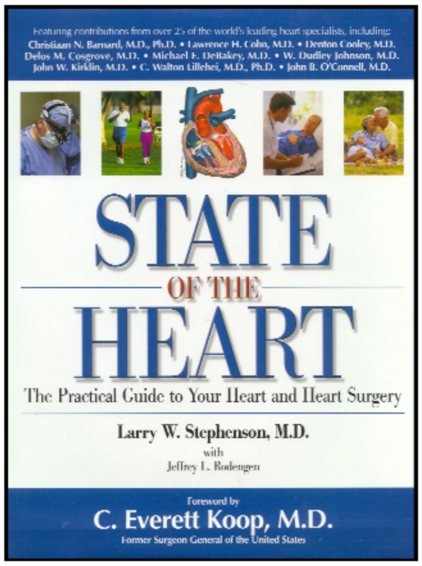

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Although it does not depict heart surgery, *The Agnew Clinic, 1889*, by Philadelphia artist Thomas Eakins, portrays what an operating room might have looked like at about the time the first heart operations were being performed. Shown right is a detailed view of an incision being made in the patient's chest. *(Photograph courtesy of the University of Pennsylvania.)*

CHAPTER ONE

The Dawn of Open Heart Surgery

FOR MANY YEARS, DOCTORS HAD assumed the heart was too important to interfere with and too fragile to be operated on. In those days, cardiac problems often meant death. During the last fifty years, however, our understanding of the complicated cardiac system has increased greatly, and doctors now routinely perform surgeries that were once beyond the furthest reaches of medical imagination.

The Early Days

The development of major surgery was retarded for centuries by a lack of knowledge and technology. Significantly, general anesthetics like ether and chloroform weren't developed until the middle of the nineteenth century. They made major surgical operations possible, which led to an interest in repairing wounds to the heart, and the first simple heart operations were soon reported in the medical literature.

On July 10, 1893, Dr. Daniel Hale Williams, an African-American surgeon from Chicago, successfully operated on a twenty-four-year-old man who had been stabbed in the heart during a fight. The patient was admitted to Chicago's Provident Hospital on July 9 at 7:30 P.M. The stab wound was slightly to the left of the breast bone (sternum) and dead center over the heart. Initially, the wound was thought to be superficial, but during the night there was persistent bleeding, pain, and pronounced symptoms of shock. Williams decided to operate. He opened the patient's chest and tied off an artery and a vein that had been injured inside the chest wall, possibly causing the blood loss. Then he noticed a tear in the pericardium (sack around the heart) and a puncture wound of the heart "about one-tenth of an inch in length."

The wound itself, in the right ventricle, was not bleeding, so Williams did not place a stitch through the heart wound. He did, however, stitch closed the hole in the pericardium. The patient recovered. Williams went on to report this case in a medical journal four years later. This is the first successful operation involving a documented stab wound to the heart.

At the time, Williams' surgery was considered bold and daring, but he never received the credit he deserved, probably because he did not actually place a stitch through the wound in the heart. Yet his treatment seems to have been appropriate

Daniel Hale Williams

under the circumstances and most likely saved that patient's life.

The first stitch closure of a human heart wound was performed by Dr. Ansel Cappelen in Norway on a twenty-four-year-old man stabbed in the left chest. Upon arrival at the hospital, the victim was unconscious, pale, and pulseless. The operation began at 1:30 A.M. on September 5, 1894. A tear of the ventricle was closed with catgut stitches. Unfortunately, the patient's condition remained poor, and he died four days later.

Two years later, Dr. Ludwig Rehn, a surgeon in Frankfurt, Germany, performed what many consider the first successful heart operation. On September 7, 1896, a twenty-two-year-old man was stabbed in the heart and collapsed. The police found him pale, covered with cold sweat, and extremely short of breath. His pulse was irregular, and his clothes were soaked with blood. On September 9, his condition was worsening.

With his patient in profound shock and near death, Rehn opened the chest and found blood and a blood clot inside the pericardium, in addition to a wound in the right ventricle that was actively bleeding (it probably started to bleed again when Rehn removed the blood clot). Rehn placed three silk stitches through the heart wound, and the bleeding stopped. The patient made a full recovery.

In his official report to a medical journal, Rehn wrote, "Today the patient is cured. He looks very good. His heart action is regular.... This proves the feasibility of cardiac suture repair without a doubt. I hope this will lead to more investigations regarding surgery of the heart. This may save many lives." Ten years after Rehn's initial heart repair, he had accumulated a series of 124 patients who had undergone suture repair of heart wounds with a survival rate of 40 percent.

On September 14, 1902, the first successful stitching of a human heart in America happened under circumstances that would be hard to comprehend by modern day heart surgeons. Henry Myrick, a thirteen-year-old boy, was stabbed by another youth earlier that day. The boy was already in profound shock when the local country doctor arrived. The doctor remembered that Dr. Luther Hill from nearby Montgomery, Alabama, had spoken on the repair of cardiac wounds at a medical society meeting. Hill was sent for and arrived sometime after midnight with his brother, who was also a physician, and five other physicians.

The surgery took place on the patient's kitchen table in a run-down shack. Since it was night, the doctors borrowed two kerosene lamps from a neighbor. One of the doctors administered chloroform anesthesia, and Luther Hill located the stab wound in the left ventricle. About forty-five minutes later, they had stitched the heart wound shut with two catgut stitches.

Although the early postoperative course was stormy, Henry made a complete recovery. He eventually moved to Chicago, where, in 1942 at the age of fifty-three, he got into a heated argument and was stabbed in the heart again, very close to the original stab wound. This time, Henry was not so lucky and died from the wound.

