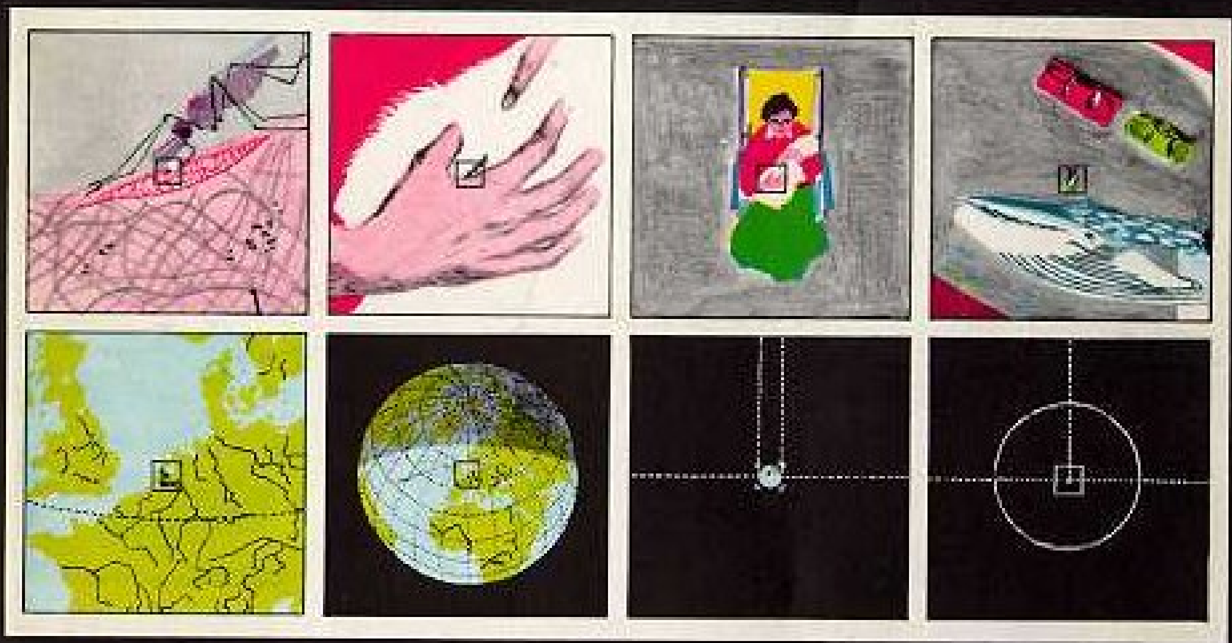
COSMIC VIEW

THE UNIVERSE IN 40 JUMPS



Open this book and journey outward through space to the edge of infinity, then through decreasing scales of size to the atom's nucleus—in a series of drawings each seen from a point ten times farther or ten times closer than the previous.

by KEES BOEKE

Introduction by

ARTHUR H. COMPTON

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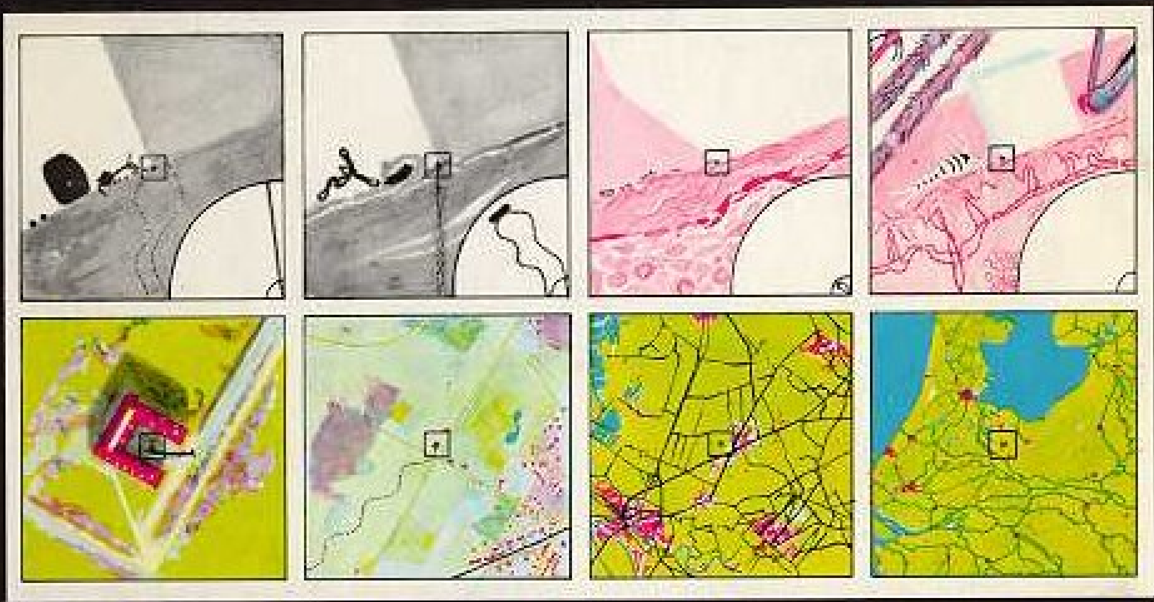


If we examine everyday objects from farther and farther away or from closer and closer, we learn many fascinating things. For example: although we think of color as part of nearly everything that exists, there is actually no such thing except within a limited segment of the vast "domain of scale." This segment is included in the partial set of this book's illustrations reproduced in miniature on this jacket.

Cosmic View

The Universe in 40 Jumps

Kees Boeke

Front Flap

COSMIC VIEW
The Universe in 40 Jumps
By KEES BOEKE

This unique book takes you on a graphic journey through the universe, to the edge of infinity in one direction and to the nucleus of the atom in the other.

It consists of a series of 40 illustrations with text and captions. The first picture, of a girl sitting in a chair, seen from above, seems ordinary enough; the magic comes when, in successive pictures, the author shows us her and her surroundings minified and magnified. The second picture shows the same girl in the same pose but from ten times farther up, the third from ten times as far as the second, etc. Each picture thus shows a greater area, and soon you are seeing the globe of the earth itself. You continue moving in imagination, out through the solar system, the Milky Way, and beyond to other galaxies, until at last even a galaxy is but a pinpoint on the printed page, and you can go no farther because man does not yet know what lies beyond.

But now, returning to the girl, you see her from closer and closer instead of farther and farther. You are shown a closeup of her hand, then microscopic views of it each ten times more magnified than the last. As you view one after the other, you see the structure of the skin tissues, mites and bacteria and bacilli, viruses, molecules, X-rays, cosmic rays, and finally - under a magnification of ten million million - the nucleus of a sodium atom. On the scale of this drawing, a man's height would be about the diameter of the solar system. Again you must stop, because one cannot imagine, much less picture, what a greater magnification would present.

In this awesome journey to the ends of the universe, you have learned an immense amount about its structure and the beings and things that occupy it, and above all about the relationships of things to each other, in their various scales of dimension, with a vividness that words cannot express.

Cosmic View is a book for everyone with a lively interest in the world he lives in. Space travel and atomic structure are no longer science fiction in this world of today, but matters of vast importance to all of us. This book is a virtual diagram of outer space, the atomic core, and everything between.

Back Flap

Kees Boeke was a Dutch schoolmaster who conceived the idea of this book as a vivid way of imparting a "sense of scale." He had developed it for years, perfecting the drawings and adding more and more information to them. Their plotting had been a towering job, for he was determined that every object shown should be in the correct relationship to every other as to position, size, and distance. For example, having chosen noon of a certain day in a certain year as the time when all the 40 pictures are conceived to have been made, he placed the planets, the sun, and even Halley's Comet in precisely the locations they would have had at that instant. In the reduced-scale pictures, to give another example, viruses are shown in their actual shapes, and in the correct sizes in relation to bacilli and other organisms; the wave lengths of radio waves and X-rays are drawn to scale, and we learn how minute by comparison are the gamma rays of the nuclear scientist.

Mr. Boeke was trained as a civil engineer and later became a teacher. He started the internationally famous Werkplaats Children's Community, a school in the Netherlands, and founded the Dutch section of the New Education Fellowship. Mr. Boeke died in 1966.

Dr. Arthur H. Compton, Nobel prize winner in physics, has written the introduction.

Cosmic View The Universe in 40 Jumps
BY
Kees Boeke
With an introduction by ARTHUR H. COMPTON

The John Day Company NEW YORK
An Intext Publisher

Published by The John Day Company, 257 Park Avenue South, New York, N.Y. 10010, and on the same day in Canada by Longman Canada Limited.

Printed in the United States of America.

ISBN: 0-381-98016.2

Library of Congress Catalogue Card Number: 57-14500

Suggestions to Teachers

This book can be used in various ways to stimulate students' initiative:

1. A group of children makes its own series of drawings, or if possible three-dimensional models, with dimensions of, say, 50 centimeters or more, starting from familiar surroundings. Certain objects are first drawn on the scale 1:10, together with part of the room in which they are situated. In the next drawing this room is shown with the school building around it on the scale of 1:100. Then, at 1:1,000, the school building is drawn with its surroundings, and so on: the town or county, the district, the state, the continent, the earth. By then the significance of scale will be sufficiently grasped, and the pictures in this book can be even more clearly understood.

2. A group of children can also make a collection of drawings, in some cases models, of comparable objects all of the some category, on the same scale. Examples: objects like automobiles, ships, buildings; living creatures like mammals, insects, bacteria, viruses. Also planets, moons, asteroids, stars, clusters and galaxies, and molecules, atoms, nuclei.

3. Comparative studies can be made of the proportions 1:100, 1:1,000, 1:10,000, for example, to show how large is the size of the atomic nucleus in relation to the atom itself.

4. A large blackboard drawing can be made with a square measuring 1.5 meters, and an illustration measuring 15 centimeters in the book can then be put in the center. In this way a stronger impression can be gotten of the meaning of the proportion 1:1,000, a "jump" which has to be made more than four times to reach the atomic nucleus from a life-size picture, and nearly nine times the other way to reach the limits of our universe.

A Note on the Scale of These Illustrations

The system of metric measurements, based on multiples of ten, is used throughout this book:

1,000 microns = 1 millimeter	Approximate equivalents are:
10 millimeters = 1 centimeter	1 centimeter = about 2/5 inch
100 centimeters = 1 meter	1 meter = about 1 yard
1,000 meters = 1 kilometer	1 kilometer = about 5/8 mile

INTRODUCTION

What are we? Where do we live? Who are our neighbors? Children and grown-ups, we all ask these questions.

The answers that Kees Boeke gives are only the beginning of the story, but that beginning is straightforward and clear. The author shows us a series of pictures of a little girl as seen from different distances. Around her are the things that form her world. We see her also as it were from within, showing the parts she is made of. These various views present one school child in an immense range of perspectives. We begin to understand how big things are and how we are related to them.

It is not easy to do what the author has done so well, to tell accurately and in simple language what the world is like. Here is a reliable framework to which further knowledge can be added. In describing this framework, the author has gone as far as the present state of our knowledge permits. Fifty years ago our cosmic view would have been much more limited. Nothing could have been drawn with confidence in pictures 20 to 26 or in pictures −8 to −14. There is reason to question whether we shall ever be able to draw what would be the next pictures, 27 or −14.

So it is that only now, in our day, we can see ourselves so clearly. In this immense and varied universe we find ourselves indeed one with other boys and girls, other men and women. In showing us how we ourselves look in perspective, Kees Boeke as a skillful teacher helps us also to know how and what our neighbors are.

The author deserves our thanks for giving us his answers to our questions in this fascinating and understandable form.

Arthur H. Compton

ACKNOWLEDGMENT

I wish to acknowledge here the valuable help I received in preparing the material for this publication from many experts in the various fields it deals with, and especially that of Els de Bouter who made the drawings for the illustrations.

K. B.

Author's Foreword

We all, children and grownups alike, are inclined to live in our own little world, in our immediate surroundings, or at any rate with our attention concentrated on those things with which we are directly in touch. We tend to forget how vast are the ranges of existing reality which our eyes cannot directly see, and our attitudes may become narrow and provincial. We need to develop a wider outlook, to see ourselves in our relative position in the great and mysterious universe in which we have been born and live.

At school we are introduced to many different spheres of existence, but they are often not connected with each other, so that we are in danger of collecting a large number of images without realizing that they all join together in one great whole. It is therefore important in our education to find the means of developing a wider and more connected view of our world and a truly cosmic view of the universe and our place in it.

This book presents a series of forty pictures composed so that they may help to develop this wider view. They really give a series of views as seen during an imaginary and fantastic journey through space - a journey in one direction, straight upward from the place where it begins. Although these views are as true to reality as they can be made with our present knowledge, they portray a wonderland as full of marvels as that which Alice saw in her dreams.

The pictures originated in a school in the Netherlands, the Werkplaats Children's Community at Bilthoven, where a group of children under my guidance drew the first versions of them. I began the project because of the importance of developing a sense of scale, and I therefore proposed to draw the same objects in different scales. In doing this I took advantage of the metric system, which logically corresponds with our numerical system, and made each successive scale one-tenth of the one before. When we do this we seem to go right up into the sky, so that we see objects from ever increasing heights, and at the same time see a constantly increasing field around them. We also notice that each imaginary jump we make to move from one scale to another one ten times smaller must be ten times greater than the previous jump. That is, if we start at, say, five meters from an object and we first move to a distance of 50 meters in order to see it at one-tenth scale, we have moved 45 meters; if we then move again, to a distance of 500 meters, to reduce the scale again to one-tenth the previous scale, we will have moved 450 meters, or ten times the length of our first jump. The next jump would be 4,500 meters, to a distance of 5,000 meters, etc. We soon find that we have started on a tremendous journey of exploration, and we begin to wonder what we shall discover if we continue in the same way.

The first 26 pictures of this book are the record of such an imaginary journey.

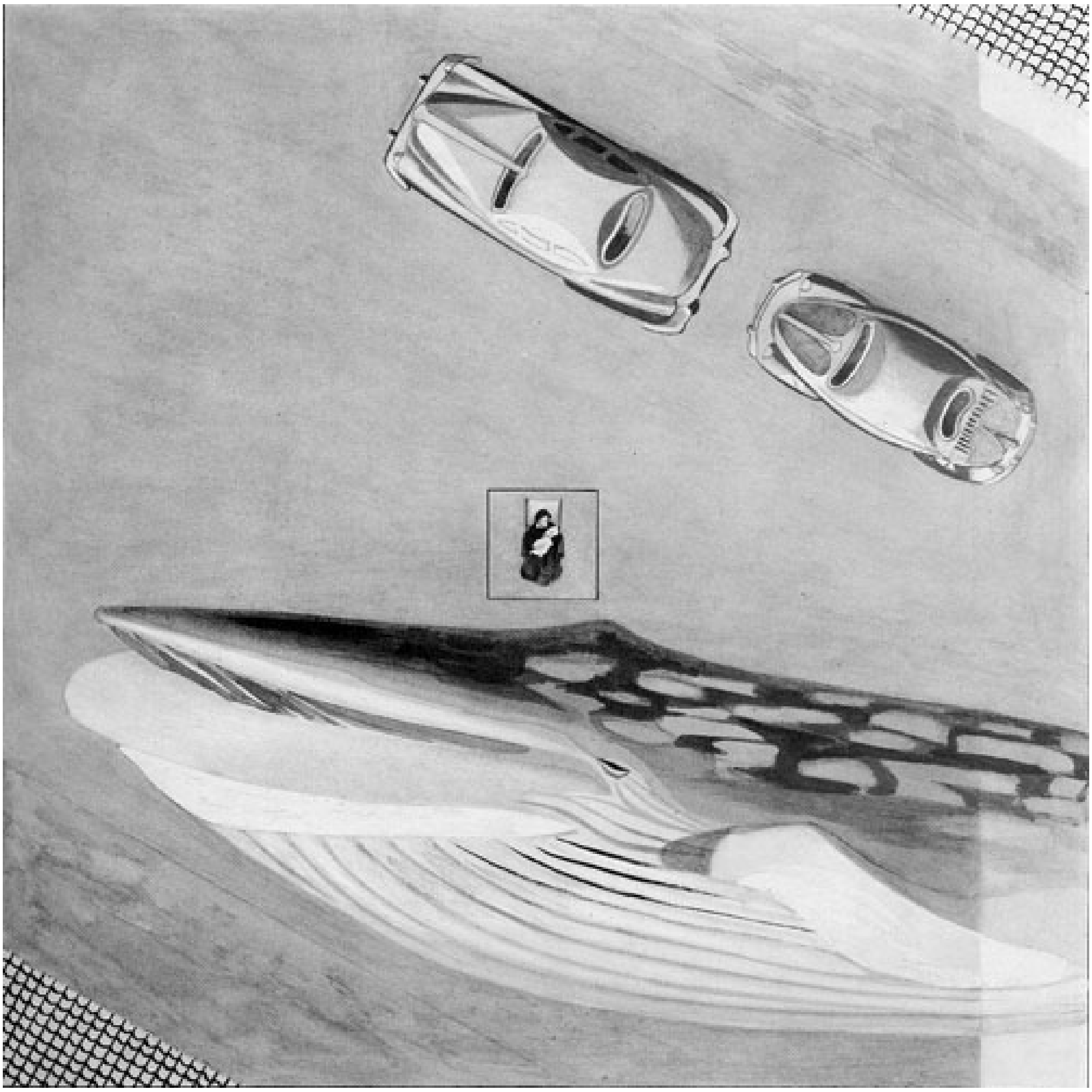
When we undertook our plan, we saw that we must first decide on the date and the time of day of the journey, for we must know where the sun would be at that moment. So we assumed that the moment of observation in each case would be and would remain December 21st at noon. We knew that the sun would then be at the winter solstice and that it would stand in the south. As an "object" to start with, we chose a child sitting in a deck chair in the courtyard of the school building, facing toward the south. As we raised our point of observation we saw first the school itself, then our village: Bilthoven near the town of Utrecht in the center of the Netherlands. Next our view included the whole central part of that country. Going still higher, we saw the western part of Europe, and then the whole earth. Soon the moon came into view, then the nearer planets and the sun. The size of the whole solar system diminished with an astonishing rapidity as the height of our viewpoint increased, tenfold each time.

As we continue in this way, our nearest neighbor stars are drawn into the picture, and before we know it we have passed right out of the Milky Way, our galaxy, and see it from the outside. As we go on in ever more stupendous jumps our whole galaxy in turn shrinks and shrinks, until finally it becomes a small spot, and we gaze through the numberless universes which are beyond and which look like a cloud of tiny specks of light.

The question then arises: What should we see if, instead of decreasing the scale, we should increase it tenfold each time? To find this out, we first go back to the original picture of the little girl sitting in front of the school, and then we begin a second journey of exploration, which proves to be as full of marvels as the first, and which will be shown in the second half of this picture story.

