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 cardiotomy 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 tambour-operated leveling sensor in a small reservoir at the bottom of the oxygenator. This was capped with an emergency instantaneous arrest activated by dropping the blood level of the reservoir below the specified level.

UNIVERSITY OF MINNESOTA CLINICAL TRIALS
The first open-heart case with machine-supported circulation and oxygenation 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 anywhere. 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 technique. The size of the defect appeared to preclude any such attempt at that prior time. The surgical 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 satisfactory 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 examination 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 compartment 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 alternating 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 graduated cum laude and Phi Beta Kappa in 1931. He received his 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 funding from the fledgling National Institutes of Health to pursue 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 permanent 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.

REFERENCES


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Clarence and Mary Dennis Honored with First Dedicated Service Award. *Focus*. May 29, 1996.