The Heart-Lung Machine

From these early operations into the twentieth century, the development of heart surgery did not move very quickly until a single innovation, the heart-lung machine, ushered in the age of modern heart surgery. Before the invention of the heart-lung machine, surgeons confronted a very simple yet seemingly insurmountable problem. If the heart was stopped and opened so the surgeon could see it directly, the patient died. The heart-lung machine finally allowed physicians to stop the beating heart yet keep their patients alive.

In the 1930s, Dr. John Gibbon was among the first doctors to begin building a heart-lung machine. His first device served as a model for later, successful cardiopulmonary bypass machines.

The solution to this great riddle came in the years after World War II. Teams of doctors at major hospitals enlisted the help of teams of engineers, in some cases at the country's largest corporations, and the race was on to develop a heart-lung machine that could support circulatory function while doctors stopped the heart.

The effort involved many doctors, yet from a research point of view, a young doctor named Dr. John Gibbon contributed more to the development of the heart-lung machine than anyone else. His interest began one October night in 1930 while at Massachusetts General Hospital in Boston. A patient was suffering from a blood clot in the lungs and was in shock. Gibbon was supposed to record blood pressure every fifteen minutes until either the patient recovered or her condition deteriorated to the point at which a high-risk operation would have to be attempted to remove the blood clot. Her condition worsened, and the operation was performed. Unfortunately, the patient did not survive the operation, but Gibbon learned an important lesson. He realized that if there were a way to keep the blood oxygenated while the surgeon operated on the lung, many people suffering from this condition might be saved.

Three years later, while he was a research fellow in surgery at Harvard Medical School, Gibbon began experimental work on the heart-lung machine. His wife, Mary, was his research assistant. His research continued at the University of Pennsylvania in Philadelphia when he became the Harrison Fellow in Surgical Research in 1936.

By 1937, he was able to demonstrate that life could be maintained with an artificial heart and lung and that an animal's own heart and lungs could later resume function when the machine was turned off. In his first demonstration, however, only three animals resumed breathing adequately after he used a primitive heart-lung machine to bypass their hearts and lungs, and even these animals died within a few hours.

His work steadily progressed, however, and by 1939, Gibbon reported at the annual meeting of the American Association for Thoracic Surgery that three cats whose circulation had been totally supported by the heart-lung machine had survived more than nine months after the surgery. Dr. Clarence Crafoord, chief of thoracic surgery at the prestigious Karolinska Institute in Stockholm, said Gibbon's report was "a pinnacle of success in the progress of surgery." Dr. Leo Eloesser, a prominent chest surgeon from San Francisco, said the work reminded him "of Jules Verne's dreamlike visions, regarded as impossible at the time but later actually accomplished."

Gibbon's work was interrupted in 1942 by World War II but resumed after the war ended and he was appointed professor of surgery and director of the surgical research laboratory at Jefferson Medical College in Philadelphia. During his tenure there, Gibbon met Thomas Watson, chairman of International Business Machines (IBM) Corporation. Watson was fascinated by Gibbon's research and promised to help him. Shortly afterward, a team of IBM engineers arrived at Thomas Jefferson University and built a heart-lung machine based on knowledge gained from Gibbon's earlier machine. It contained a rotating oxygenator apparatus and a modified rotary blood pump. The pump was based on one developed earlier by Dr. Michael DeBakey.

Gibbon successfully used the new IBM heart-lung machine for the repair of heart defects in small dogs and had several long-term survivors. The blood oxygenator, however, was too small for humans. The team soon developed a larger oxygenator that IBM engineers incorporated into a new machine.

By 1949, Gibbon's mortality in animals was 80 percent (meaning that only 20 percent survived the surgery), but it was improving, and he was ready to move to human patients. His first human patient was a fifteen-month-old girl with severe heart failure. She didn't survive the procedure; at autopsy, an unexpected congenital heart malformation was found.

Gibbon's second patient was an eighteen-year-old woman also with heart failure due to a congenital defect. On May 6, 1953, Gibbon successfully repaired the defect with the Gibbon-IBM heart-lung machine. The woman recovered, and several months later, the defect repair was confirmed repaired by cardiac catheterization. Unfortunately, Gibbon's next two patients did not survive operations using the heart-lung machine.

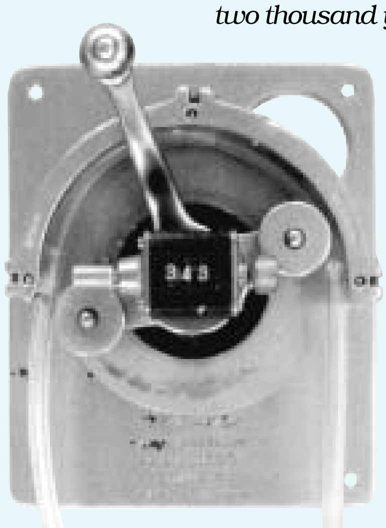
The Roller Pump

During Dr. John Gibbon's work on the heart-lung machine, he turned to a pump developed by Dr. Michael DeBakey while DeBakey was still a medical student at Tulane University in New Orleans.

In those early days, DeBakey worked as a technician in the medical lab and remembered his first exposure to blood pumps:

"I didn't get paid very much, but I liked the work. The faculty member I was working with wanted a pump in the laboratory because he was interested in the pulse wave so he asked me to get a pump for him. I went to the library to learn something about pumps, and I didn't find a great deal in the medical school library. A friend of mine who was a college mate and went into engineering said, 'You know, you ought to go to the Engineering School library. They have a lot of articles on hydraulics.'

"I went to the Engineering School and found a wonderful bibliographic record of pumps going back to Archimedes, two thousand years ago. There was an article about rubber tubing, which came into being in the middle of the last century, being used to pump fluid by compressing it. That's what gave me the idea for my roller pump, which John Gibbon adapted, and that's how I contributed to the development of the heart-lung machine."