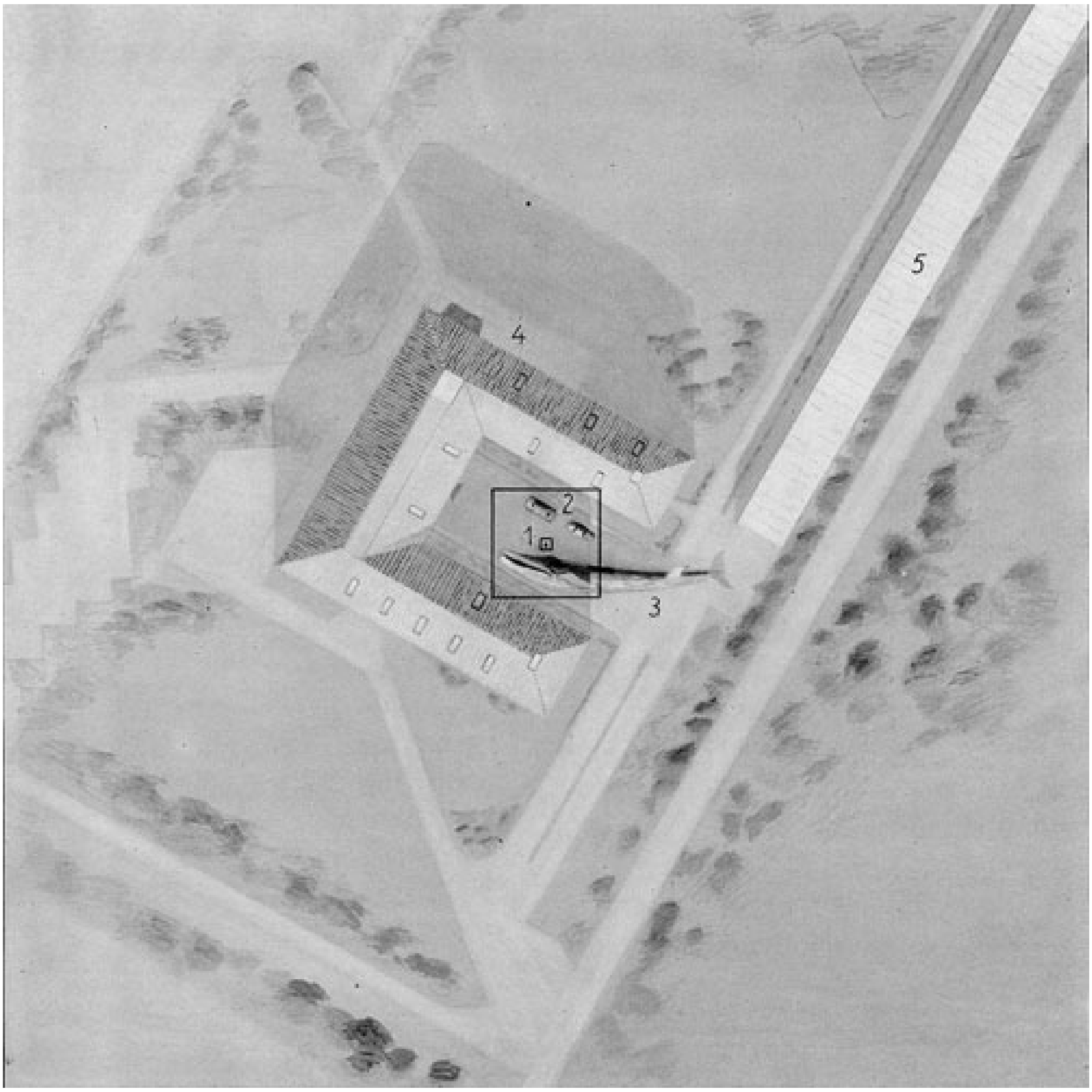
1 The first picture, from which we start, is as we said already one of a child sitting in front of the school, with a cat on her lap. It is drawn on a scale of 1 to 10. This means that a centimeter on the drawing is in reality 10 centimeters. A centimeter (abbreviated "cm.") is the hundredth part of a meter, which corresponds to the yard as a unit of length. To be precise, a meter is 3.37 inches longer than 1 yard. One centimeter is therefore nearly 0.4 inch. In both length and height, the picture measures 15 centimeters, or nearly 6 inches. An arrow shows the direction of north.

1 cm. in picture = 10 cm. in actuality. Scale of picture therefore = 1:10



2 In the center of this second illustration we see a square 1.5 centimeters on each side and in it the picture of the opposite page to one-tenth size, for the sake of comparison. Shown to the same scale are two automobiles, a smaller and a larger type, and also a strange object which at first we hardly recognize as the front part of a whale. A long and unlikely story would certainly be needed to make the presence of a whale at this place and time plausible or even possible. For our present purpose, however, we shall not be held back by such considerations; our aim in putting the poor dead whole there lying on its side is only to enable us to compare the size of the young human being with one of the largest living creatures, also a mammal. Later this will enable us to observe in how many of the domains of scale living creatures occur.

1 cm. in picture = 100 cm. = 1 meter in actuality. Scale = 1:100 = $1:10^2$



3 In the center we now see a tiny square, the sides of which are only 1.5 millimeters in width (abbreviated 1.5 mm.). It clearly represents the illustration two pages before: 1. The child (1) in it is barely visible, but the cars (2) can easily be distinguished and the whale (3) shows up nicely in its full length of some 30 meters, which is about the record length these fellow-mammals reach. The U-shaped building (4) tells a story of the war years, when the German military built it during the occupation of the Netherlands. After the liberation it was rebuilt and enlarged to become the central building for the Werkplaats Children's Community. The long building (5), typical of Holland, is a bicycle shed. Note that the number of each picture corresponds with the exponent of the power of 10 in the statement of the boldface line below each caption giving the scale.

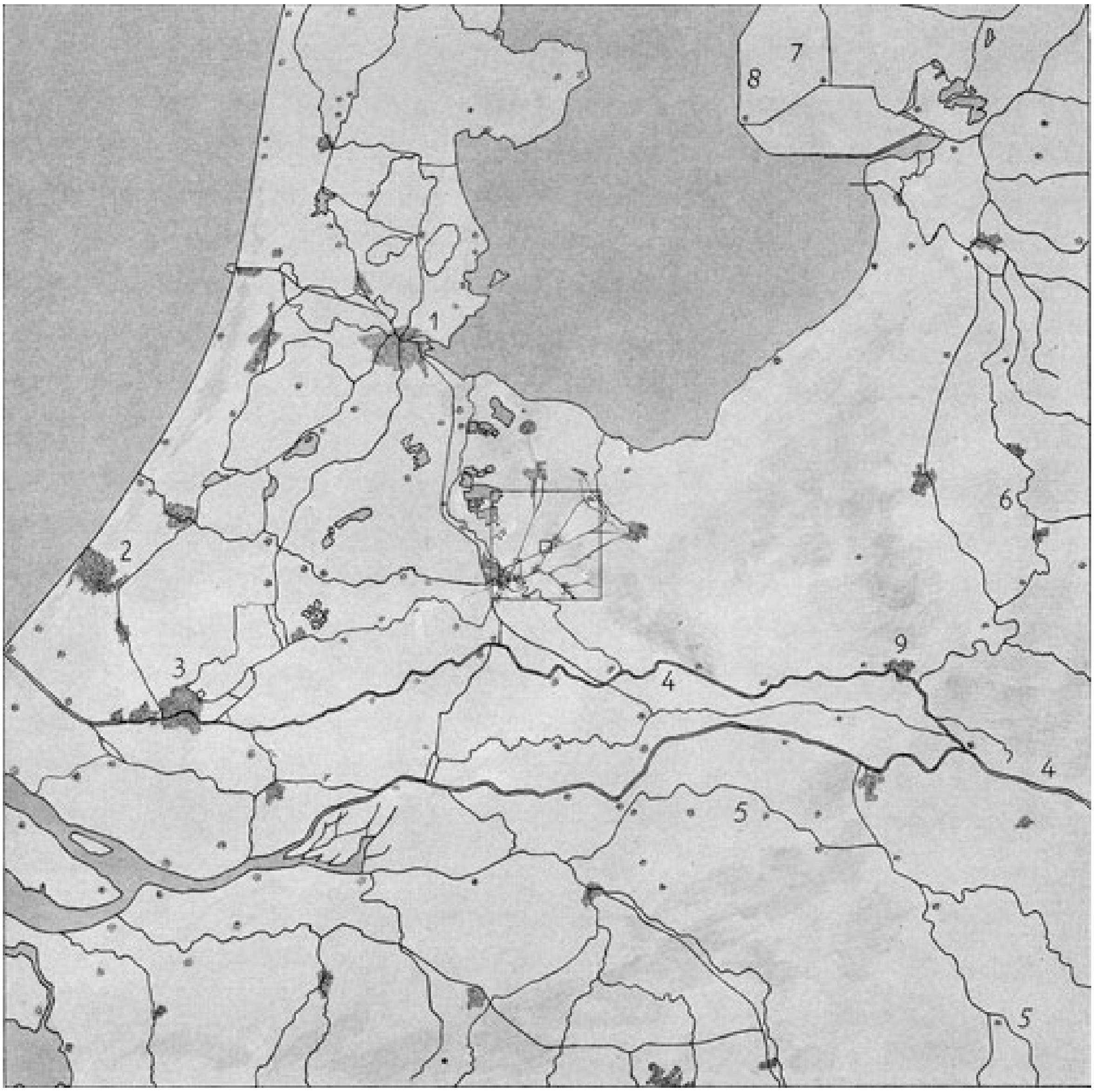
1 cm. in picture = 1,000 cm. = 10 m. Scale = 1:1000 = $1{:}10^3$

4 It is surprising that already in this fourth illustration the child, who filled the greater part of the first picture, has completely disappeared. The reason, as we said in the introduction, is that each time we jumped upward, we had to go ten times higher than we were, in order to produce an image at a scale one-tenth that of the one before. If we viewed the little girl from a height of, say, 5 meters in picture 1, we had of necessity risen to 50 meters to see 2, to 500 meters for 3, and now we look down from a height of 5000 meters. That is higher than Mont Blanc, Europe's highest mountain! No wonder that the huge whale can now hardly be distinguished. We notice a strange wavy line reaching the school building. We wonder what that is. The next drawing will show.

1 cm. in picture = 10,000 cm. = 10^4 cm. = 100 m. Scale = 1:10,000 = 1:10^4

5 We have now jumped to a height of 50,000 meters or 50 kilometers, that is more than 30 miles, and we notice a second effect of our jumps: not only are all lengths we see reduced tenfold each time, but the area which comes into our field of vision increases a hundredfold. So the above illustration covers a square 15 kilometers on a side, and we see Bilthoven (1) as a suburb of Utrecht (2). A dotted wavy line symbolizes a radio wave of 298 meters wave length reaching Bilthoven from the transmitter southwest of Utrecht, called "Hilversum" after the town (3) where its studios are. The 1.5-centimeter square in the middle gives again, as it has done each time, a reduced representation of the preceding illustration. As this illustration contains a photograph of a detailed plan of Bilthoven, it just shows the houses, though very minutely.

1 cm. in picture = 10^5 cm. = 1,000 m. = 1 km. Scale = 1:100,000 = 1:10^5

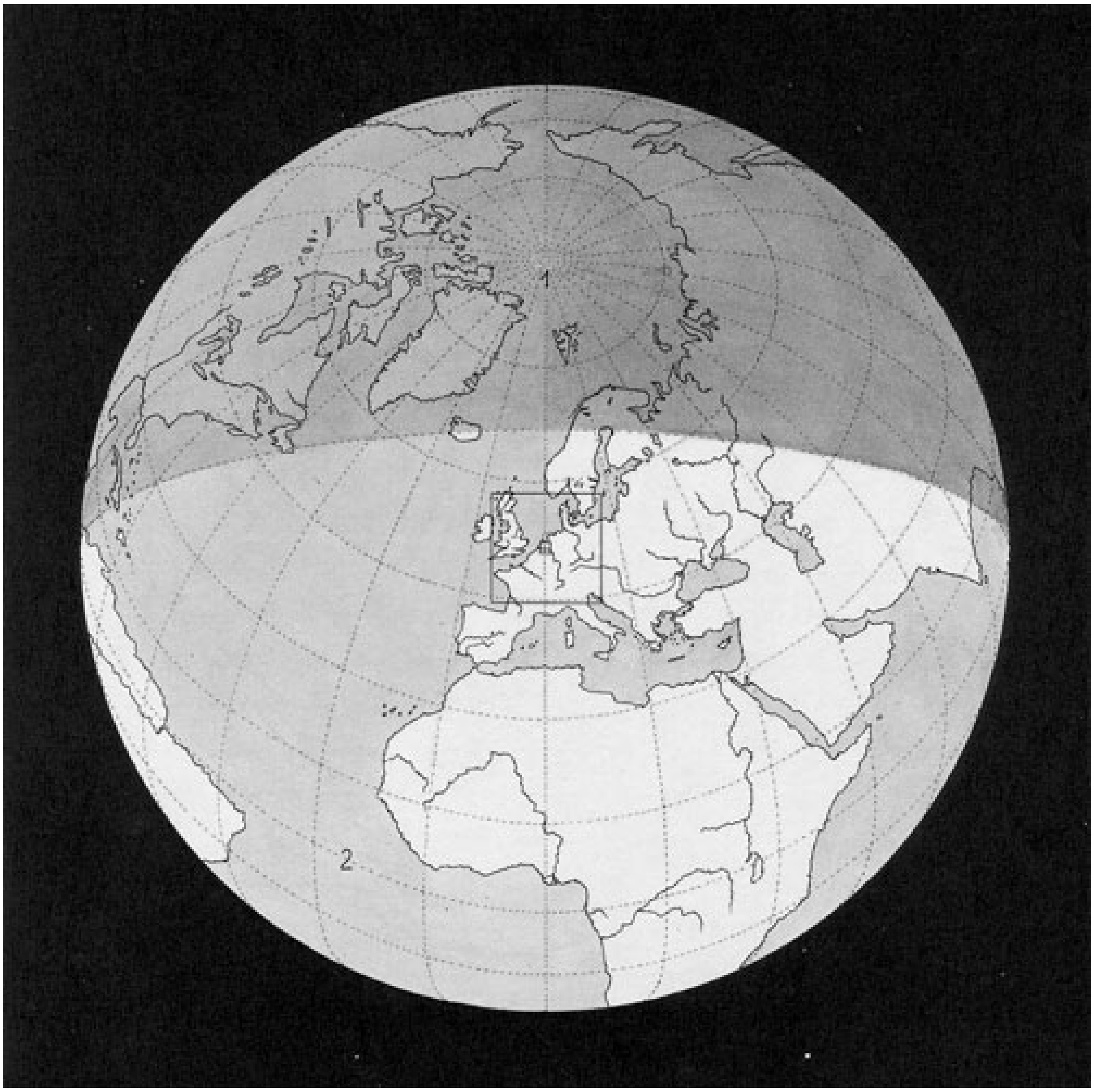


6 Here we see the central part of the Netherlands. The small square in the middle of course shows the town of Utrecht, and the tiny square inside is the twice-reduced picture of illustration 4. There is Bilthoven, and ... there is the little girl: we know she must be there, but we cannot see her! The drawing has now become like a geographical map of central Holland. We see the largest towns: Amsterdam (1), The Hague (2), Rotterdam (3), also the rivers Rhine (4) and Meuse (5). The bay in the North used to be the Zuyder Zee. It now has become a lake, the "Yssel Lake", named thus after the Yssel (6), the arm of the Rhine which flows into it. In the Yssel Lake new land (7) is being reclaimed by making dykes (8) and removing the water by pumping. In the lower right center the town of Arnheim (9) is shown.

1 cm. in picture = 10^6 cm. = 10 km. Scale = 1:1,000,000 = 1:10^6

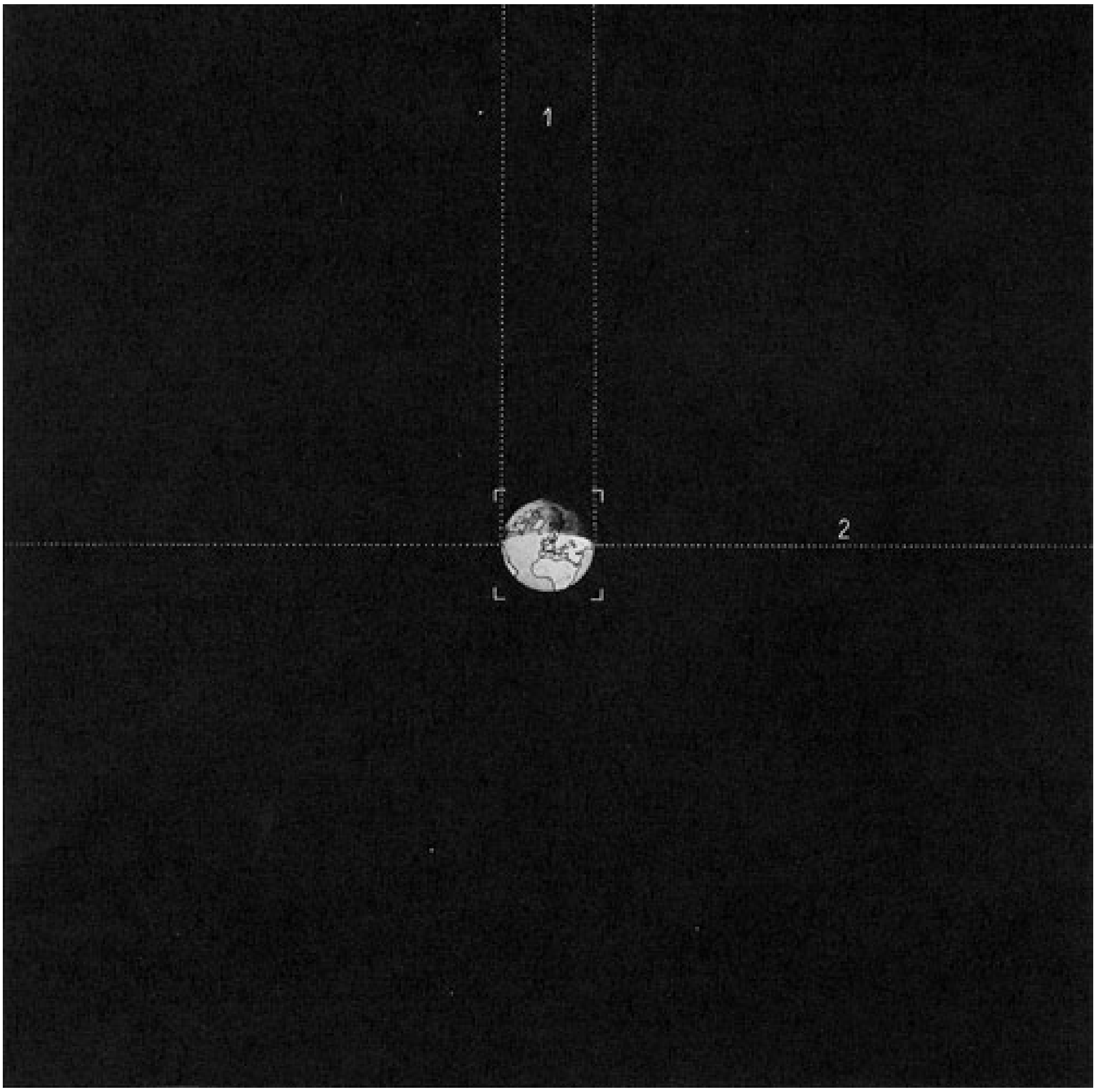
7 Whereas picture 5 gave us the villages of a local district, and 6 the towns of a country, this 7th drawing covers part of a continent - Western Europe - and shows a number of its countries. Actually 15 different countries are wholly or partly visible, as well as 10 of their capitals and a number of rivers, too many to mention by name. The map further shows three seas - the North Sea, the Baltic, and the Adriatic - and a portion of one of the oceans, the Atlantic. As a square 1500 kilometers on a side is covered, the spherical shape of the earth becomes visible; one of the parallels of latitude is drawn to demonstrate this, but the curvature is still so slight that the map can still be thought of as flat. It will need one more jump to reveal it as part of the surface of a sphere.

