PART I

Becoming a Mathematician in Poland

CHAPTER 1

Childhood

1909–1927

MY father, Jozef Ulam, was a lawyer. He was born in Lwów, Poland, in 1877. At the time of his birth the city was the capital of the province of Galicia, part of the Austro-Hungarian Empire. When I was born in 1909 this was still true.

His father, my grandfather, was an architect and a building contractor. I understand that my great-grandfather had come to Lwów from Venice.

My mother, Anna Auerbach, was born in Stryj, a small town some sixty miles south of Lwów, near the Carpathian Mountains. Her father was an industrialist who dealt in steel and represented factories in Galicia and Hungary.

One of my earliest memories is of sitting on a window sill with my father and looking out at a street on which there was a great parade honoring the Crown Prince, who was visiting Lwów. I was not quite three years old.

I remember when my sister was born. I was told a little

girl had arrived, and I felt—it is hard to describe—somehow grown up. I was three.

When I was four, I remember jumping around on an oriental rug looking down at its intricate patterns. I remember my father's towering figure standing beside me, and I noticed that he smiled. I felt, "He smiles because he thinks I am childish, but I know these are curious patterns." I did not think in those very words, but I am pretty certain that it was not a thought that came to me later. I definitely felt, "I know something my father does not know. Perhaps I know better than my father."

I also have the memory of a trip to Venice with the family. We were on a vaporetto on a canal, and I had a balloon which fell overboard. As it bobbed along the side of the boat, my father tried to fish it out with the crooked end of his walking stick but failed. I was consoled by being allowed to select a souvenir model of a gondola made of Venetian beads and still remember the feeling of pride at being given such a task.

I remember the beginning of the first World War. As a boy, I was a Central Powers patriot when Austria, Germany, and Bulgaria—the "Central Powers"—were fighting against France, England, Russia, and Italy. Most of the Polish-speaking people were nationalistic and anti-Austrian, but nevertheless, at about the age of eight I wrote a little poem about the great victories of the Austrian and German armies.

Early in 1914, the Russian troops advanced into Galicia and occupied Lwów. My family left, taking refuge in Vienna. There I learned German, but my native language—the language we spoke at home—was Polish.

We lived in a hotel across from St. Stephen's cathedral. The strange thing is that even though I visited Vienna many times afterwards, I did not actually recognize this building again until one day in 1966 while I was walking through the streets with my wife. Perhaps because we were talking about my childhood I suddenly remembered it and pointed

it out to her. With this a number of other memories buried for over fifty years surfaced.

On the same visit, while walking through the Prater gardens, the sight of an outdoor café suddenly brought back the memory of how I had once choked in the wind with a sort of asthmatic reaction in front of that very café—a feeling that I was not to experience again until many years later in Madison, Wisconsin. Curiously the subsequent sensation did not make me recall the childhood episode. It is only when I was at that very spot many years later that this sensory memory returned as a result of the visual association.

I will not try to describe the mood of Vienna as seen through the eyes of a six-year-old. I wore a sort of military cap; when an officer saluted me on Kärntner Strasse (one of the main streets of Vienna) I remember vividly that I was absolutely delighted. But when somebody mentioned that the United States would have ten thousand airplanes (there was such a rumor) I began to have doubts about the victory of the Central Powers.

At about this time in Vienna I learned to read. Like so much of learning throughout my life, at first it was an unpleasant—a difficult, somewhat painful experience. After a while, everything fell into place and became easy. I remember walking the streets reading all the signs aloud with great pleasure, probably annoying my parents.

My father was an officer in the Austrian Army attached to military headquarters, and we traveled frequently. For a while we lived in Märisch Ostrau, and I went to school there for a time. In school we had to learn the multiplication tables, and I found learning arithmetic mildly painful. Once I was kept home with a cold just as we were at six times seven. I was sure that the rest of the class would be at twelve times fifteen by the time I went back. I think I went to ten times ten by myself. The rest of the time I had tutors, for we traveled so much it was not possible to attend school regularly.

I also remember how my father would sometime read to me from a children's edition of Cervantes' *Don Quixote.* Episodes that now seem only mildly funny to me, I considered hilarious. I thought the description of Don Quixote's fight with the windmills the funniest thing imaginable.

These are visual pictures, not nostalgic really but bearing a definite taste, and they leave a definite flavor of associations in the memory. They carry with them a consciousness of different intensities, different colors, different compositions, mixed with feelings which are not explicit—of well-being or of doubt. They certainly play simultaneously on many physically separate parts in the brain and produce a feeling perhaps akin to a melody. It is a reconstruction of how I felt. People often retain these random pictures, and the strange thing is that they persist throughout one's life.