An early roller pump that was used to move blood through the first heart-lung machines.

Dr. Clarence Crafoord started a research team in Sweden that worked toward developing an open-heart program. However, he became best known for a pioneering operation that corrected a defect in the aorta called coarctation of the aorta.

These failures upset Gibbon, who declared a one-year moratorium on use of the machine in humans until more work could be done to solve the problems.

Meanwhile, other groups were working to develop a heart-lung machine. They included those led by Crafoord at the Karolinska Institute in Stockholm, Sweden; Drs. S.S. Brukhonenko and N.N. Terebinsky in Moscow, Russia; Dr. J. Jongbloed at the University of Utrecht in Holland; Dr. Clarence Dennis at the University of Minnesota; Dr. Mario Dogliotti at the University of Turino in Italy; and Dr. Forrest Dodrill in Detroit, Michigan.

The Dodrill Pump

At Harper Hospital in Detroit, Dr. Forrest Dodrill and colleagues used a mechanical blood pump on a forty-one-year-old man on July 3, 1952. The pump had been developed in conjunction with engineers at General Motors. It was used to substitute for the left ventricle, the heart's main pumping chamber, for fifty minutes while an attempt was made to repair a defective heart valve. This was the first time the human left ventricle had been successfully bypassed. For his first human patient, Dodrill used the patient's own lungs to oxygenate the blood.

In an interview twenty-seven years later, the patient recalled seeing dogs romping on the roof of a nearby building from his hospital room. He later learned those dogs had been used in the final test of the Dodrill-General Motors mechanical heart machine.

Several months after its first demonstration in a human, Dodrill and associates used their machine on a sixteen-year-old boy with a narrowed pulmonary heart valve. They were able to open the valve as they viewed it directly while the patient's right ventricle, which pumps blood to the lungs, was supported by the Dodrill-General Motors blood pump. This operation was also successful, and the patient was alive and well forty-six years later.

During the same period, other innovative methods were being tested to close abnormal holes inside the heart without having to use a heart-lung machine. One technique used hypothermia. The patient's body temperature was lowered using an ice bath until the heart stopped. The hole in the heart was repaired, and the patient was rewarmed. The cold body temperature protected the patient from oxygen starvation by decreasing the metabolic rate and the body's consumption of oxygen.

Lillehei's Cross-Circulation

The heart-lung machine, in its various forms, was not considered the only practical way to bypass the circulation. A young surgeon named Dr. C. Walton Lillehei and colleagues at the University of Minnesota studied a technique they called cross circulation, which did not use a bypass machine at all. Using this technique, the circulation of one dog was used to support that of another dog while the second dog's heart was temporarily stopped and opened. After a simulated heart repair in the second dog, the circulations of the two animals were disconnected and they were allowed to recover.

But this technique was fraught with ethical issues. Lillehei himself remarked that "clinical cross circulation for intracardiac surgery was an immense departure from the established surgical practice.... This thought of taking a normal human to the operating room to serve as a donor circulation (with potential risk, however small) even temporarily was considered by critics at that time to be unacceptable, even immoral."

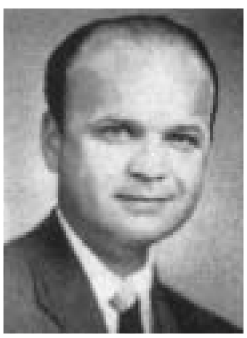
Others were "quick to point out that this proposed operation was the first in all of surgical history to have the potential for a 200 percent mortality."

Moreover, there were practical problems with the technique, including blood type. Cross circulation would work only for people with the same blood type. There was also a problem with blood volume — how much work would the nonsurgical patient's heart have to do?

In spite of these obstacles, Lillehei wrote, "The continued lack of any success in the other centers around the world that were working actively on heart-lung bypass made the decision to go ahead (with cross circulation) inevitable. I felt the technique was ready to use in a human; however, even in such a progressive and primary medical school as the University of Minnesota, there was opposition to the idea. Dr. Owen Wangensteen, chairman of the Department of Surgery, was a tremendous help. He was well aware of these experiments and wholeheartedly supported them. Where there seemed a possibility that the first clinical operation might be canceled the night before because of opposition, I left a note for Dr. Wangensteen, 'Is our case still on in the morning?' His answer: 'Dear Walt: By all means, go ahead.'"

During cross circulation for repair of a congenital defect in a child, a major artery and vein in the parent's groin were

C. Walton Lillehei



C. Walton Lillehei's Legacy

OPEN-HEART SURGERY WAS NOT possible when Dr. C. Walton Lillehei completed his surgical training. Indeed, Lillehei had only switched into medical school at the last minute, veering away from pre-dentistry at the University of Minnesota. As did a select group of surgeons around the world, Lillehei spent much of his early career trying to find a practical way to conduct open-heart surgery. This led him to the novel idea of cross circulation, or using one person's circulation to support that of another, while heart surgery was performed.

For his first patient, he selected "an infant who was about one year of age and had been in the hospital most of his life," Lillehei remembered in a 1999 interview.

Around the same time, ninety miles away, Dr. John Kirklin and his team at the Mayo Clinic were working on a machine that would support patients during cardiopulmonary bypass — and the competition between the teams was fierce.