1 cm. in picture = 10^7 cm. = 100 km. Scale = 1:10,000,000 = 1:10^7



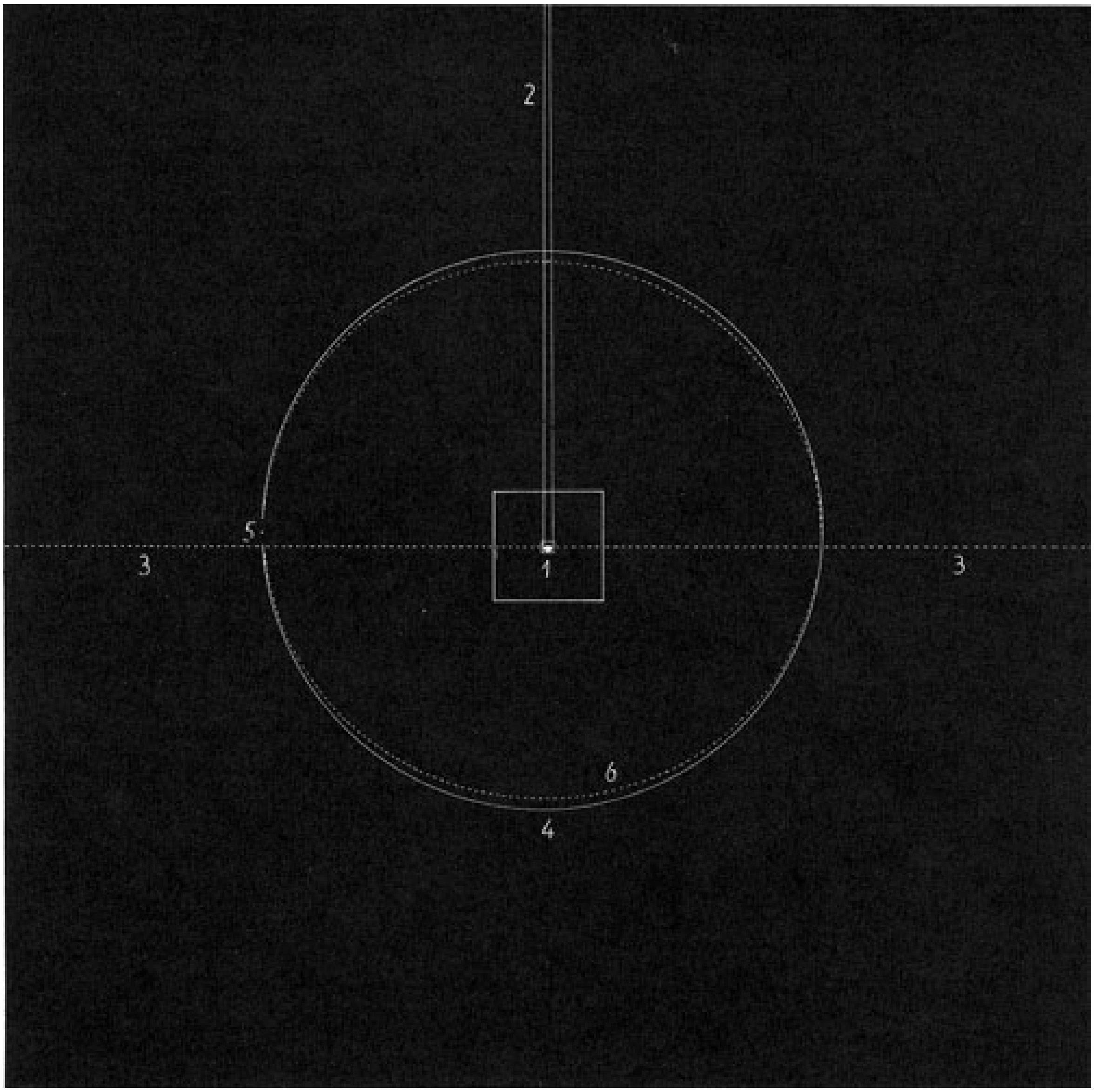
8 Until now we have been getting each time a wider view of our "world." We now see the whole of it as a limited dwelling place in the surrounding blackness of space. Whereas in the last picture we could see countries, we now can see five of the six continents: only Australia does not come into the picture. We notice that the northern part of the globe is in shadow; as the picture was taken on December 21st at noon, the sun was in the south, and daylight did not reach farther north than the Arctic Circle. This shaded part of the earth in reality would have been much darker. It has, however, been left a dark grey, in order to show the visible portions of North America and northeast Asia. The North Pole (1) and the equator (2), as well as the meridians and the parallels of latitude for every 15 degrees, are shown as dotted lines.

1 cm. in picture = 10^8 cm. = 1,000 km. Scale = 1:100,000,000 = $1:10^8$



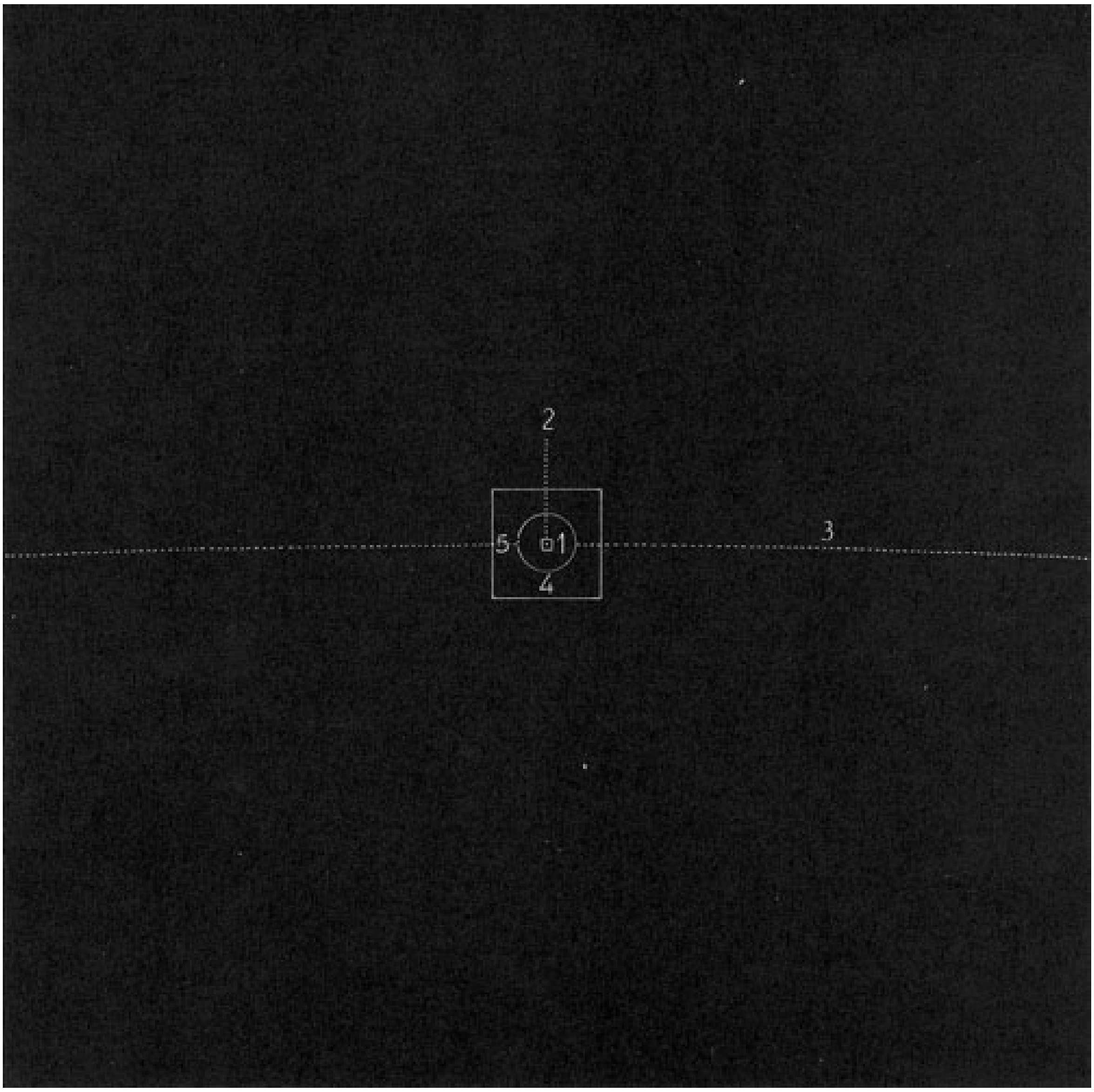
9 The earth, which reached nearly to the large square on the previous page, now fits into the small square. The distance we have had to travel straight up, to get its size thus reduced, is tremendous: according to our reckoning in drawings 4 and 5, we should be now 500,000 kilometers up, or about 312,500 miles - more than the distance to the moon. From here we see the earth as a planet spinning counterclockwise in the empty, dark, surrounding space. The sun, in the south, makes it shed its shadow toward the north. Two faint dotted lines mark the limits of this "umbra" (1). Another dotted line (2) gives the path along which the earth moves, from right to left. Many faraway stars would be visible, but these are left out in this drawing and others that follow, to concentrate attention on our "immediate surroundings".

1 cm. in picture = 10^9 cm. = 10,000 km. Scale = 1.1,000,000,000 = 1.10^9



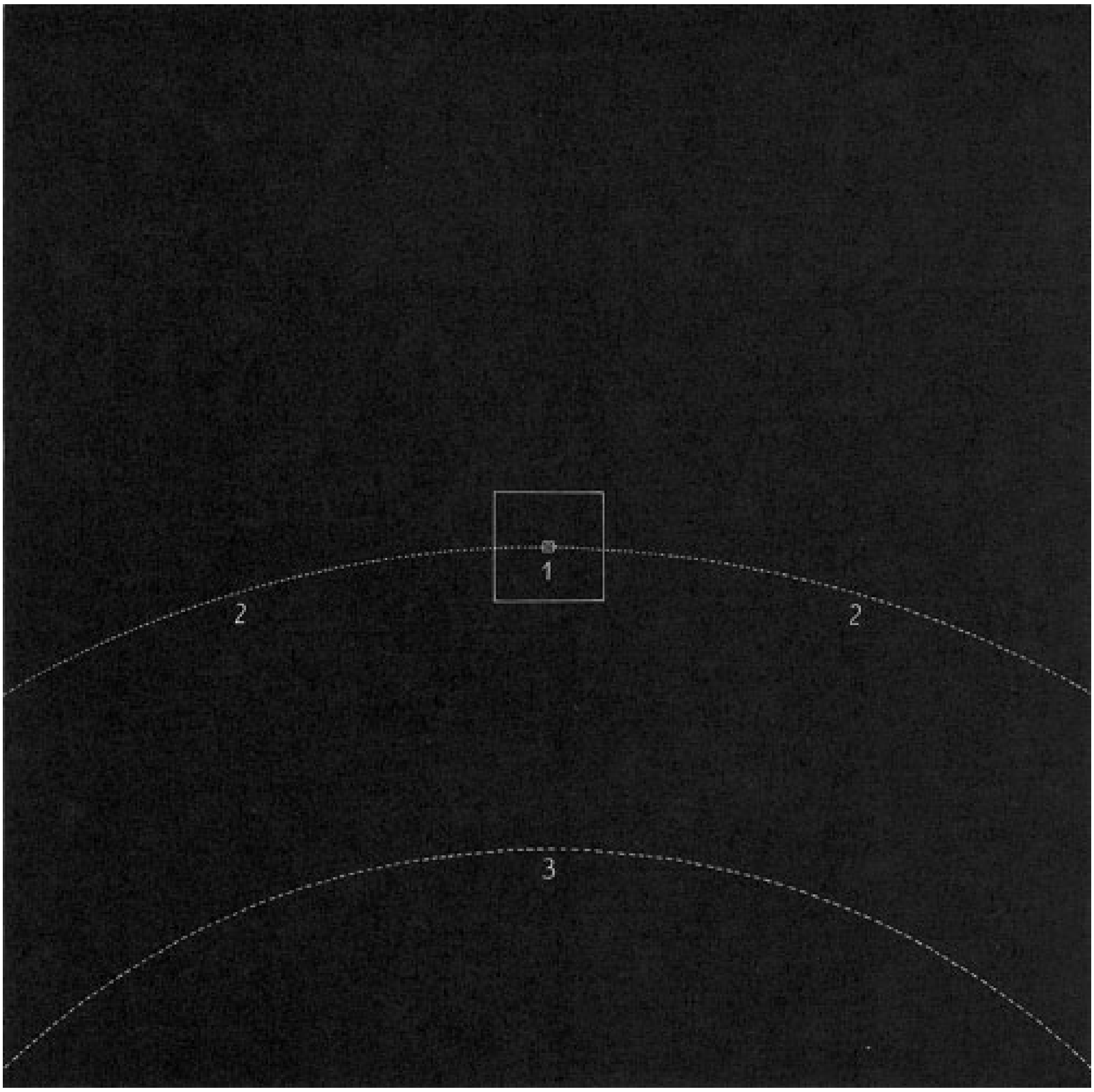
10 It must have struck the reader that in the last two illustrations the shaded part of the earth was not of even darkness, but was clearly lighter on the left hand side. The cause of this becomes clear in this picture. In it we not only see the earth (1), its umbra (2) and the path (3) along which it moves, but we notice around the earth what looks like a circle. This line (4) is the path or orbit of the moon as it moves around the earth. The actual position of the moon (5) on that December 21st when we were supposed to make our celestial jump of exploration is shown. It now is clear that as the moon was there on the left, the night on earth was lit up on that side. As light travels 300,000 kilometers per second (that is, 3 centimeters on this scale), we see that it would need 1.3 seconds to cover the distance from the moon to the earth.

1 cm. in picture = 10^{10} cm. = 100,000 km. Scale = 1:10,000,000,000 =1:10^{10}



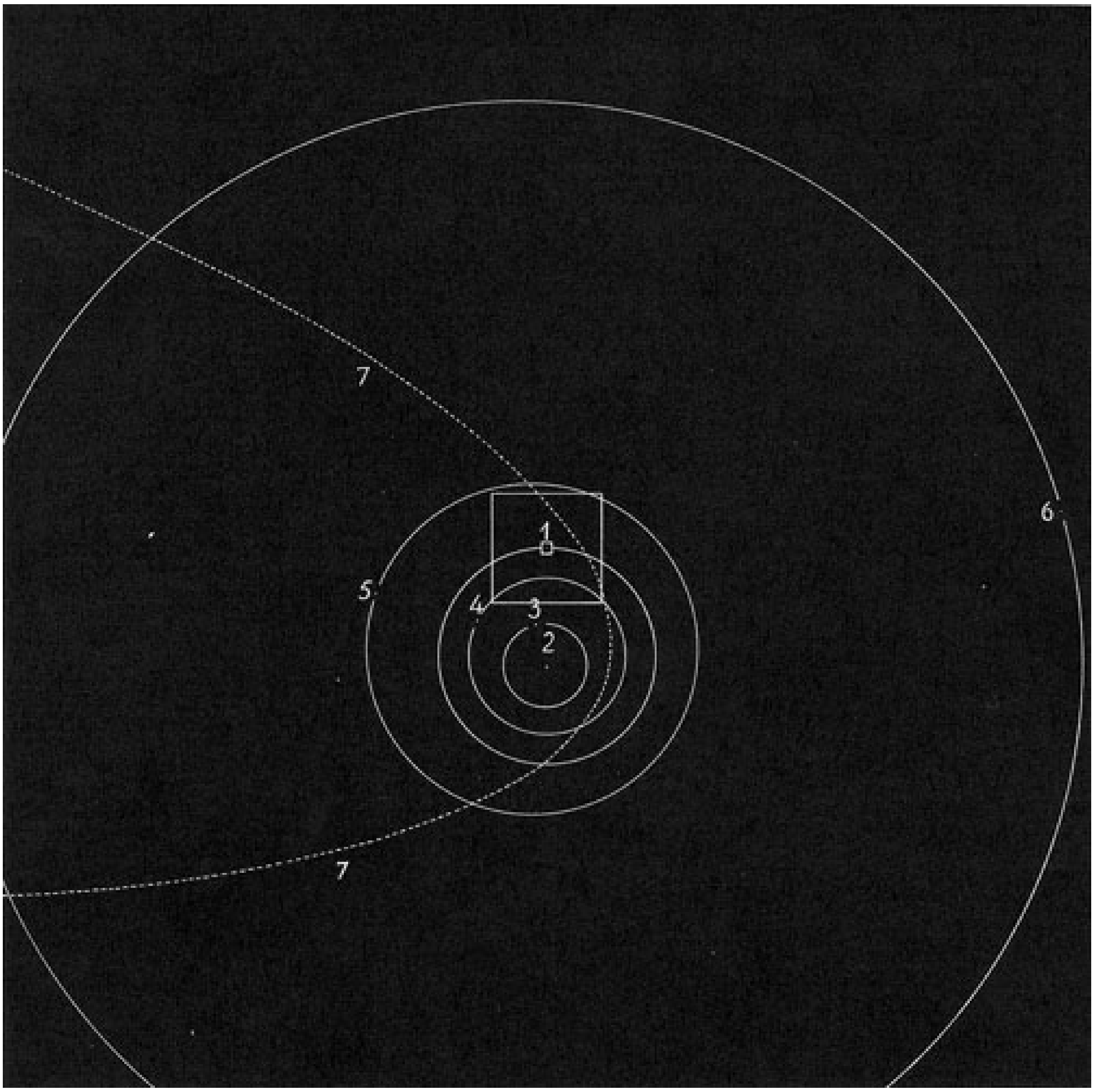
11 In the preceding drawing, the actual shape of the moon's orbit appears to be practically a circle. As a matter of fact, it is not exactly a circle, but the difference is so slight that it is only visible in the position of the earth, which is in one focus of the ellipse, and therefore not in the center. There actually would be a slight flattening of the circle, because we are perpendicular above the earth, and therefore not straight above the plane of the moon's orbit, which itself makes a small angle with the earth's. These factors have been taken into account in composing the curve (6), i.e., the orbit as it would really appear to us from above; but they are small even in 10 and in this drawing they are not noticeable. It shows the earth (1), the moon (5), and its orbit (4); the earth's umbra (2), and its orbit (3), which now can be seen to be very slightly curved.

