesota and the  
administrative head of Surgery at Minneapolis General  
Hospital. In that year, he first obtained federal research fund-  
ing from the fledgling National Institutes of Health to persue  
the development of the heart-lung machine. As the head of a  
team of surgeons and technicians, Dr. Dennis built and tested  
a series of prototypes that ultimately led to the machine that  
was used to support the successful 1955 open heart surgery in  
Brooklyn, where Dr. Dennis was chairman of the Department of  
Surgery at Downstate Medical Center from 1951 through  
1974. A rebuilt version of that machine is part of the perma-  
nent collection of the Smithsonian Institution in Washington,  
D.C. Following his tenure at Downstate, he continued his  
research at the SUNY Health Science Center at Stony Brook  
and the Veterans Administration Hospital in Northport, NY from

1975 through 1988. During the development years, Dr. Dennis shared his research and worked closely with other leading scientists and surgeons in the United States, the most notable among them being Dr. John Gibbon, who performed the first successful open heart surgery in Philadelphia in 1953.

Dr. Dennis was awarded an Honorary Doctor of Science degree from SUNY Health Science Center at Brooklyn in 1988. In 1990, Dr. Dennis was made an Honorary member of the Alumni Association of the College of Medicine. In 1996, Dr. Dennis returned to Downstate to make a \$1 million gift to the Health Science Center to fund a surgical research professorship. The gift is the largest endowment ever made to the State University of New York Health Science Center at Brooklyn.

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## READ MORE ABOUT IT

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