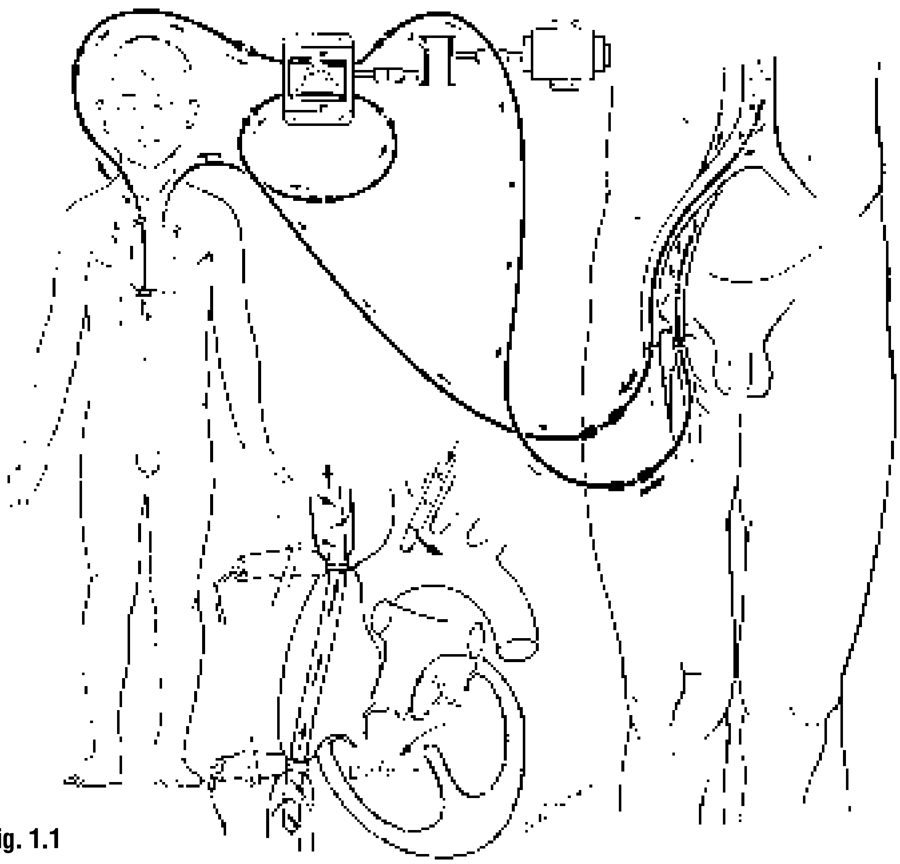


Fig. 1.1

Fig. 1.1:
Dr. C. Walton Lillehei (opposite page), working at the University of Minnesota, developed a novel technique of cardiopulmonary bypass called cross circulation, in which the circulation of one person is used to support that of another during an open-heart operation. It was used successfully in sick children.

"There was significant competition, obviously," Lillehei commented during a 1999 interview. "Kirklin knew the schedule that we were going on, and we didn't operate on Saturday, and they did. So our team was inclined to go down to the Mayo Clinic on Saturday and see what was going on!"

Before long, both teams were using different forms of bypass successfully, and, for more than a year, they were the only ones in the world performing open-heart surgeries. Throughout this time, doctors traveled from all over the world to see the first open-heart operations and their incredible results.

With Kirklin's success with the machine, however, Lillehei began a slow transition away from cross circulation and toward a heart-lung machine of his own design. In the beginning, Lillehei used the heart-lung machine for the simpler, more straightforward cases and continued using cross-circulation, with which he was more familiar, for the more serious cases.

Along with his own pioneering work, Lillehei, who passed away on July 5, 1999, had another lasting effect. Beginning in 1952, he was involved in the training of more than 150 cardiac surgeons at the University of Minnesota. These young physicians came from the U.S., Canada, and thirty-nine other countries, and many have become preeminent in their field and have gone on to make important contributions in their own rights.

John Kirklin

Ductus Arteriosus: A tube connecting the pulmonary artery to the aorta. After birth, when the lungs begin to function, this tube normally closes. If it stays open, the condition is known as patent ductus arteriosus. Over time, this can cause problems such as heart failure and may need to be surgically closed.

John Kirklin's Inspiration: How We Would Fix the Inside of the Heart

DR. JOHN KIRKLIN, WHO WAS more interested in football than medicine in his undergraduate days, remembers clearly the moment he became a cardiac surgeon. He was enrolled in the medical school at Harvard University when Dr. Robert Gross, a Boston surgeon, visited to give a lecture. It was the 1930s, and heart surgery was almost nonexistent — except for Gross, who had become "the only world-famous cardiac surgeon" by successfully closing a patent **ductus arteriosus** a few months before.

"On this Saturday morning, into this lecture hall, down on the ground level, walked this man," Kirklin said in a 1999 interview. "He was very young,

connected through tubes to the child's circulation, and the heart of the parent pumped enough oxygenated blood to also support the circulation of the small child (Fig. 1.1). A mechanical pump was used to control the interchange of blood between the patient and the donor.

On March 26, 1954, Lillehei and associates used the cross-circulation technique at the University of Minnesota to correct a ventricular septal defect, or a hole in the wall between the heart's two pumping chambers, in a twelve-month-old infant.

The patient had been hospitalized ten months for uncontrollable heart failure and pneumonia. During the operation, the child's circulatory system was connected to his father's. The procedure was a success, and the patient seemed to be making a good recovery until death on the eleventh postoperative day from an infection of the trachea. At autopsy, the hole between the pumping chambers was confirmed closed. Two weeks later, and only three days apart, the second and third patients with ventricular septal defect underwent successful heart surgery. Both became long-term survivors with normal heart function.

A year later, Lillehei published a report on thirty-two children with various types of cardiac malformations that had undergone surgical repair. Although Lillehei had met with fairly good success with his technique, it would not become established. After its use in forty-five patients during 1954 and 1955, it was discontinued. Although its clinical use was short lived, cross circulation was an important stepping stone in the development of cardiac surgery.