1 cm. in picture = 10^{11} cm. = 1,000,000 km. Scale = 1:10^{11}



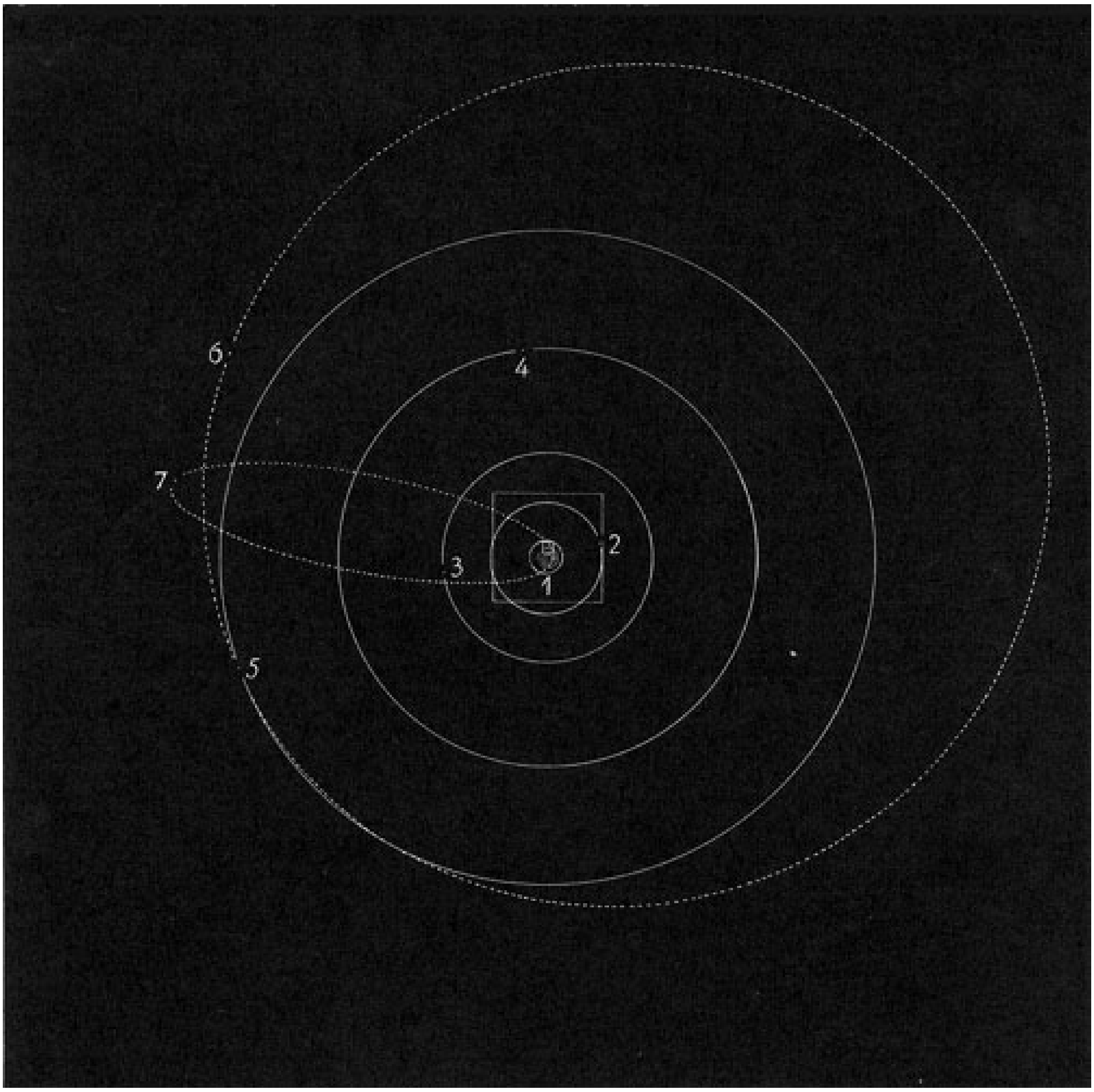
12 The tiny circle (1) in the center of the smallest square is now the moon's orbit. The earth's position is marked by a dot, although the dot is much too large and actually the earth would be invisible on this scale. Its orbit (2) is now clearly curved. Under the earth's orbit another curve (3) is drawn. That is the orbit of the planet Venus, which moves around the sun as the earth does and in the same direction: in this drawing, from right to left. The size of the sun, if it were drawn at this scale, would be 1.4 millimeters. We will repeat here that the black area of the above square would in reality be studded with a multitude of stars. We leave them out in this drawing and in the following drawings for the reason stated earlier.

1 cm. in picture = 10^{12} cm. = 10,000,000 km. Scale = 1:10^{12}



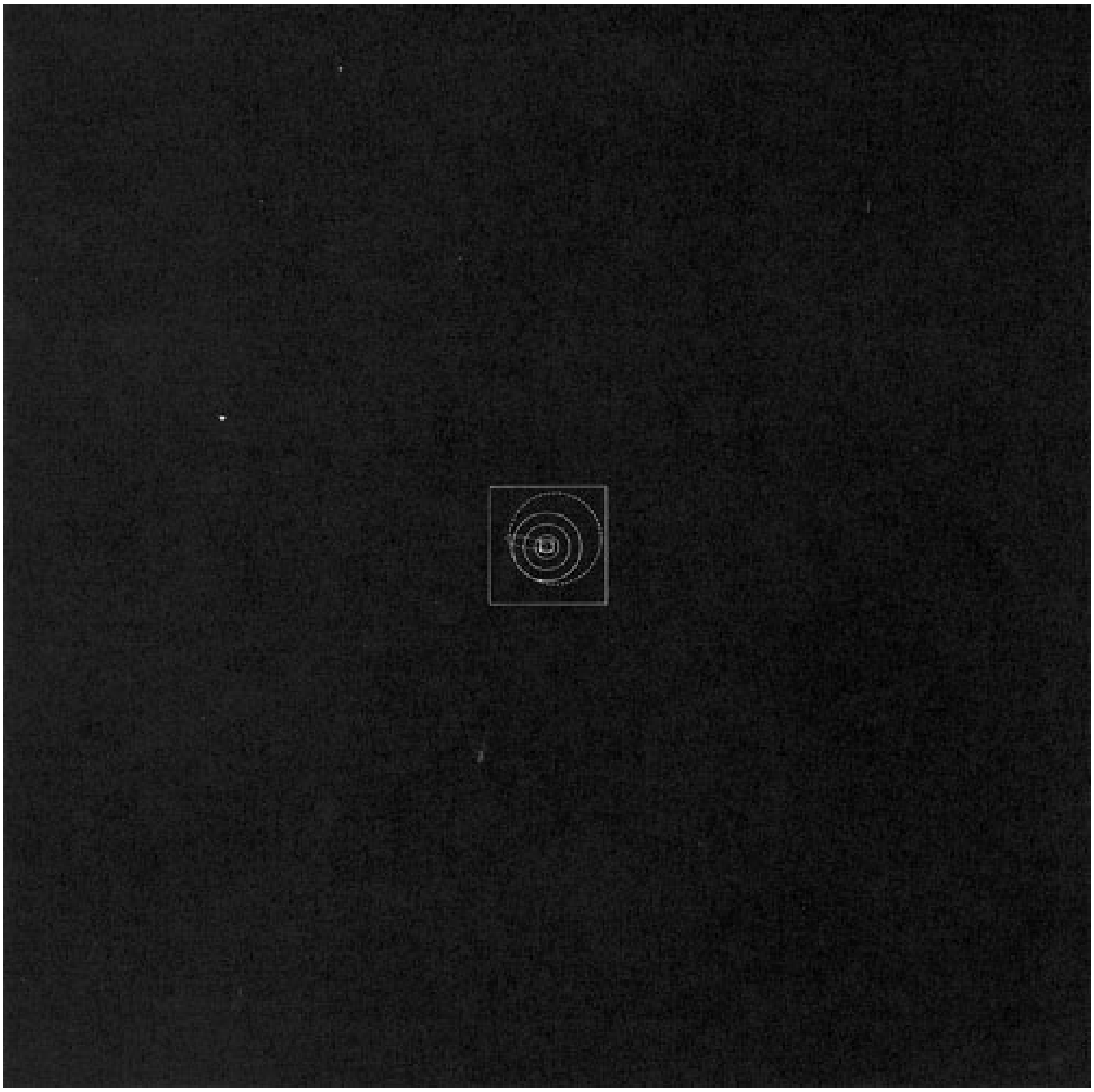
13 The sun (2) has now come into the picture. It is 1.5 centimeters away from the earth (1). The size of the earth has shrunk to 1.3 micron and even the sun's size should be only 140 microns. The dots denoting them are therefore much too big, for a micron is only a thousandth of a millimeter! Inside the earth's orbit we see the planets Mercury (3) and Venus (4). Outside it are Mars (5) and Jupiter (6) with their orbits. The positions of the planets (just as that of the moon in 10) in this and following drawings are those which they occupied when we undertook our miraculous and timeless journey through space. We will now state more precisely when this was: It was December 21st of the year 1951. In addition to the sun and the planets we see part of the orbit of Halley's comet (7), which comes into our "neighborhood" once every 77 years.

1 cm. in picture = 10^{13} cm. = 100 million km. Scale = 1:10^{13}



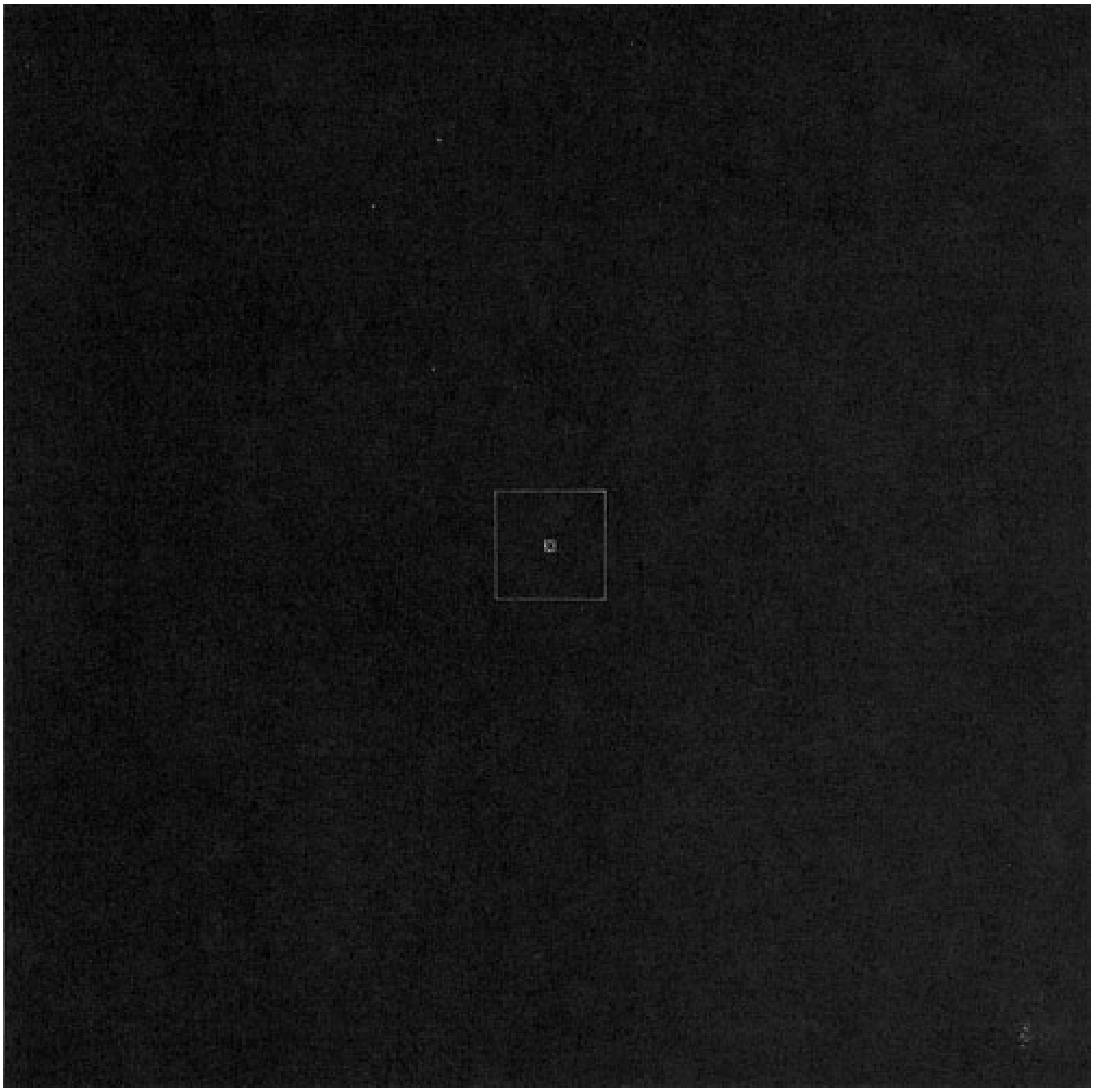
14 The whole solar system is now in view. The sun and the planets nearest it - Mercury, Venus, Earth, Mars - have together been reduced to a tiny circle (1), but the other planets and their wider orbits are clearly seen; Jupiter (2), Saturn (3), Uranus (4), Neptune (5), and Pluto (6). The latter's orbit at one place comes inside Neptune's. The whole orbit of Halley's Comet is here; also its position in 1951 (7). It will be near the earth again in 1986. The elliptic nature of the planets' orbits has been taken into account. In most cases, however, this again means only that the sun is not in the center of an orbit, for the difference of its shape from the circle cannot be seen in any of them except Pluto's. The inclination of the orbits to the plane of the horizon of Bilthoven has been neglected. Light would on this scale travel about 1 centimeter per hour.

1 cm. in picture = 10^{14} cm. = 1,000,000,000 km. Scale = 1:10^{14}



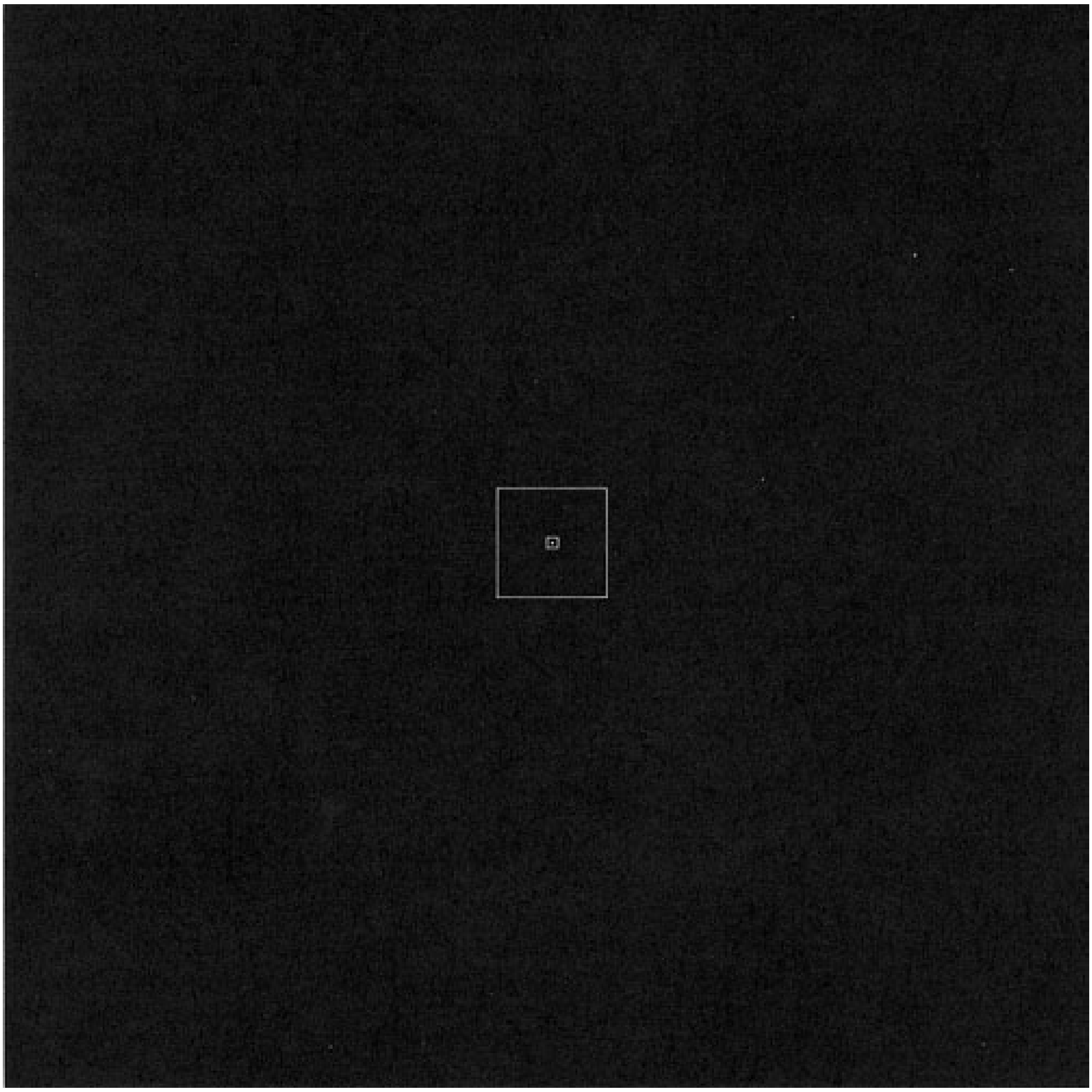
15 In this drawing the whole solar system, that is, the sun with all the smaller bodies which move around it, has been reduced to the space of a circle a little over 1 centimeter in diameter. Apart from the planets and Halley's Comet, which were shown in 13 and 14, there are a number of very small bodies, which we leave out because they are too small to be seen from such distances. These pictures really give a wrong impression of what the solar system would look like, for all the orbits are shown. What would be seen would be only the sun as a small star (it would at this distance seem only about 100 times as bright as Venus looks from the earth) and near it the planets, which themselves give no light but are merely lit up by the sun on the sides turned toward it. Light takes nearly 11 hours to travel across the solar system.

1 cm. in picture = 10^{15} cm. = 10,000,000,000 km. Scale = $1:10^{15}$



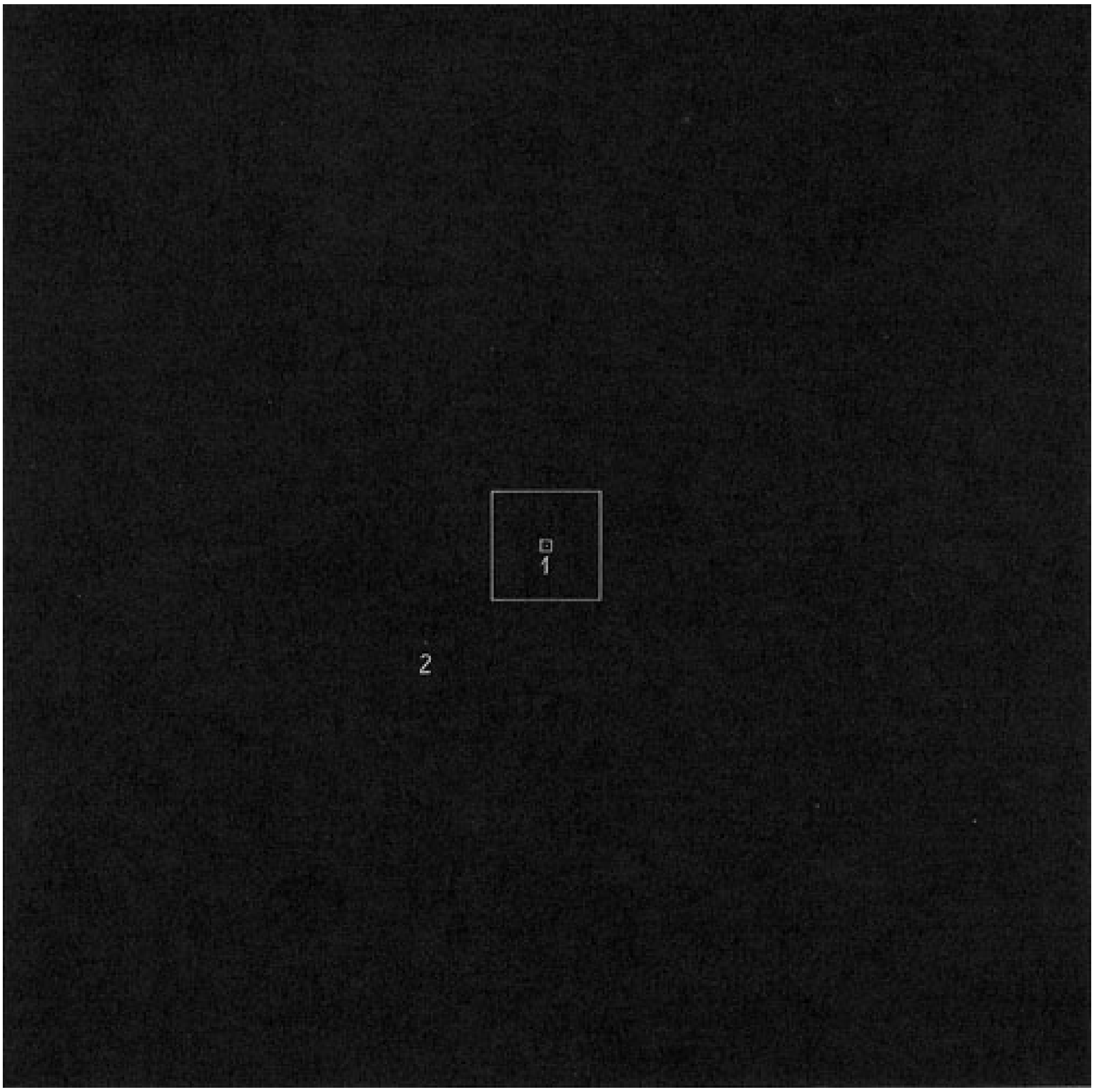
16 The tiny circle inside the smallest square now contains the whole field in which the vicissitudes of the solar system take place. If we continue the reckoning we used in drawings 4, 5, and 9, we should be now at a height of 5 million million kilometers above the horizon of that village in Holland from where we started. As we have imagined all along that we are making our trip without spending time, this means that it would have taken the light rays which we now see more than six months to cover the enormous distance from the earth, even though they travel at the rate of 299,800 kilometers per second! It also means that if we had a marvellously good telescope and could see details of events on earth, the events we watched would be those that happened more than six months ago!