Certain scenes are easier of access, but there are probably many other impressions which continue to exist: Experiments have re-created certain scenes from the past when areas of a patient's brain were touched with a needle during an operation. The scenes that can be summoned up from one's memory at will have a color or flavor which does not seem to change with time. Their re-creation by recollection does not seem to change them or refresh them. As far as I can tell when I try to observe in myself the chain of syllogisms initiated by these impressions, they are quite analogous now as to what they were when I was little. If I look now at an object, like a chair, or a tree, or a telegraph wire, it initiates a train of thought. And it seems to me that the succession of linked memories are quite the same as those I remember when I was five or six. When I look at a telegraph wire, I remember very well it gave me a sort of abstract or mathematical impulse. I wondered what else could do that. It was an attempt at generalization.

Perhaps the store of memory in the human brain is to a large extent already formed at a very early age, and external stimuli initiate a process of recording and classifying the im-

pressions along channels which exist in large numbers in very early childhood.

To learn how things are filed in the memory, it obviously helps to analyze one's thoughts. To understand how one understands a text, or a new method, or a mathematical proof, it is interesting to try to consciously perceive the temporal order and the inner logic. Professionals or even interested amateurs have not done enough in this area to judge by what I have read on the nature of memory. It seems to me that more could be done to elicit even in part the nature of associations, with computers providing the means for experimentation. Such a study would have to involve a gradation of notions, of symbols, of classes of symbols, of classes of classes, and so on, in the same way that the complexity of mathematical or physical structures is investigated.

There must be a trick to the train of thought, a recursive formula. A group of neurons starts working automatically, sometimes without external impulse. It is a kind of iterative process with a growing pattern. It wanders about in the brain, and the way it happens must depend on the memory of similar patterns.

Very little is known about this. Perhaps before a hundred years have passed this will all be part of a fascinating new science. It was not so long ago that scientists like John von Neumann began to examine analogies between the operation of the brain and that of the computer. Earlier, people had thought the heart was the seat of thought; then the role of the brain became more evident. Perhaps it actually depends on all the senses.

We are accustomed to think of thinking as a linear experience, as when we say "train" of thought. But subconscious thinking may be much more complicated. Just as one has simultaneous visual impressions on the retina, might there not be simultaneous, parallel, independently originated, abstract impressions in the brain itself? Something goes on in our heads in processes which are not simply strung out on

one line. In the future, there might be a theory of a memory search, not by one sensor going around, but perhaps more like several searchers looking for someone lost in a forest. It is a problem of pursuit and of search—one of the greatest areas of combinatorics.

What happens when one suddenly remembers a forgotten word or name? What does one do when one tries to remember it? Subconsciously something is turning. More than one route is followed: one tries by sound or letters, long words or short words. That must mean that the word is filed in multiple storage. If it were only in one place there would be no way to recover it. Time is a parameter, too, and although in the conscious there seems to be only one time, there may be many in the subconscious. Then there is the mechanism of synthesizer or summarizer. Could one introduce an automatic search system, an ingenious system which does not go through everything but scans the relevant elements?

But I have digressed enough in these observations on memory. Let me now return to this account of my life. I only wish that I could have some of Vladimir Nabokov's ability to evoke panoramas of memories from a few pictures of the past. Indeed one can say that an artist depicts the essential functions or properties of a whole set of impressions on the retina. It is these that the brain summarizes and stores in the memory, just as a caricaturist can convey the essentials of a face with just a few strokes. Mathematically speaking, these are the global characteristics of the function or the figure of a set of points. In this more prosaic account I will describe merely the more formal points.

In 1918 we returned to Lwów, which had become part of the newly formed Republic of Poland. In November of that year the Ukrainians besieged the city, which was defended by a small number of Polish soldiers and armed civilians. Our house was in a relatively safe part of town, even though occasional artillery shells struck nearby. Because our house was safer, many of our relatives came to stay with us. There

must have been some thirty of them, half being children. There were not nearly enough beds, of course, and I remember people sleeping everywhere on rolled rugs on the floor. During the shelling we had to go to the basement. I still remember insisting on tying my shoes while my mother was pressing me to hurry downstairs. For the adults it must have been a strenuous time to say the least, but not for us. Strangely enough, my memories of these days are of the fun I had playing, hiding, learning card games with the children for the two weeks before the siege was lifted with the arrival of another Polish army from France This broke the ring of besiegers. For children wartime memories are not always traumatic.