Kirklin's Heart-Lung Machine

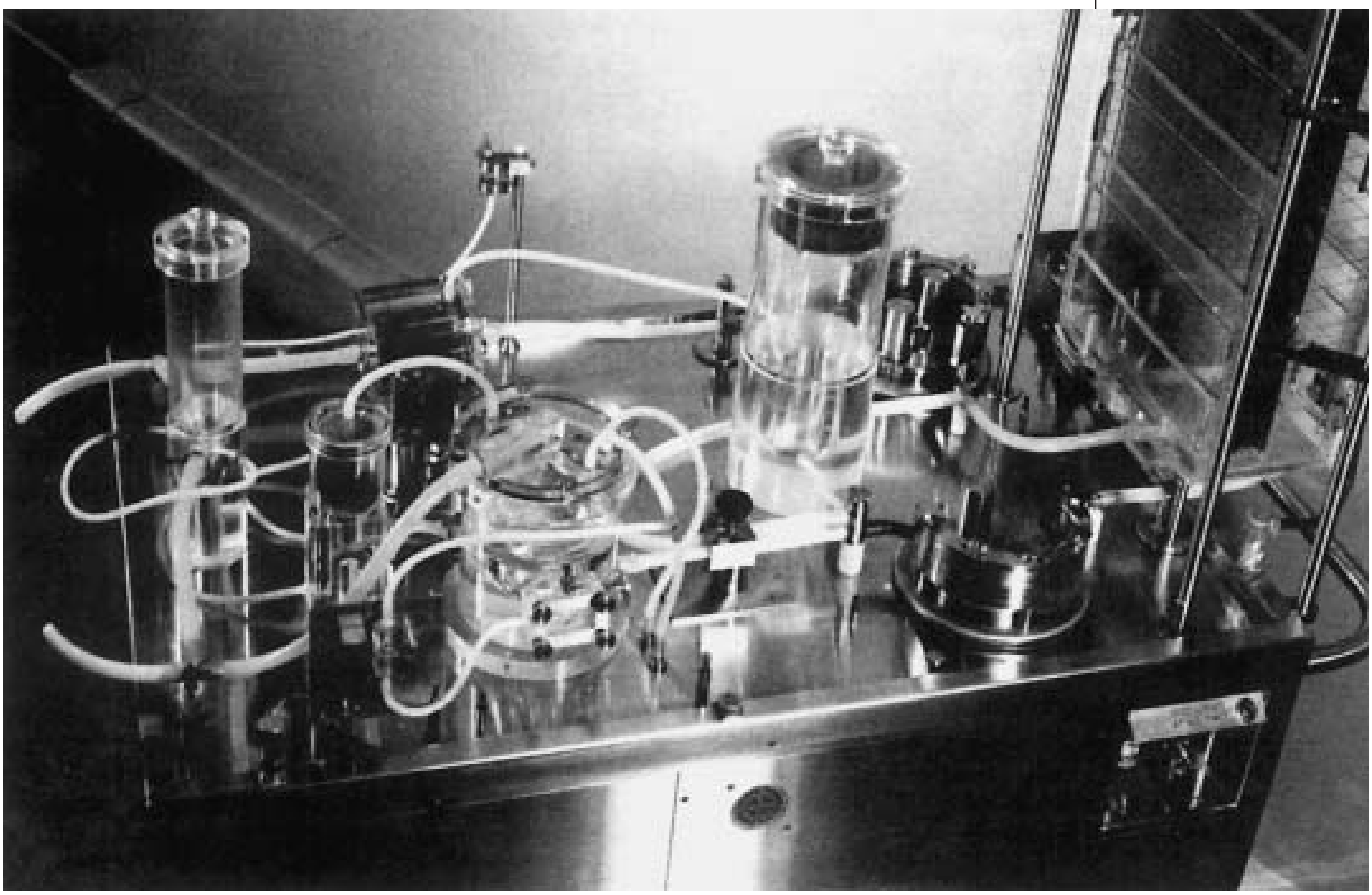
At the same time Lillehei was working on cross circulation, Dr. John W. Kirklin announced he was launching an open-heart program at the Mayo Clinic, only ninety miles away from Lillehei's operating room. Kirklin and his team had developed their own heart-lung machine, basing it on the Gibbon-IBM machine, but with their own modifications.

At that time, there were perhaps fewer than a dozen laboratory research programs, very neat, with slicked-back hair. He was a good-looking man in a blue suit. He walked in and looked around that amphitheater with a slightly haughty look and said he was giving a lecture on wound healing. At that moment, 110 cardiac surgeons came into existence, of which a few of us stayed in business."

Over the next years, Kirklin remembers sitting with colleagues filling notebooks "about how we would fix the inside of the heart if we could get there. We couldn't, of course, but being young, you dream!" The obstacles to overcome in creating an open heart surgery program were awesome. Doctors on the Mayo team thought they were only months from performing the procedure on their first patient when a prominent pathologist, having observed a practice run with the heart-lung machine, said it was impractical and would never work. This pathologist happened to be in charge of the blood bank and declared it would not be possible to supply enough fresh blood to prime the machine for an ongoing open heart surgery program.

Kirklin's development program at the Mayo Clinic did, in fact, overcome the obstacles, resulting in a successful heart-lung machine that finally gave him the opportunity to realize those early ambitions. He was first to have a series of patients successfully undergo heart surgery using the heart-lung machine.

At the Mayo Clinic, Dr. John Kirklin used Gibbon's basic design to build the Mayo-Gibbon heart-lung machine. Pictured below is the screen oxygenator, which was responsible for infusing the blood with oxygen much like a lung does. This model was used in 1955 during the first open-heart operations.



including Kirklin's and Lillehei's, focusing on open heart surgery in the world. Of them all, these two were among the most promising, and, because of their proximity to each other, the competition between the two teams of doctors was fierce, yet remained focused on the goal. Medicine appeared to be on the brink of open cardiac surgery, and doctors from around the world visited the developing programs.