1 cm. in picture = 10^{16} cm. = 100,000,000,000 km. Scale = 1:10^{16}



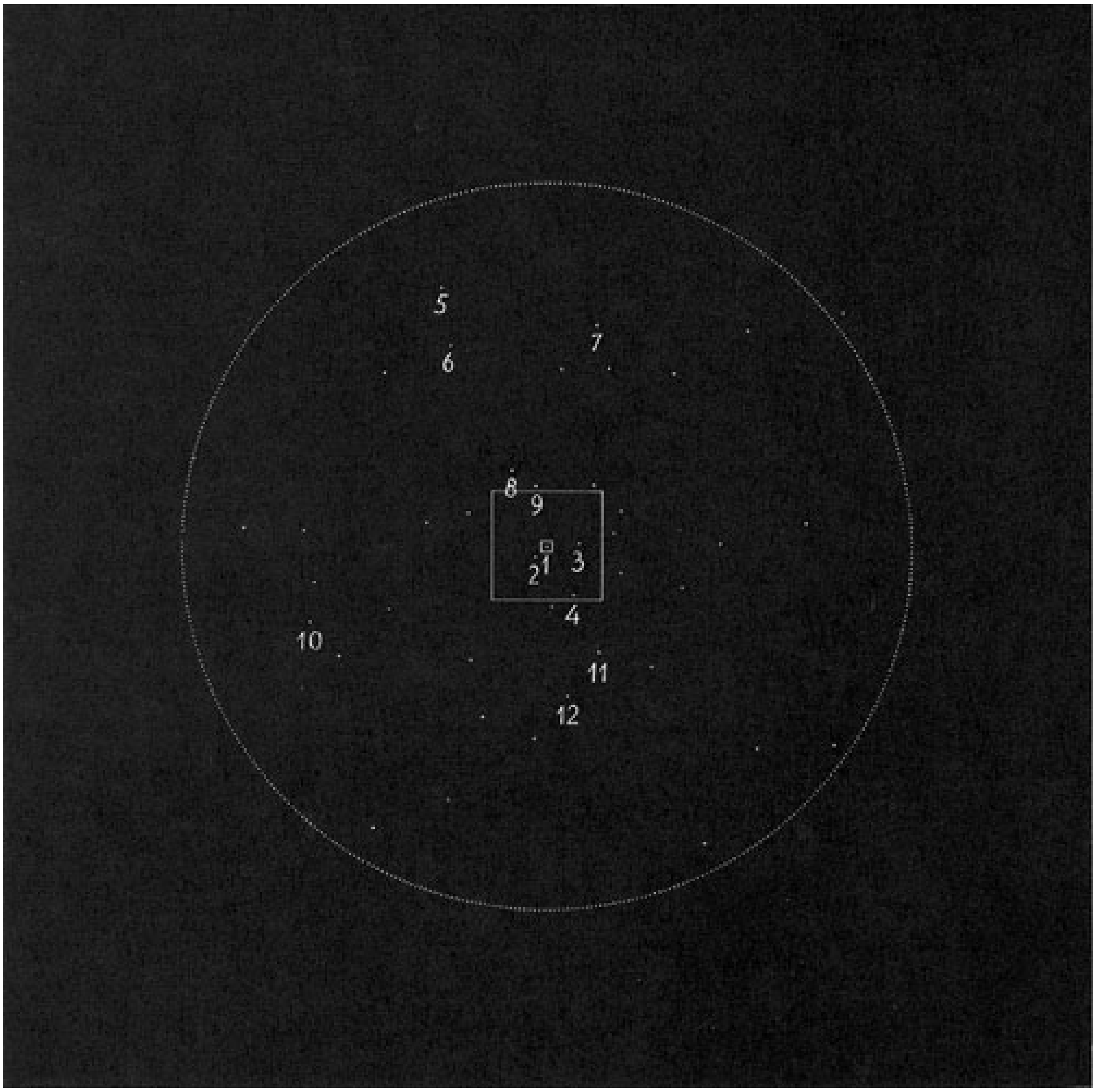
17 This seems a very uninteresting picture: it contains no more than one tiny white spot in the center of a black square! That spot, however, stands for the whole solar system, which on this scale would be only little more than 0.1 millimeter in diameter. In reality this illustration therefore is a very interesting one, because we now know and understand that that little speck of light contains not only the sun, but with it, all the planets, comets, asteroids, and meteorites which move around it ... and their orbits! And we now realize that it is quite possible that numberless other stars that we see at night may have such satellites moving around them. All other stars that could be seen besides our sun are still left out, as our aim is primarily to show our own "immediate surroundings." Light, on this scale, would travel 9.46 centimeters, or about 4 inches, in a year.

1 cm. in picture = 10^{17} cm. 1 light-year = 9.46 cm. Scale = 1:10^{17}



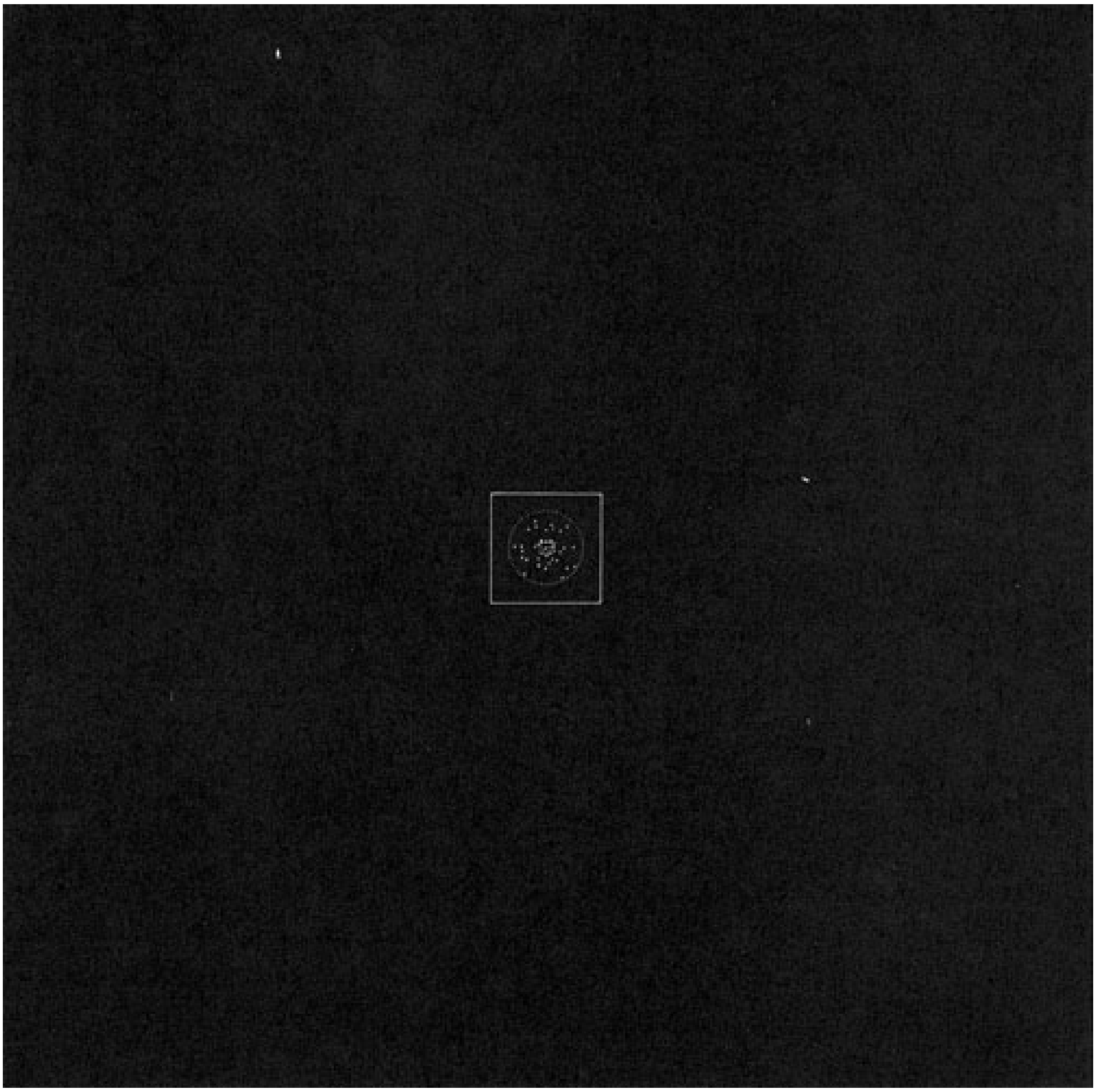
18 For the first time we now show just one star besides the sun; there is no longer fear of confusion, as the whole solar system has been reduced to a point (1). The star marked (2) is the double star called Alpha in the constellation Centaurus. This star, Alpha Centauri, is the star nearest to the earth, if we do not reckon the very faint Proxima Centauri, which may be slightly nearer. Its distance from the earth is about 4 light years, which means that light needs about 4 years to cover that distance. On the scale of this drawing, 1 light year would be 0.946 centimeters, that is, about 1 centimeter. Alpha Centauri is therefore at a distance of about 4 centimeters from the sun. In the drawing it seems nearer. The explanation of this seeming discrepancy is that Alpha Centauri is farther away than the sun from our faraway point of observation.

1 cm. in picture = 10^{18} cm. = about 1 light-year. Scale = 1:10^{18}



19 Every time, the jump we make to our next point of observation gets more inconceivably large. From the present one we could no longer see the sun with the naked eye, for without the help of a telescope a star such as the sun is barely visible at a distance of 55 light years, and our point of observation would now be at a distance of 500 light years. It is not surprising that the sun could no longer be seen with the naked eye from that distance, as its size at the scale of this drawing would only be 0.00014 micron, or about the size of an atom! Apart from the sun and Alpha Centauri, 36 stars are shown all of which are known to be at less than 50 light years distance from the sun. They are all where they would seem to be if we looked down on them on December 21st, 1951, at noon. A circle marks the distance of 50 light years from the sun.

1 cm. in picture = 10^{19} cm. = about 10 light-years. Scale = 1.10^{19}

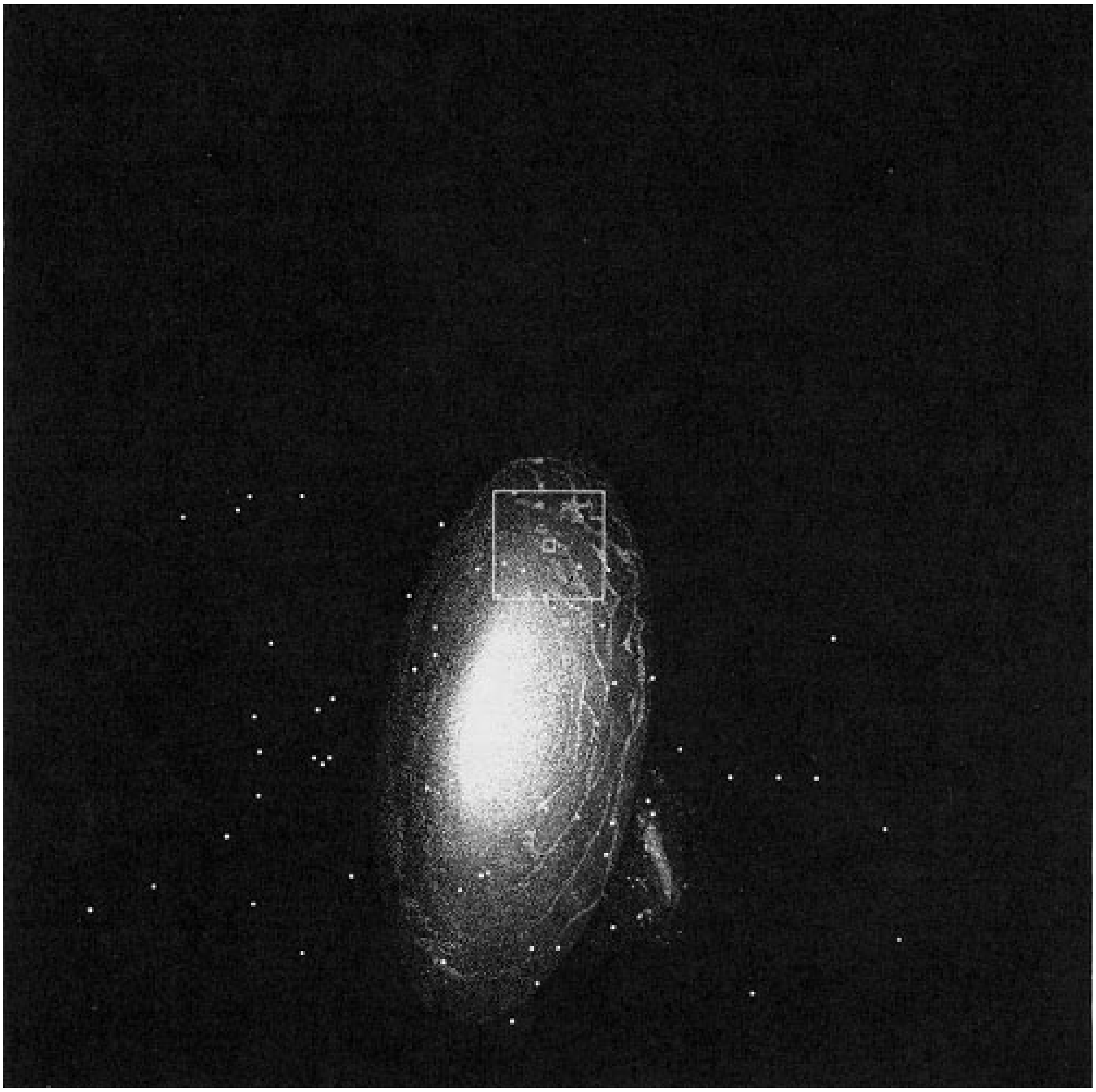


20 This little group of stars is of course the same as the one on 19, but seen from ten times farther away. We could give for all of them the names by which the astronomers know them, but we mention only 12 of the best known, putting numbers under the corresponding stars in 19, as there is room for them there. First the sun (1); then Alpha Centauri (2), Beta Hydri (3), Delta Pavloni (4), Castor (5), Pollux (6), Capella (7), Procyon (8), Sirius (9), Arcturus (10), Altair (11) and Vega (12). No attempt has been made to indicate the relative brightness of the stars shown, for it would be very different as seen from our present faraway point of observation from what it appears to be from the earth.

1 cm. in picture = 10^{20} cm. = about 100 light-years. Scale = $1:10^{20}$

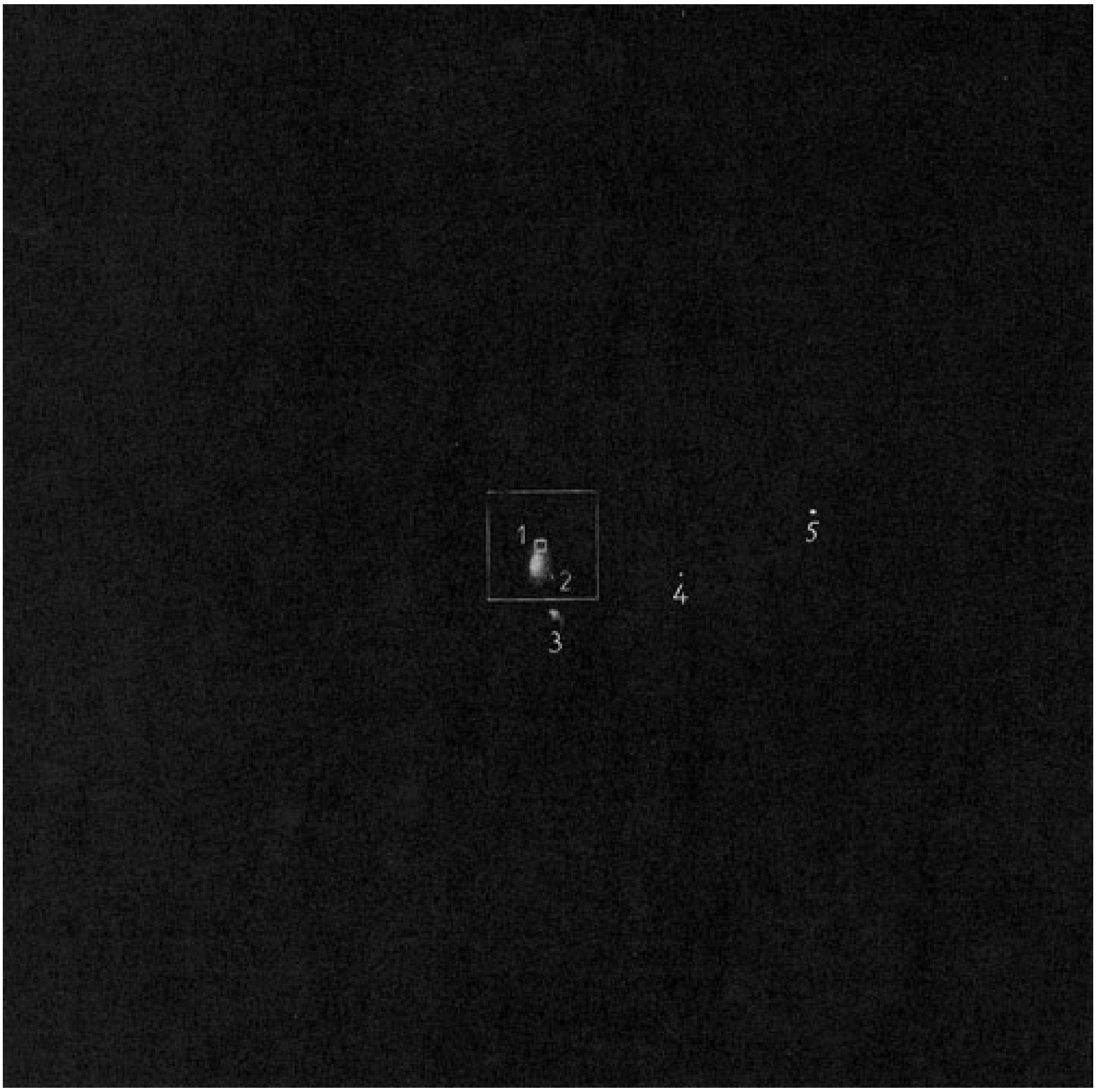
21 We have now jumped so high that we have come out of the complex of stars to which our solar system belongs, and which we can see on a clear starlit night the galactic system and contains many thousand millions of stars. The sun is only a faintly lighted strip right across the sky: the Milky Way. It is usually called the galactic system and contains many thousand millions of stars. The sun is only a very unimportant one of these, and it is situated not in the center but in the outskirts, which we see in the above drawing. In the tiny square we notice that the sun and its 37 neighbor stars, which in 20 filled the small square, have now become but one dot. The other stars are huddled together in irregularly formed groupings, in which we can hardly discover any clear shape or line. We shall need to make another jump to discover the general form of the galaxy and of the formation of stars nearest to the sun.