During the Polish-Russian war in 1920 the city was threatened again. Budenny's cavalry penetrated to within fifty miles, but Pilsudski's victory on the Warsaw front saved the southern front and the war ended.

At the age of ten in 1919 I passed the entrance examination to the gymnasium. This was a secondary school patterned after the German gymnasia and the French lycées. Instruction usually took eight years. I was an A student, except in penmanship and drawing, but did not study much.

One of the gaps in my education was in chemistry. We did not have much of it in school and fifty years later, now that I am interested in biology, this handicaps me in my studies of elementary biochemistry.

About this time I also discovered that I did not have quite normal binocular vision. It happened in the following way: the boys in the class had been lined up for an eye examination. Awaiting my turn to read the charts, I covered my eyes with my hand. I noticed with horror that I could only read the largest letters with my right eye. This made me afraid that I would be kept after school, so I memorized the letters. I think it was the first time in my life when I consciously cheated. When my turn came I "read" satisfactorily and was let off, but I knew my eyes were different, one was myopic. The other, normal, later became presbyotic. This

condition, rather rare but well known, is apparently hereditary. I still have never worn glasses, although I have to bend close to the printed text to read with my myopic eye. I am not normally aware which eye I use; once later in life a doctor in Madison told me that this condition is sometimes better than normal, for one or the other eye is resting while the other is in use. I wonder if my peculiar eyesight, in addition to affecting my reading habits, may also have affected my habits of thought.

When I try to remember how I started to develop my interest in science I have to go back to certain pictures in a popular book on astronomy I had. It was a textbook called *Astronomy of Fixed Stars,* by Martin Ernst, a professor of astronomy at the University of Lwów. In it was a reproduction of a portrait of Sir Isaac Newton. I was nine or ten at the time, and at that age a child does not react consciously to the beauty of a face. Yet I remember distinctly that I considered this portrait—especially the eyes—as something marvelous. A mixture of physical attraction and a feeling of the mysterious emanated from his face. Later I learned it was the Geoffrey Kneller portrait of Newton as a young man, with hair to his shoulders and an open shirt. Other illustrations I distinctly remember were of the rings of Saturn and of the belts of Jupiter. These gave me a certain feeling of wonder, the flavor of which is hard to describe since it is sometimes associated with nonvisual impressions such as the feeling one gets from an exquisite example of scientific reasoning. But it reappears, from time to time, even in older age, just as a familiar scent will reappear. Occasionally an odor will come back, bringing coincident memories of childhood or youth.

Reading descriptions of astronomical phenomena today brings back to me these visual memories, and they reappear with a nostalgic (not melancholy but rather pleasant) feeling, when new thoughts come about or a new desire for mental work suddenly emerges.

The high point of my interest in astronomy and an unforgettable emotional experience came when my uncle Szy-

mon Ulam gave me a little telescope. It was one of the copper- or bronze-tube variety and, I believe, a refractor with a two-inch objective.

To this day, whenever I see an instrument of this kind in antique shops, nostalgia overcomes me, and after all these decades my thoughts still turn to visions of the celestial wonders and new astronomical problems.

At that time, I was intrigued by things which were not well understood—for example, the question of the shortening of the period of Encke's comet. It was known that this comet irregularly and mysteriously shortens its three-year period of motion around the sun. Nineteenth-century astronomers made several attempts to account for this as being caused by friction or by the presence of some new invisible body in space. It excited me that nobody really knew the answer. I speculated whether the $1/r^2$ law of attraction of Newton was not quite exact. I tried to imagine how it could affect the period of the comet if the exponent was slightly different from 2, imagining what the result would be at various distances. It was an attempt to calculate, not by numbers and symbols, but by almost tactile feelings combined with reasoning, a very curious mental effort.

No star could be large enough for me. Betelgeuse and Antares were believed to be much larger than the sun (even though at the time no precise data were available) and their distances were given, as were parallaxes of many stars. I had memorized the names of constellations and the individual Arabic names of stars and their distances and luminosities. I also knew the double stars.

In addition to the exciting Ernst book another, entitled *Planets and the Conditions of Life on Them,* was strange. Soon I had some eight or ten astronomy books in my library, including the marvelous Newcomb-Engelmann *Astronomie* in German. The Bode-Titius formula or "law" of planetary distances also fascinated me, inspiring me to become an astronomer or physicist. This was about the time when, at the age of eleven or so, I inscribed my name in a notebook, "S.