The implications for a major improvement in the treatment of heart birth defects were enormous, and it was an extraordinarily exciting time in the development of medicine. Remembering this period, Kirklin later wrote:

> *"Dr. Earl Wood, a great physiologist and my coworker, and I went back to his office ... and decided that we would either have to be content with cardiac surgery as a rather minor specialty, limited to passing instruments into the heart, or we would need a heart-lung machine.... 'It's the oxygenator that is the problem,' said Wood.*
>
> *"We investigated and visited the groups working intensely with the mechanical pump oxygenator. We visited Gibbon in his laboratories in Philadelphia and Dodrill in Detroit, among others. The Gibbon pump oxygenator had been developed and made by International Business Machines Corporation and looked quite a bit like a computer. Dodrill's heart-lung machine had been developed and built for him by General Motors, and it looked a great deal like a car engine. We came home, reflected, and decided to try to persuade the Mayo Clinic to let us build a pump oxygenator similar to the Gibbon machine but somewhat different.*
>
> *"Most people were very discouraged with the laboratory progress. The American Heart Association and the National Institutes of Health had stopped funding any projects for the study of heart-lung machines because it was felt that the problem was physiologically insurmountable. Dr. David Donald and I undertook a series of laboratory experiments lasting about a year and a half, during which time the engineering shops at the Mayo Clinic constructed a pump oxygenator based on the Gibbon model....*
>
> *"Of course a number of visitors came our way, and some of them came to the laboratory to see what we were doing. One of those visitors was Dr. Ake Senning (from Stockholm, Sweden). I still remember one day when he was there and one of the connectors came loose, and we ruined his beautiful suit as well as the ceiling of the laboratory by spraying blood all around the room.*
>
> *"The electrifying day came in the spring of 1954 when the newspapers carried an account of Walt Lillehei's successful open-heart operation on a small child. Of course, I was terribly envious, and yet I was terribly admiring at the same moment. That admiration increased exponentially when a short time later a few of my colleagues and I visited Minneapolis and observed one of what was now a series of successful open-heart operations with controlled cross-circulation. Walt then took us on rounds, and it was absolutely exciting to see small children recovering from these miraculous operations. However, it was also a difficult time for me. Some of my colleagues at the Mayo Clinic, and some of my influential ones, indicated to me that we had wasted much time and money. After all, this young fellow in Minneapolis was successful with a very simple apparatus and did not even require an oxygenator....*
>
> *"However, in the winter of 1954 and 1955, we had nine surviving dogs out of ten cardiopulmonary bypass (heart-lung machine) runs. With my wonderful colleague and pediatric cardiologist, Dr. Jim DuShane, we had earlier selected eight patients for intracardiac repair. Two had to be put off because two babies with*

very serious congenital heart disease came along, and we decided to fit them into the schedule.

"We did our first open heart operation on a Tuesday in March 1955. That evening, I had a telephone call from Dr. Dick Varco in Minneapolis who indicated that Sir Russell Brock (a prominent chest surgeon from England) was visiting their cardiac surgical program at the University of Minnesota. Walt Lillehei and Dick Varco indicated to Sir Russell that we had done an operation earlier that day, and they called to see if he could come to Rochester the next day to see the patient, to which I said 'Certainly.' "

Kirklin later remembered that he was worried Sir Russell would ask to sit in on another surgery, which he did. "So I sort of said yes, but imagine it," Kirklin said.

"It was one of the world's great surgeons saying to some kid, 'May I come and visit?' He was a very imperious, tough guy with a bad reputation, which I think he totally did not deserve. I asked him if he'd like to be on the operating team. 'No. No,' he said, 'I wouldn't. I don't want to be a problem. I just want to watch. Do you have a gallery? I'll sit in the gallery.'

"The next morning, I walked in to do the second case. He was already in the gallery, but in a place that I knew he wouldn't be able to see very well. I suggested that he might want to move, but he said, 'I'll be in your field of vision and I don't want you to be distracted by my presence.' He didn't move and that was a great, great man, a world-famous man with a bad reputation who was wonderful to me."

By this time, he and Lillehei "were on parallel but intertwined paths," Kirklin later wrote. "I am extremely grateful

Dr. Richard DeWall helped develop the bubble oxygenator that eventually replaced the screen oxygenator and became a standard in heart-lung machines.

to Walt Lillehei and am very proud for the two of us that during that twelve- to eighteen-month period when we were the only surgeons in the world performing open intracardiac operations with cardiopulmonary bypass and surely in intense competition with each other, we shared our gains and losses with each other. We continued to communicate, and we argued privately in nightclubs and on airplanes rather than publicly over our differences."

In Kirklin's first group of eight patients, four survived the surgery. He was able to lower his open-heart mortality rate to 20 percent the following year and 10 percent the year after that.

During 1955, Lillehei began to gradually switch over from cross circulation to a heart-lung machine of his own team's design. With a colleague, Dr. Richard DeWall, they developed a "bubble" type of oxygenator that, with modifications made by Dr. Denton Cooley in Houston, Texas, became popular. The concept is still used today.