1 cm. in picture = 10^{21} cm. = about 1,000 light-years. Scale = 1:10^{21}



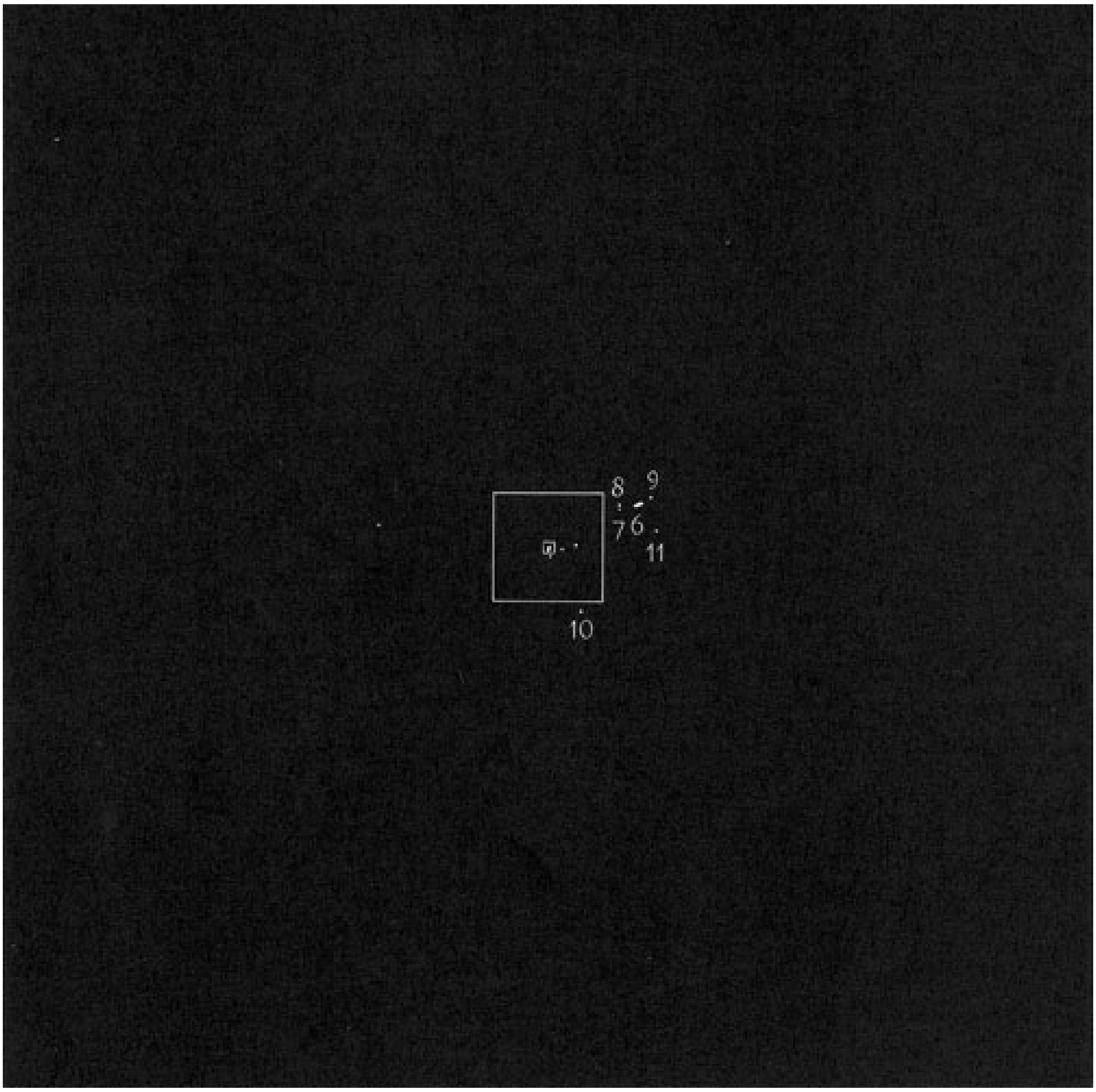
22 Here we have the entire galactic system or galaxy, of which on the previous page we saw only what is now in the small square. Our galaxy is a spiral; it has the shape of a disk from which a number of spiral arms protrude. At the center the disk is much thicker than at the edges, where it is quite thin; the bright shining center bulges out. We see this circular disk partly tilted from the side, so that it looks like an ellipse. In the small square we now recognize in the streak of light a rather irregular spiral arm near which our solar system is situated. Apart from this one, other spiral arms can be seen. Below on the right there is a strange nebulous body. It is the Great Magellanic Cloud, a much smaller galaxy, far behind our own Milky Way. The white spots around the galaxy are the hundred and more globular clusters of stars which surround it.

1 cm. in picture = 10^{22} cm. = about 10,000 light-years. Scale = 1:10^{22}



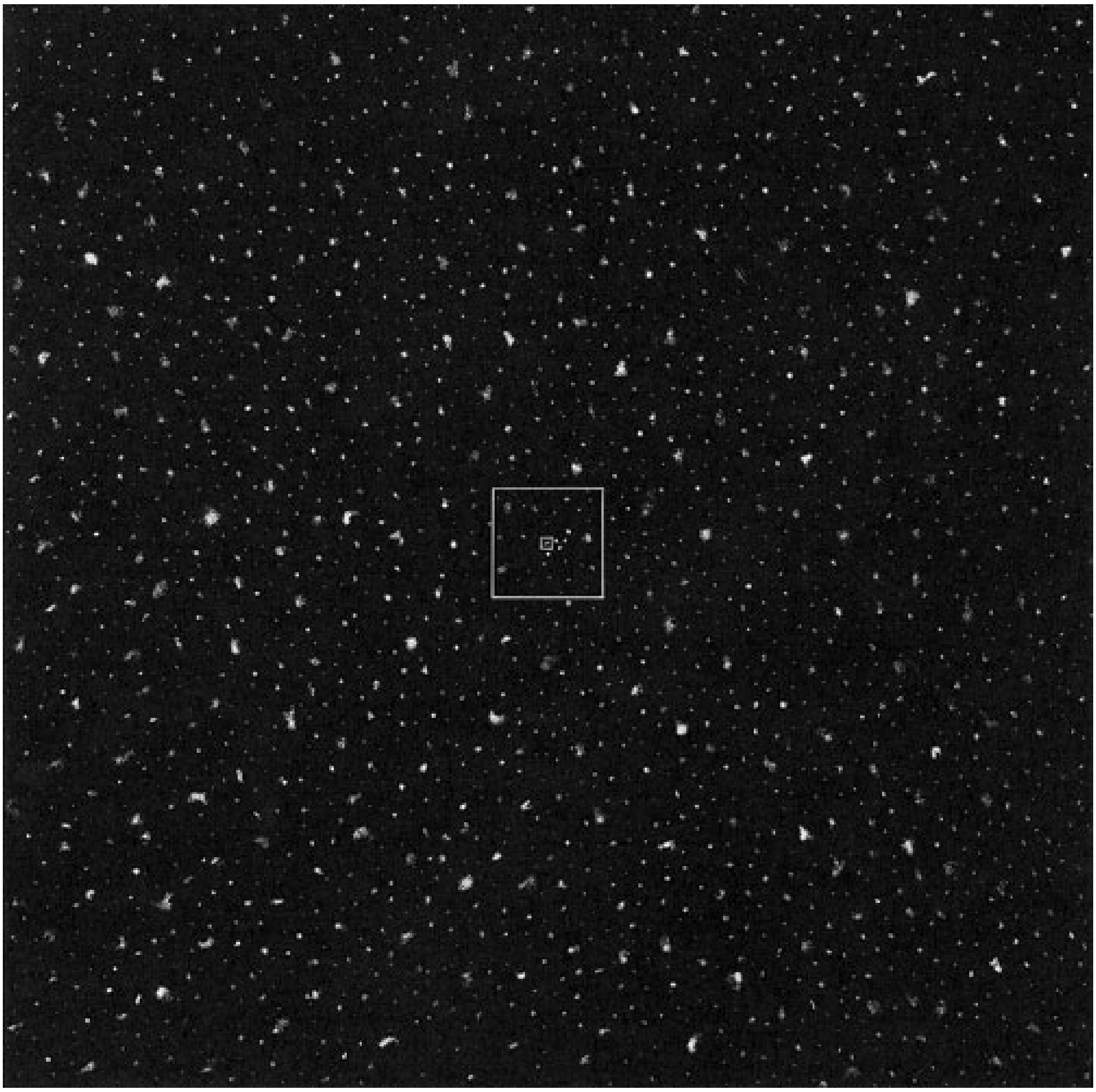
23 However large the object is, the next jump reduces it to one tenth its size. So here we find our galaxy again, but as an ellipse (1) barely 8 millimeters in length, and inside the small square. The Great Magellanic Cloud (2) is again partly visible, but it lies far behind it. The Small Magellanic Cloud (3) can now be seen, and also two more of the galaxies which are relatively near our Milky Way. They are the Sculptor (4) and the Fornax (5) systems. No other galaxies are drawn, although many further away would be visible, for again we want to concentrate attention on "our own world" and its "nearest neighbors". We must think of our galaxy whirling around, clockwise, only once in 200 million years. And yet this movement gives to our solar system, because it is so close to the edge of the disk, the terrific speed of 216 kilometers per second!

1 cm. in picture = 10^{23} cm. = about 100,000 light-years. Scale = $1:10^{23}$



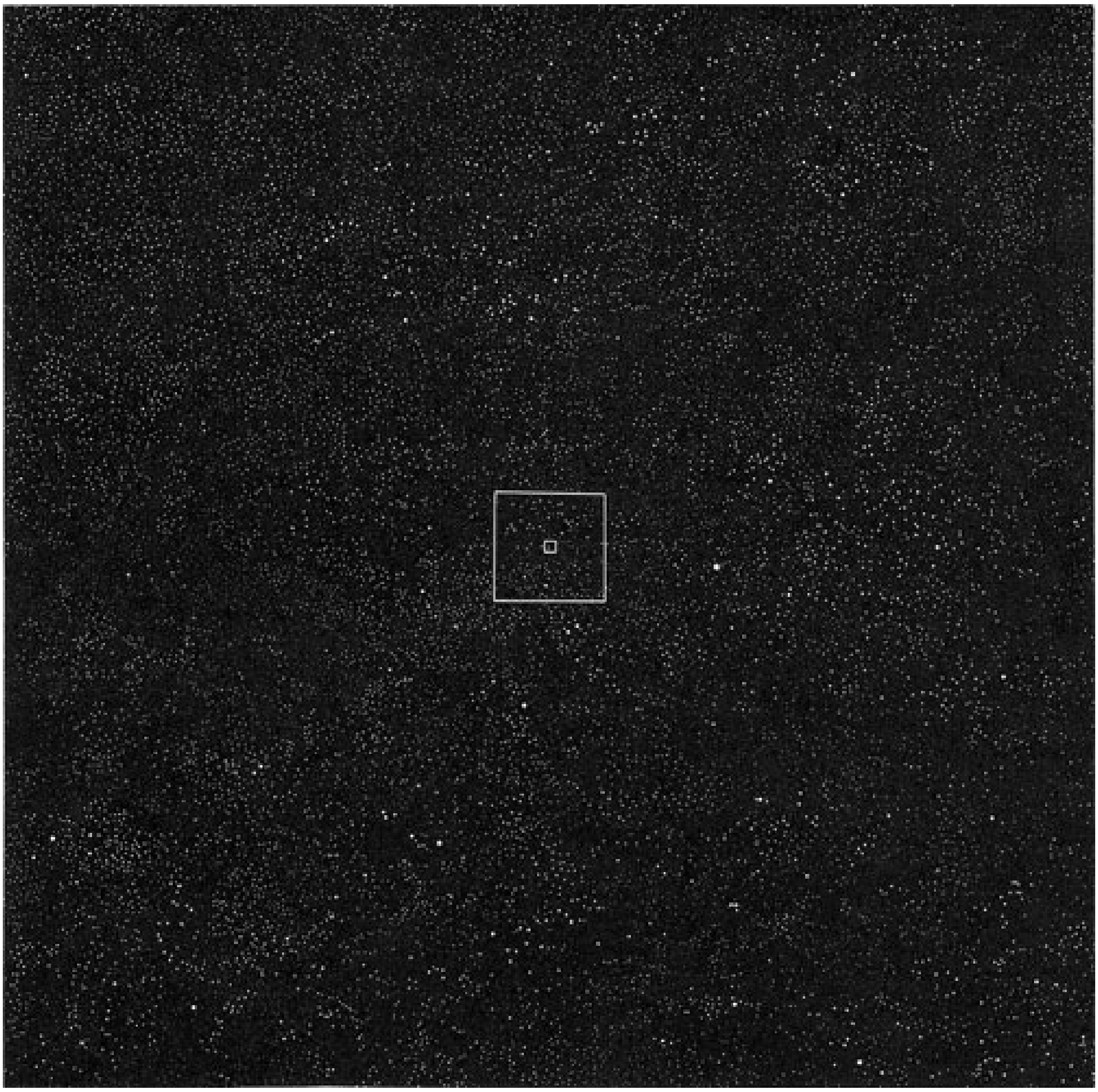
24 In this illustration we show only what astronomers call our local group of galaxies, leaving out all others. There is a general tendency of galaxies to gather in groups, some not numerous, others several hundred or even a thousand strong. How many must be reckoned to belong to our local group it is not possible to say; at these stupendous distances, it is no longer possible to obtain very precise data. It is certain that our local group includes the galaxies numbered 1, 2, and 3 in the previous drawing, and also, in the above illustration, the great spiral in Andromeda called Messier 31 (6) with its companions NGC 147 (7) and NGC 185 (8) and the spiral system Messier 33 in the constellation Triangulum (9). Other galaxies which are usually considered to belong are those numbered 4 and 5 on the previous page and the systems NGC 6822 (10) and IC 1613 (11).

1 cm. in picture = 10^{24} cm. = about 1 million light-years. Scale = $1{:}10^{24}$



25 Now that our whole local group of galaxies has shrunk to the size of less than 2 millimeters in the center of the small square, we have in the above drawing indicated some of the countless other galaxies and clusters of galaxies which are spread out in all directions. Their distribution is known to be fairly uniform. Naturally the above drawing does not try to be an exact representation. In the two previous ones the galaxies shown were actually placed in the positions they would be in, with reference to our galaxy, if we could look at them from our imaginary point of observation above that place on earth and on that moment when we undertook our fantastic flight. Now, however, all we can do is to sketch a large number of galaxies and groups of galaxies of different sizes and to make their average distance the kind of dimension it is known to be.

1 cm. in picture = 10^{25} cm. about 10 million light-years. Scale = 1:10^{25}



26 In this last picture of the series at reduced scales, we naturally find that all galaxies and groups of galaxies, even the largest of them, are reduced to dots of various sizes. It goes without saying that the placing of them has been of necessity quite arbitrary. The object is merely to give a very faint idea of the inconceivably large number of galaxies in the midst of which our Milky Way is placed. The number of galaxies which are visible with our present telescopes is of the nature of a thousand million. The farthest of these would be at a distance from the earth of 2,000 million light years, that is, something like the length of a diagonal of the large square above. What is drawn here is therefore certainly less than what exists. For the galaxies would be much nearer to each other than the picture shows, and they would continue far beyond its confines …

1 cm. in picture = 10^{26} cm. = about 100 million light-years. Scale = 10^{26}

On this page there might have been put a drawing 27 to continue the series, representing what would be seen if we could take up a point of observation 10 times farther away and thus reduce the lengths of 26 to one tenth. But we have not attempted it for more reasons than one. To begin with, it would be quite impossible to draw the galaxies and clusters of galaxies small enough and near enough to each other. But also, the limits of what is supposed to be the curved space of our universe would be within that 27th square, and there would be no possibility at all of portraying or even visualizing the "curvature of space," which would be the determining factor there.

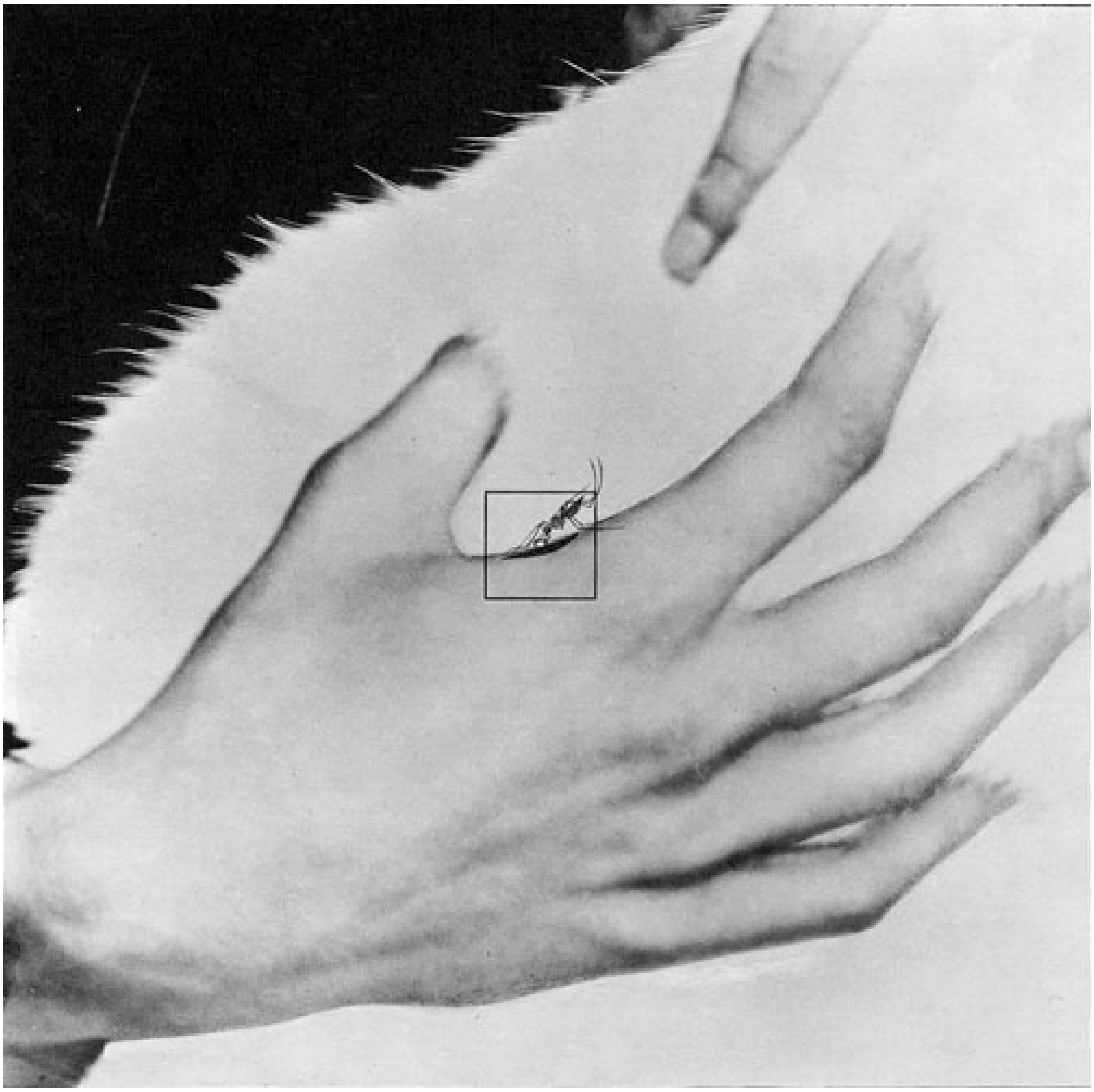
How far the countless millions of universes would continue in this picture 27, if we attempted to draw it, is not known. All these worlds seem to be rushing away from a center somewhere, and therefore from each other, and their speeds seem to increase the farther they have proceeded on their ways.