Kirklin's heart-lung machine, which was known as the Mayo-Gibbon heart-lung machine, was the accepted standard in those early days. By this time,

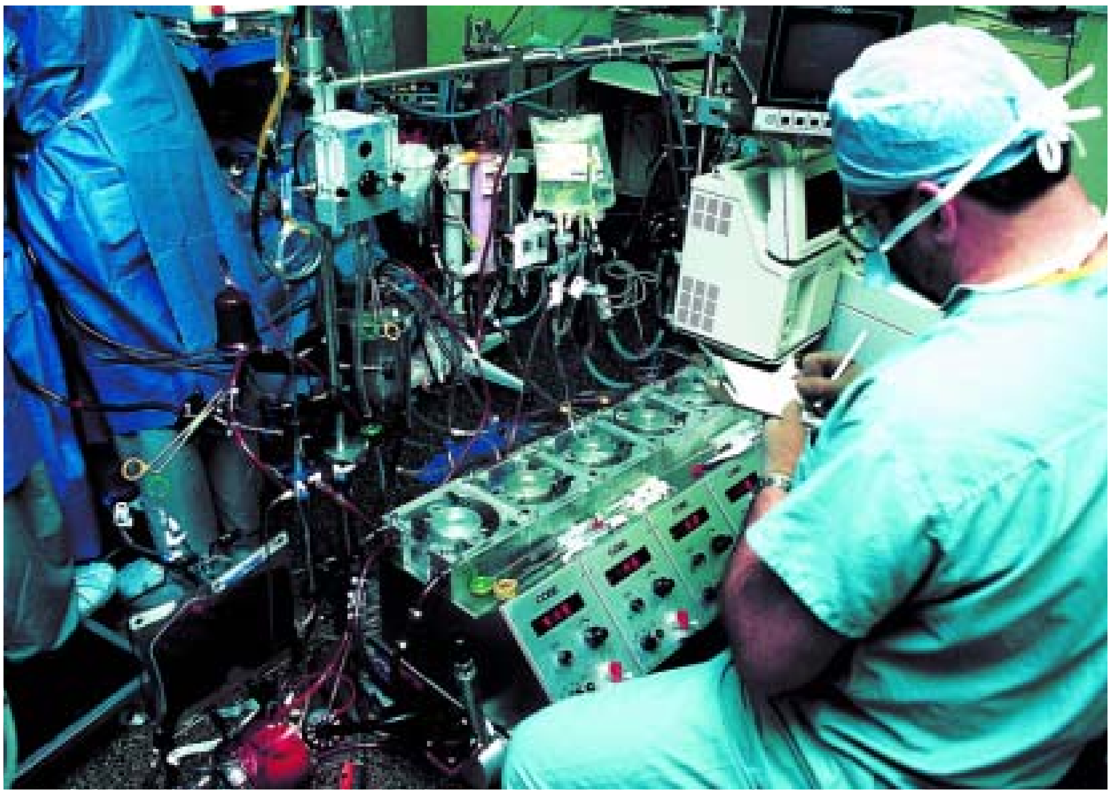
DENTON COOLEY: INVENTOR AND PIONEER SURGEON

DR. DENTON COOLEY, ONE OF heart surgery's most noteworthy pioneers, originally planned on becoming a dentist and taking over his father's practice.

Although he was interested in medicine, he was worried that the academic track to a medical degree was too difficult. This fear was put to rest when he achieved the highest grades in his college fraternity. Soon after, Cooley transferred into medicine and eventually graduated from Johns Hopkins Medical School. During World War II, he also interned at Johns Hopkins, training under Dr. Alfred Blalock, where he was present at the world's first "blue baby" operation.

"There was a great superstition about the heart at the time," Cooley remembered during a recent interview, "and whether one could operate inside of the heart with expectation of survival. I went through what I called the closed era, when we operated on the surface of the heart, to the open era, when we were actually inside the heart doing much more extensive types of repairs."

The open era of heart surgery is credited to the heart-lung machine, an exciting innovation that Cooley studied in development. His laboratory re-



A modern heart-lung machine.

search in this area started in 1952 and was initially slow, causing him to visit Minnesota.

> *"I had gone up to Minnesota to visit Lillehei in Minneapolis and then Kirklin over at Rochester. There, within the space of two or three days, I got to see what could be done. Lillehei was using cross circulation, which seemed to work well but obviously could not be used safely in adult patients. Then I saw Kirklin, who had a very elaborate machine, modeled after what Gibbon had devised, but it was very complex. From that experience, I decided I was going to go with the bubble oxygenator and pump."*

Cooley felt that a bubble oxygenator, which Lillehei and DeWall had just developed, was simpler than the oxygenator Kirklin was using, and he began developing a reusable bubble oxygenator made of stainless steel.

His first chance to use it in a human came when a desperately ill forty-nine-year-old man was referred to him. The patient had a ruptured ventricular septum caused by a heart attack. Cooley successfully repaired the hole in the ventricular septum on April 6, 1956. This marked the beginning of open-heart surgery in Texas. In time, other patients began to follow.

"Within an eight-month period, I had done ninety-five open-heart operations, which far exceeded what anyone else had done anywhere in the world," Cooley said. "At that time, we enjoyed almost a monopoly on open-heart surgery in that there were only two other institutions that were really active in the field, and they were both in Minnesota [at the University of Minnesota and the Mayo Clinic]."

Dr. Denton Cooley began performing open-heart operations in the mid-1950s, soon after the heart-lung machine had been developed. He helped develop the bubble oxygenator.

many university groups around the world had developed open heart programs, and the modern era of cardiac surgery had begun. With their greatest obstacle overcome, teams of surgeons began to tackle ever-more-complex cardiac problems in both children and adults. Right after the introduction of the heart-lung machine, the pace of advance was so rapid that by the 1960s, surgeons were treating coronary artery disease, congenital heart defects, cardiac injuries, heart valve problems, and diseased or damaged major arteries in the chest.

As the field became more specialized, the role of the heart surgeon became more narrowly focused, and pediatric congenital heart surgery separated from adult heart surgery into a specialty of its own. For the most part, cardiac surgery in the adult addresses acquired heart disease. Nevertheless, a close connection between adult and pediatric heart surgery continues because advances in one subspecialty usually are applicable in the other, and this kinship will probably remain for the foreseeable future.

Currently, almost one million cardiac operations are performed each year worldwide with the use of the heart-lung machine. In most cases, the operative mortality is quite low, approaching 1 percent for some operations. Today, hundreds of thousands of physicians, scientists, and engineers are involved in a broad and deep effort to develop new and safer operations and procedures, new valves, new biomaterials, new heart substitutes, and new life-support systems. These efforts are supported by a vigorous infrastructure of basic science, biology, medicine, chemistry, pharmacology, engineering, and computer technology.

Tetralogy of Fallot: A congenital heart defect that consists of four different abnormalities: 1. An abnormal opening between the right and left ventricles; 2. An abnormal position of the aorta so that it partially overrides the right and left ventricular hole; 3. Obstruction of blood flow to the lungs; 4. An abnormal thickening of the right ventricle.

Nikolay Amosov: Heart Surgeon and Public Servant in the U.S.S.R.

THE INITIAL DRIVE TO DEVELOP heart surgery was a worldwide effort, with doctors in North and South America, Europe, the U.S.S.R., and elsewhere all pushing towards open heart surgery and techniques to correct many forms of heart disease. In the former Soviet Union, Dr. Nikolay Amosov became one of the leading surgeons of his day. In a recent interview, Amosov remembered his introduction to medicine and his early days as a surgeon.

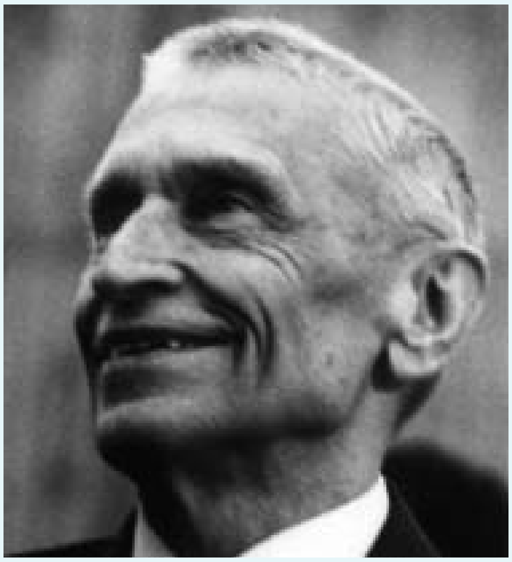
"I had been interested in medicine since my childhood," Amosov said. "However, I happened to choose the only post-graduate degree available in the medical school in Arkhangelsk, and this was military surgery. There I began my surgical career. I spent only one year in post-doctoral training and went to the city of Cherepovets, where I worked as a surgeon for a year before World War II broke out. They were recruiting to the military field hospital in Cherepovets, where there was a need for a chief surgeon. I was offered the spot and served in this hospital throughout the war."

Amosov's workload was enormous. His two-hundred-bed hospital with only five doctors treated forty thousand wounded Russian soldiers throughout the war.

By 1953, after additional, nonwartime surgical experience in Moscow, Amosov moved to the Ukrainian capital of Kiev and became chairman of the Department of Surgery in the Kiev State Medical School. Like other surgeons around the world, he performed heart operations such as opening narrowed mitral valves and placing the Blalock-Taussig shunt for **tetralogy of Fallot**. These operations did not require a heart-lung machine.

"Of course, I had never been out of the country and had never seen heart surgery done by someone else," he said. "Mostly, I used books to educate myself. It was very difficult to start."

In 1957, Amosov traveled with a group of Russian surgeons — including Dr. Boris Petrovsky, a prominent pioneer chest surgeon and minister of health of the U.S.S.R. for sixteen years — to the Mexico International Congress of Surgeons. There, for the first time, he saw an operation performed with a heart-lung machine.



"When we came back, I wanted to start that kind of surgery, but I did not have the opportunity to buy a heart-lung machine. But, because in addition to medical school, I also had a degree in engineering, I created a heart-lung machine myself in 1958. A local factory built it. In 1959, we did our first case of tetralogy of Fallot using our own heart-lung machine."

Slowly, Amosov and his team advanced into more complicated cases. Nevertheless, their surgical results were very good, and in 1962, his team in Kiev was the first in the U.S.S.R. to replace a mitral valve with nylon leaflets. Interestingly enough, he used nylon from a shirt he had bought in the United States.

Throughout his career, Amosov was widely recognized for his standing as a world-class heart surgeon. Even the Communist Party leadership admired the doctor, who had never been a member of the Communist Party, and named him to the Supreme Soviet.

"It was important for the Party bosses to have somebody in the Supreme Soviet who was popular in the public eye," he said. "People supported me, and I was elected unanimously. But then, everyone was elected unanimously. I was not attracted to being a deputy in the Supreme Soviet, but you could not refuse this kind of offer. You might lose your job. The Supreme Soviet had its sessions biannually. Every vote was unanimous. Debates were not too long. I made a speech once. I spoke about health care and was very critical. In 1979, after seventeen years on the Supreme Soviet of the Soviet Union, my services there came to an end."

By the late 1980s, the volume at the Institute of Cardiovascular Surgery in Kiev grew to about five thousand surgical cases a year, making it one of the busiest cardiovascular centers in the world.

"In 1988, when I became seventy-five, I decided it was inappropriate for me to continue as director of the Cardiovascular Institute. An election was held at the Institute, and Dr. Gennady Knyshov was elected my successor. And then I made one more call to public service in 1989. Everyone had so much enthusiasm that our country would be a democracy. Employees of our institute nominated me. Elections were held, but on a democratic basis and without interference. On election day, 60 percent of the ballots were cast for me. This time when I was elected to the Supreme Soviet, it was organized like a real parliament. However, all my hopes to improve the health care system never succeeded.

"In December 1992, the Soviet Union ceased to exist. With its demise, my public service ended."

This text was based on an interview conducted for this book by Dr. Gennady Knyshov, director, Cardiovascular Institute, Kiev, Ukraine, and translated by Dr. Vitaly Piluiko.