As all this is still so vague and uncertain, we end our imaginary journey into these infinite expanses of space and turn back, to go through all the stages we passed on our flight upward. We would advise you, reader, to concentrate your thought on this return journey. Try to picture how what you see in front of you would extend and extend as you came down ..., how the small central square would grow, until it was the size of the large square on the previous page; how the small square on that page would in its turn extend as you dropped down and down ... It is clear that on this return journey the height from which we view the panorama each time decreases tenfold from station to station. When we have returned to the original picture of the little girl in her chair, which we reproduce again on the right, the height of our point of observation has once more become only 5 meters, and when we go on in the same way to the next picture, it will be one tenth of this, that is, only 50 centimeters.

We shall find, when we continue our exploration in the same way, that on this leg of our journey we can go through only half the number of stages that we passed on the first: we shall reach the unknown already after 13 of them, whereas in the journey up we counted just twice that number, 26. But who will say what wonders are hidden beyond the limits of man's investigations of today?

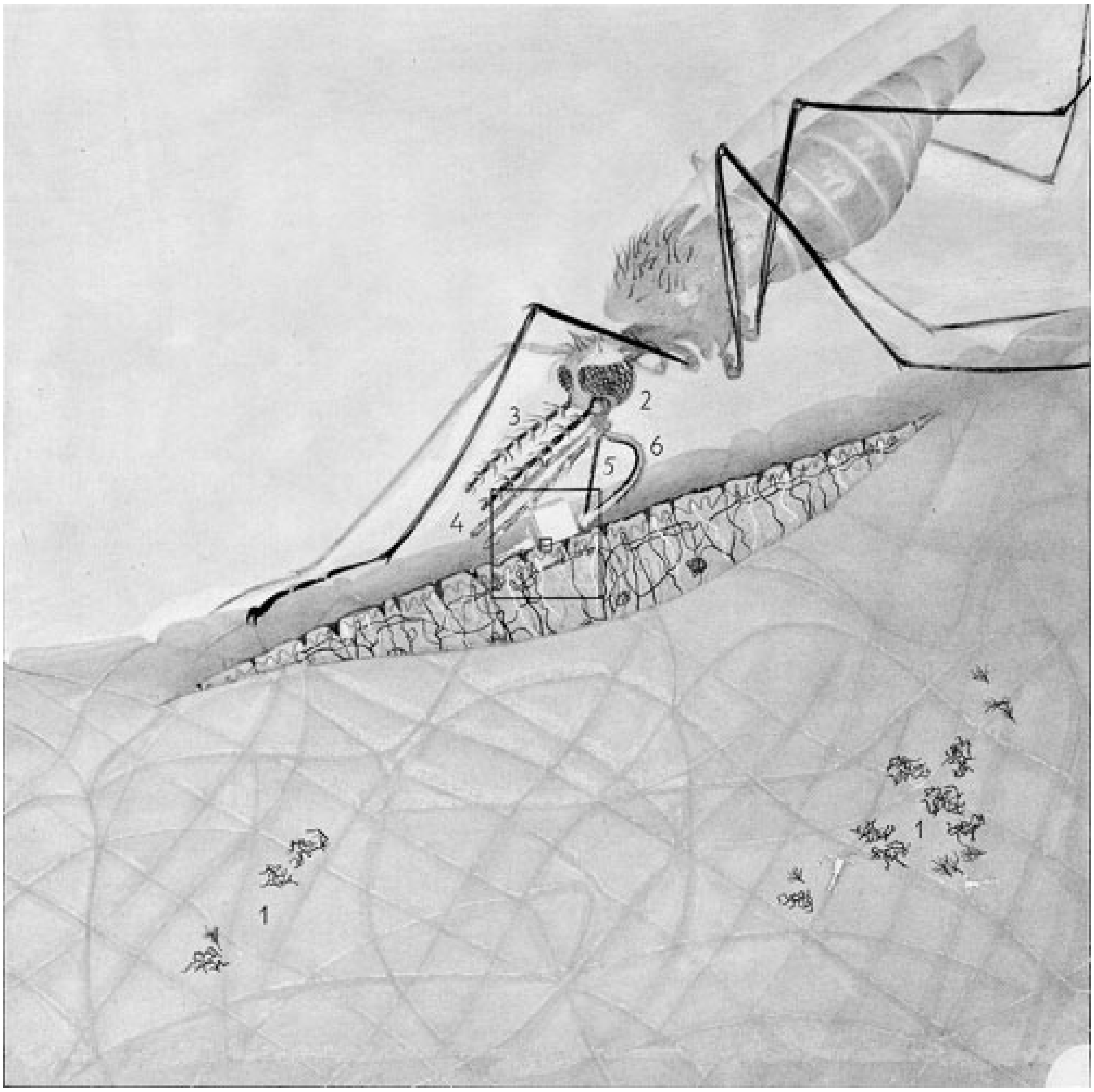
1 We said before that the reason why we took as the initial picture this little girl with her cat was that we wanted to find out in how many of the total number of domains of scale living creatures are known to occur. We have found them so far only in pictures 1, 2, and 3. Now we shall continue to look for representatives of the living world in all succeeding scales. Rather strange coincidences will occur in the following pictures: unexpected things coming together on the hand of this child! We feel justified, however, in bringing them together, as this helps us to compare their sizes. In this and all the remaining pictures, of course, the small square in the center encloses what is to be found in the next picture, rather than in the preceding one as in the first series; and the tiny square (beginning with 0) shows the area of the second following picture.

1 cm. in picture = 10 cm. in actuality. Scale = 1:10



1 The living creature portrayed in this drawing is a mosquito, to be exact an anopheles, or malaria mosquito. We can see this from the way it sticks up its hind legs. This is the first strange coincidence, for from the first series of pictures we know that it was in December that the scene occurred, and this insect is rather rare in Holland in winter. We notice that there is a little cut in the girl's finger. Right in the center of the tiny square in the middle is a minute white spot. It is a grain of salt which stuck to the girl's hand, having been left there, we may assume, after she ate her lunch. As it is not exactly the thing we would most expect to find there, it will be evident that there is a special reason for choosing it. That reason will appear later.

1 cm. in picture = 1 cm. in actuality. Scale: "life size" = 1:1 = 1:100

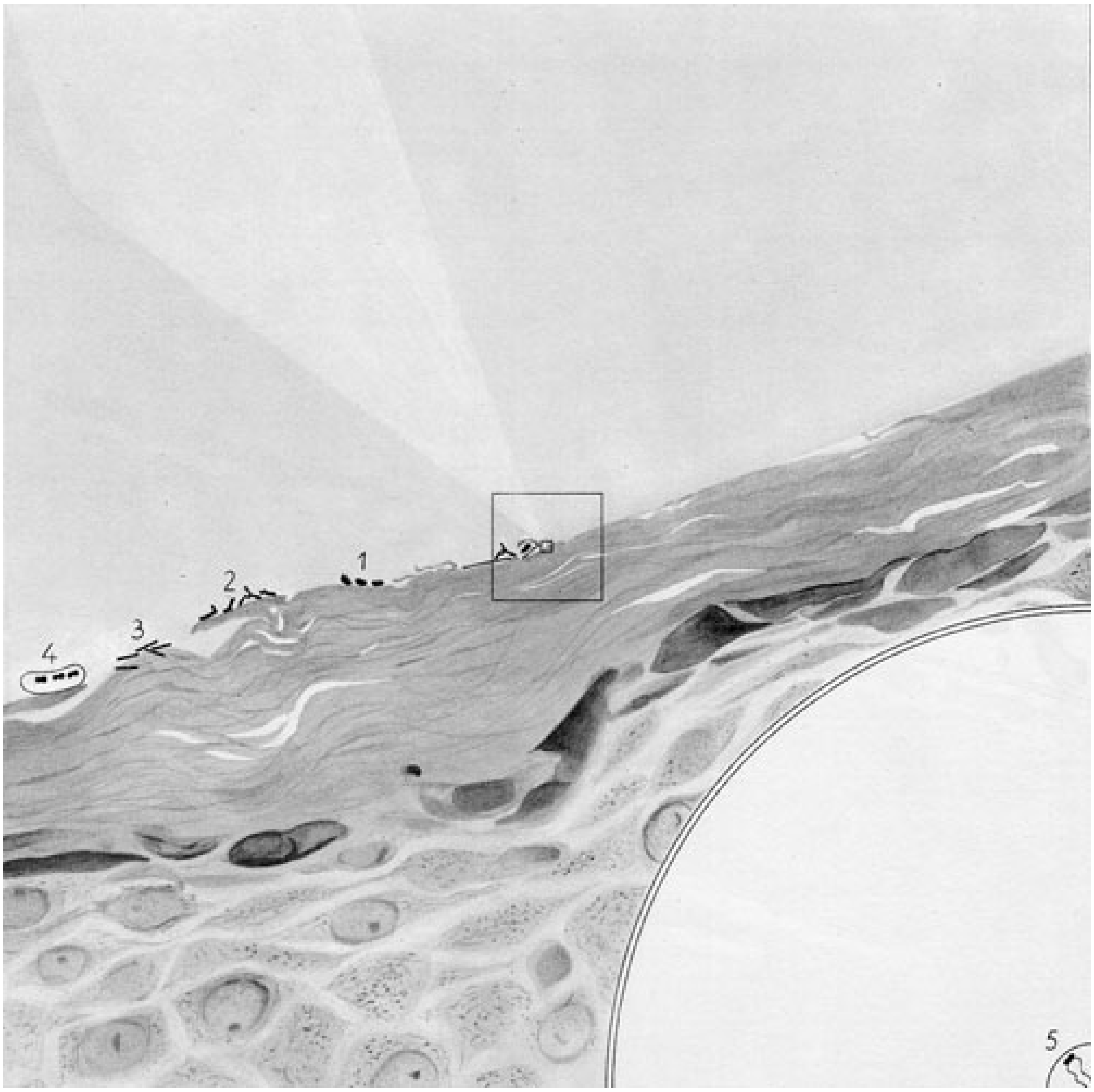


—1 We have now come down to 5 centimeters above the girl's hand, and with a magnifying glass we can distinguish the grooves in its skin. On it we notice some small organisms (1): water mites and bacteria. They got there, probably, when the girl put her hand in the water of a ditch nearby. In the right hand bottom corner inside the quarter circle there is a bacterium, which however is so small that we can't see it. In the cut we see a section of the epidermis. In a real cut in a finger not all the detail shown here could be distinguished, but it is interesting to include it. The malaria mosquito is clearly visible: its large compound eyes (2), feelers (3), and jaws (4); also its proboscis (5), with which it is busy stinging the poor child. We see the flexible sheath (6) bent in a curve as it touches the skin.

1 cm. in picture = 0.1 cm. = 10^{-1} cm. = 1 mm. Scale = 10:1 (Enlarged 10 times)

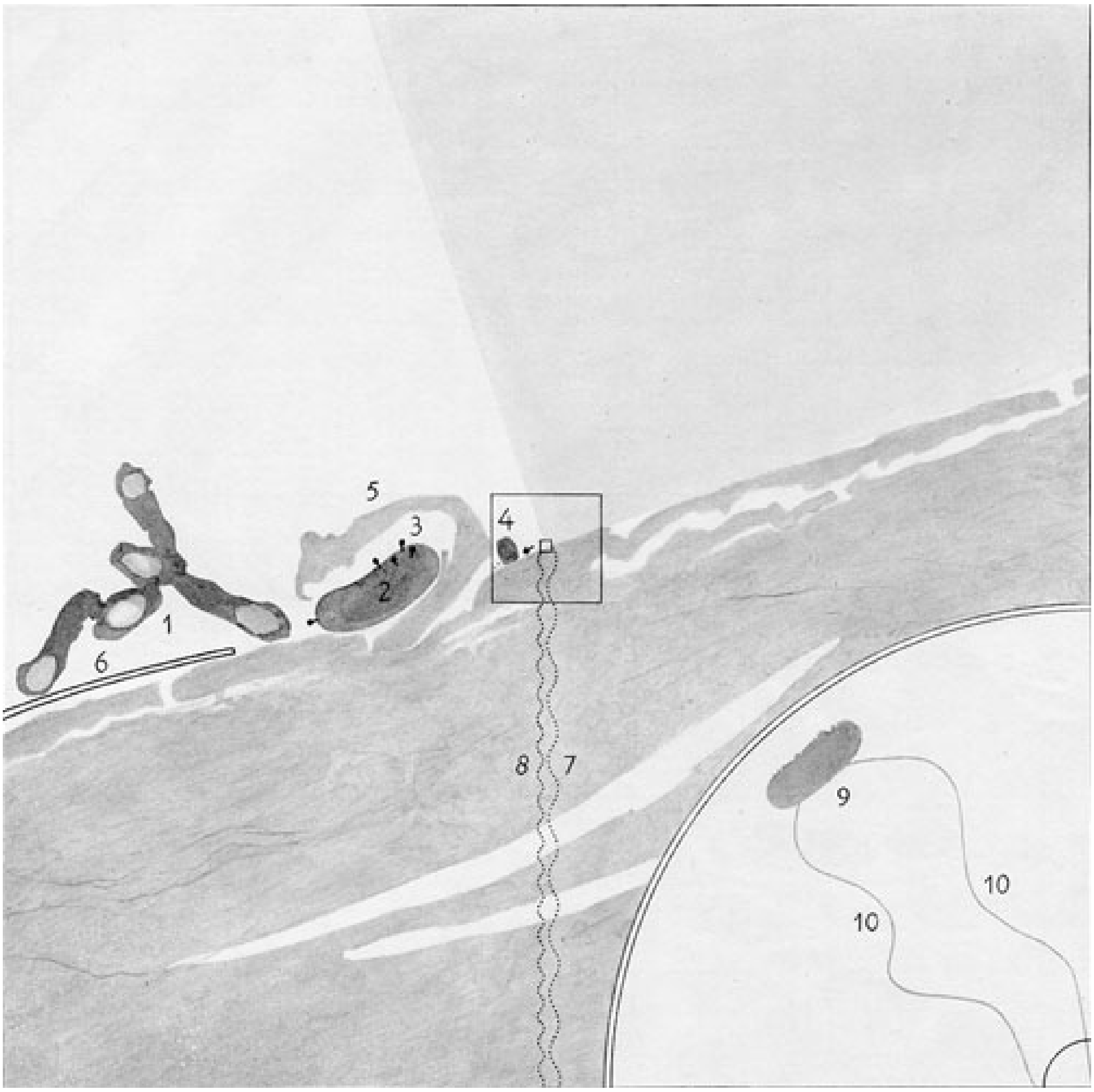
—2 To see this picture, taken from a height of only 5 millimeters, we should need a microscope. Again there is a member of the animal kingdom visible: one of the water mites we saw on the previous drawing, a cyclops (1). This is again not the most likely thing to happen, that it would lie thus comfortably with its feelers over the edge of the cut in the girl's finger, but it could happen! In the section of the skin we notice the horny keratin layer (2) on top. Under it is the Malpighian layer (3) with its numerous cells and the orifice of a sweat duct (4). Under that lies the Corium (5) with its nerve papillae (6), small blood vessels (7), and fat cells (8). We see how the mosquito's proboscis (9) sticks into the skin. In the smaller of the two quarter circles in the right hand bottom corner we can now just see the bacterium (10).

1 cm. in picture = 0.01 cm. = 10^{-2} cm. Scale = 100:1 = 10^2



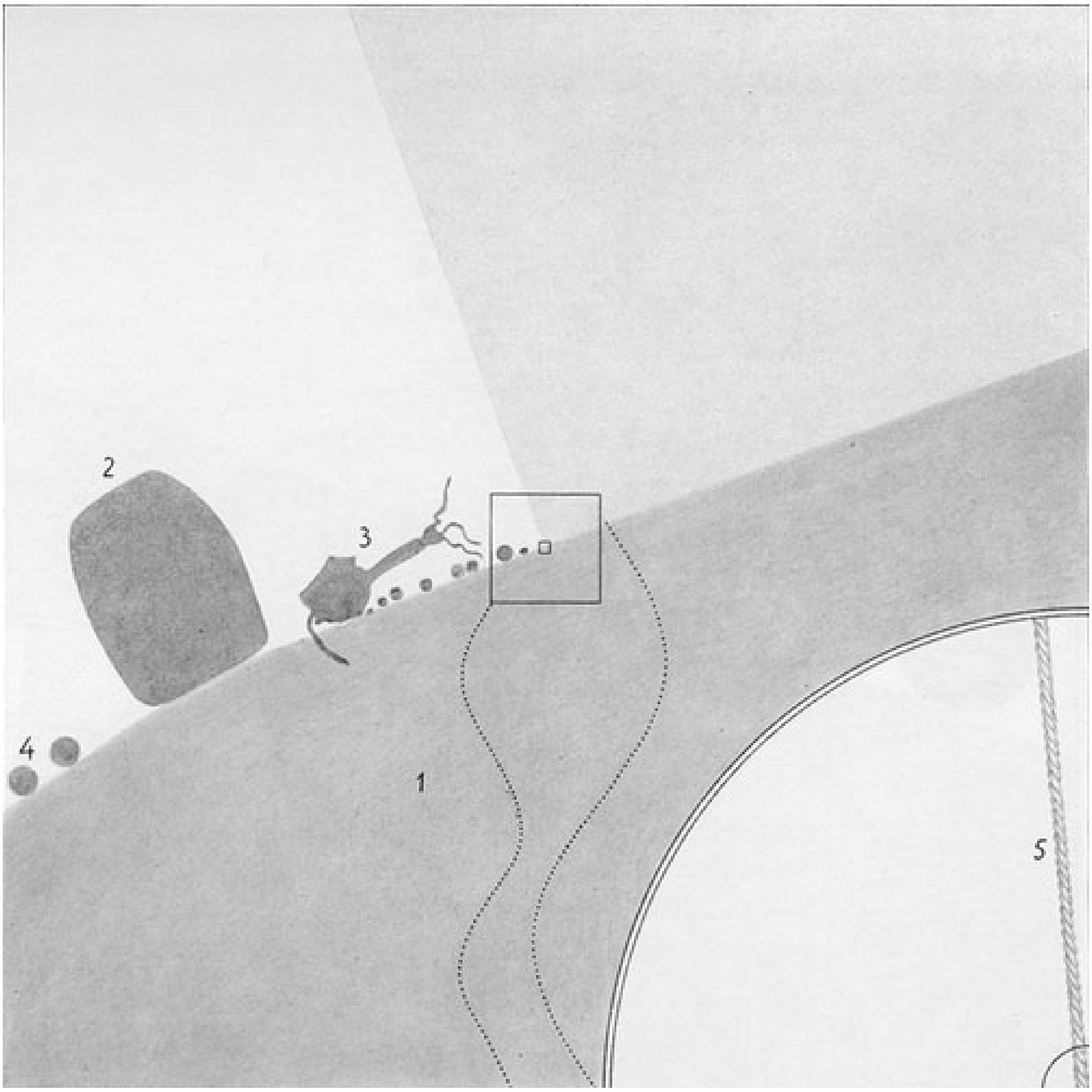
—3 The height from where we are supposed to be looking has now been reduced to 0.5 millimeters or 500 microns. This is the last domain of scale in which an impression of color can be gotten by the human eye. The living creatures here are bacteria. We see some on the girl's hand: colon bacilli (1) and diphtheria bacteria (2), tubercle bacilli (3), and pneumonia bacteria (4). The bacterium in the inset in the lower right corner can now be recognised as a typhoid bacillus (5), such as humans may "carry" unknowingly for a long time. Its flagella (by which it moves) are clearly shown. We shall magnify it separately in an inset at the same place in the following pictures. This means that what is shown in the small quarter circle will each time be magnified 10 times, so that it will fit into fhe large quarter circle in the next picture.

1 cm. in picture = 10^{-3} cm. Scale = 1,000:1 = 10^3



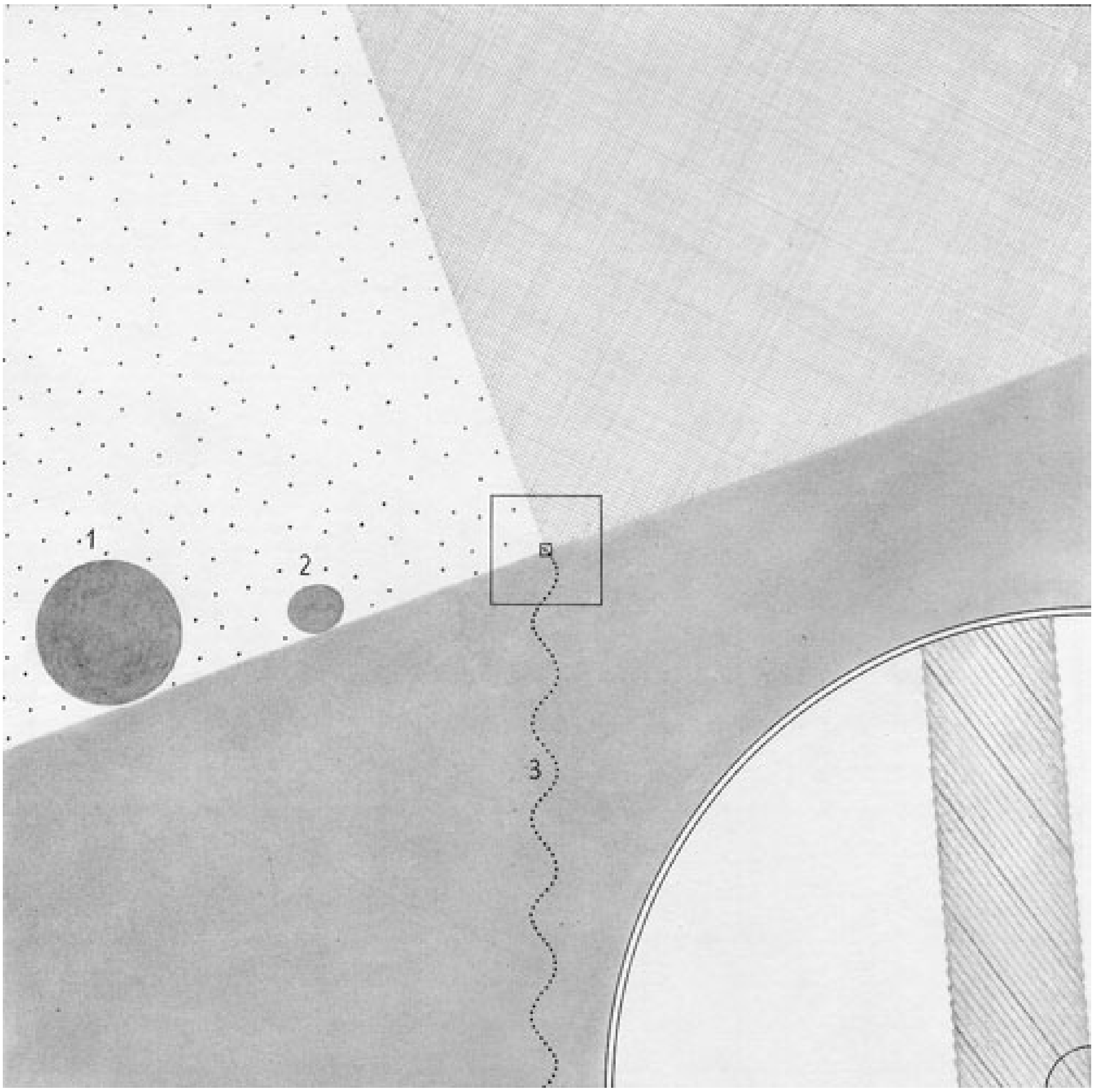
—4 The electron microscope helps us to get an idea of the shapes of some of the living creatures. We see a diphtheria bacillus (1) and a colon bacillus (2), which itself is being attacked by bacteriophages (3), as well as a smallpox virus (4). We see how keratin of the skin is curling up (5) before falling off. Some gold leaf (6) left on the girl's hand, possibly from book binding, demonstrates its extreme thinness; in fact this gold leaf is so thin that you could use it to cut a bacterium, such as is depicted near it, in two, if only you could hit it. The visible rays from the sun are symbolically represented by two sinusoids (waves) with the wave lengths of red (7) and violet (8) light. The inset shows the typhoid bacillus (9) with its flagella (10). The salt crystal's height on this scale would be 5 meters.

1 cm. in picture = 10^{-4} cm. = 1 micron. Scale = 10,000:1 = 10^4



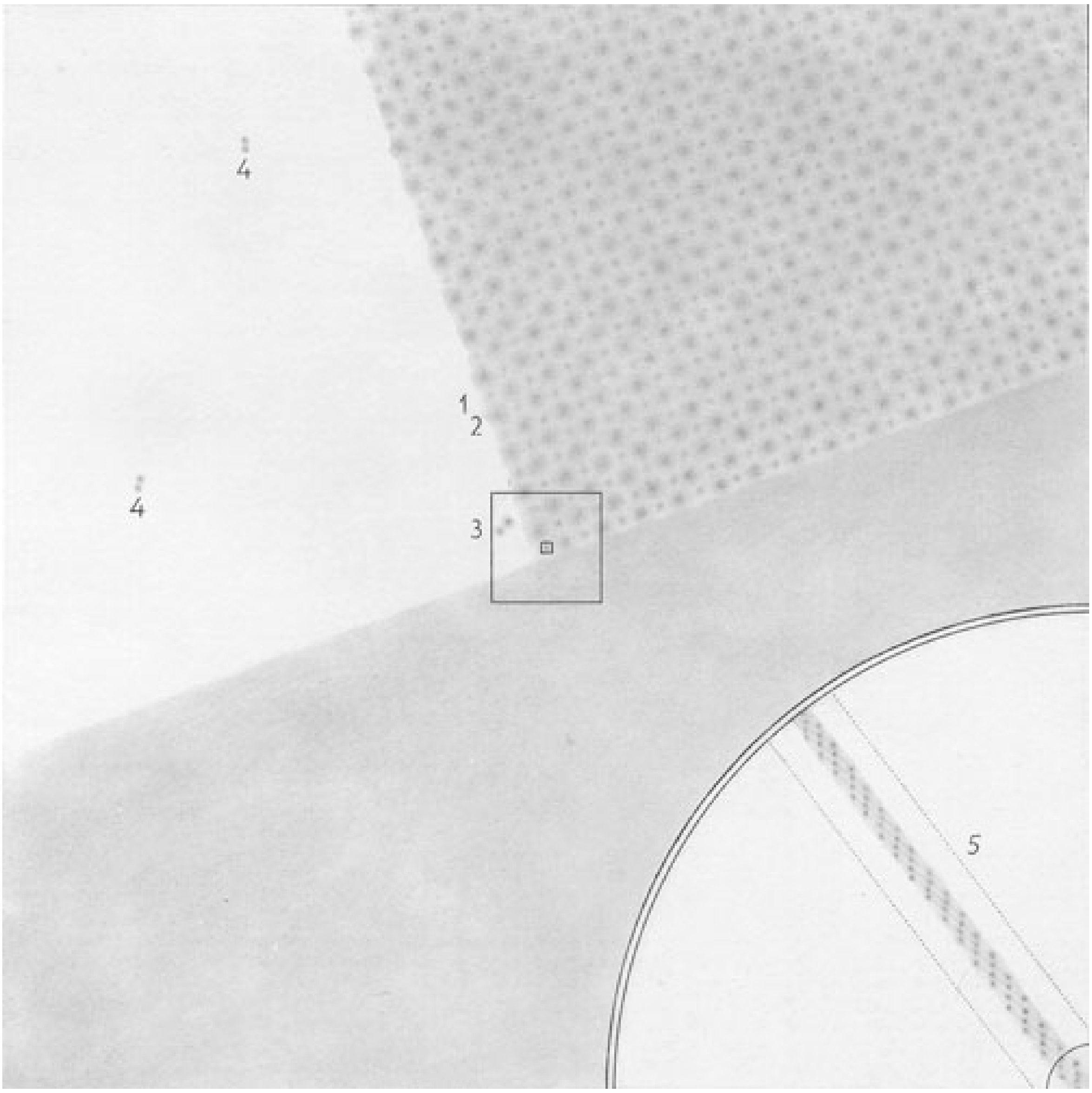
—5 On the upper layer of keratin (1) a number of viruses are crowded together, as they often actually are on the skin. One of the larger ones is smallpox (2). A bacteriophage (3) of medium size as we saw in the previous drawing is shown here very distinctly from an electron- microscopic observation - just to give its size and shape, for it would not be likely to lie here by itself! Many molecules could be shown on this scale. Some starch molecules (4) are drawn. The inset shows the helical structure of the flagellum (5) as seen in the electron microscope. The flagellum clearly is composed of three strands wound into what looks like a cord. Magnification is here 100,000 times, about the maximum that can be reached with the electron microscope. The height of the salt crystal on this scale would be 50 meters.

1 cm. in picture = 10^{-5} cm. = 0.1 micron. Scale = 100,000:1 = 10^5



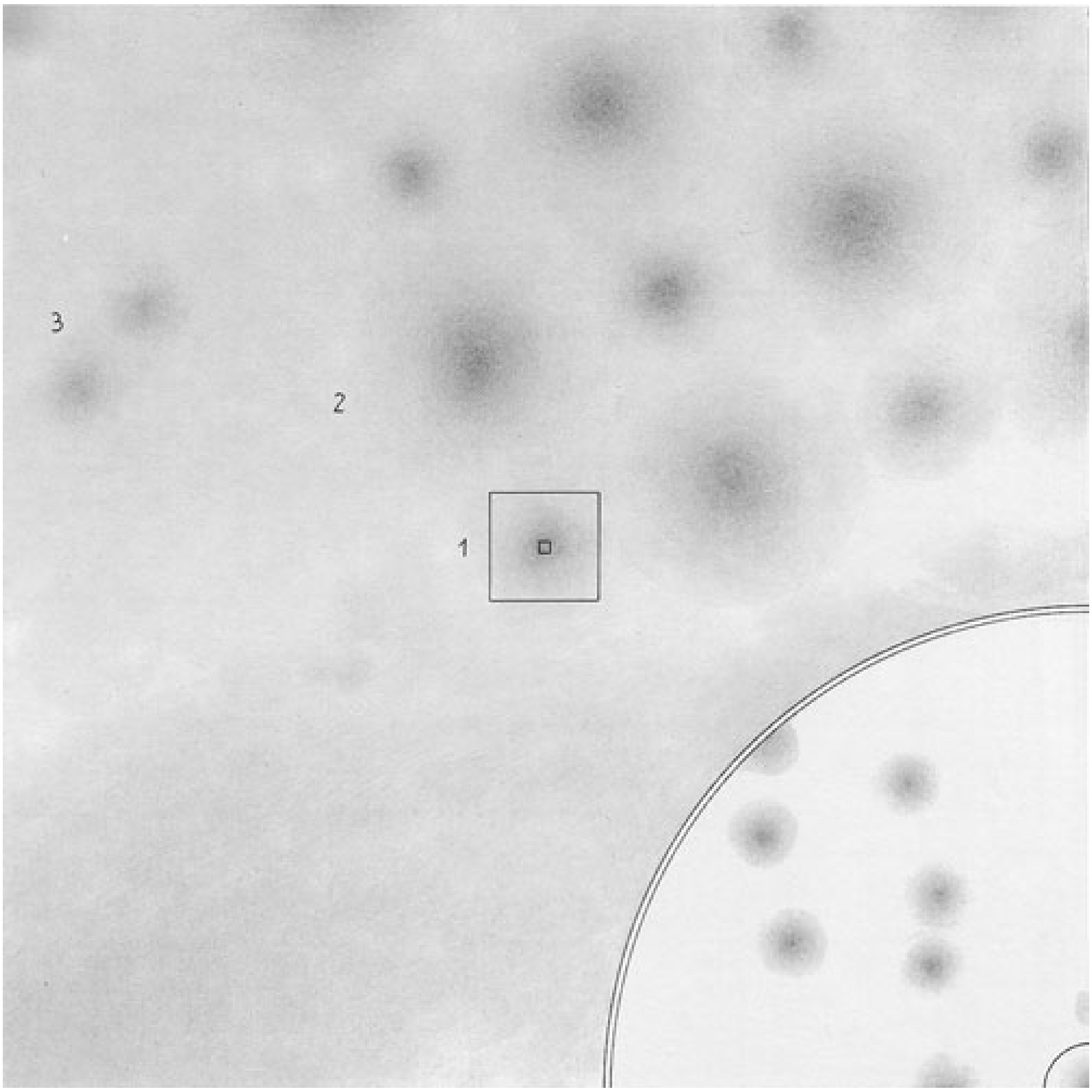
—6 This scale has a magnification of a million. The electron microscope therefore can no longer give us clear images, for at most it can magnify 100,000 times. A more schematic image is therefore unavoidable, that is, a diagram rather than a photographic enlargement. Yet we know that there would still be living creatures. We show the infantile paralysis virus (1), already visible in —5, and one of hoof and mouth disease (2). The latter is about the smallest now known. Apart from the viruses shown there exist several with shapes sharply different from these wholly or nearly spherical forms. The sinusoid (3) shown is of an ultraviolet ray. The dots in the upper left quadrant indicate molecules of the air. The inset has the flagellum composed of three strands as already shown in —5. The height of the salt crystal on this scale would be 500 meters.

1 cm. in picture = 10^{-6} cm. = 0.01 micron. Scale = 1,000,000:1 = 10^{6}



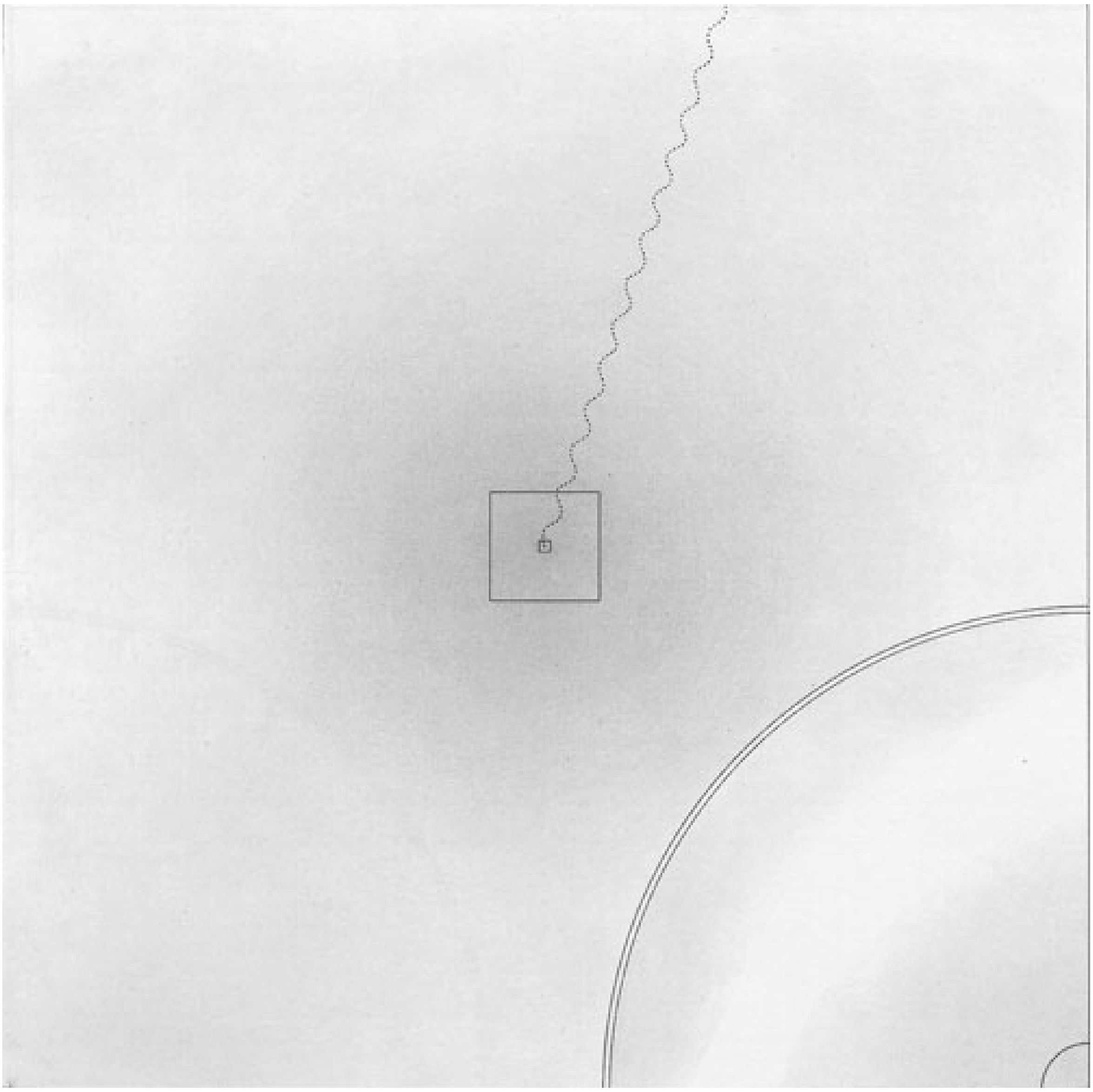
—7 Magnification here is ten million times, and the structure of the salt crystal can be shown. Distances between the successive layers of sodium (1) and chlorine (2) atoms in the lattice of the crystal are known, though its height would be 5 kilometers on this scale. To the left oxygen (3) and nitrogen (4) molecules are moving about as air at average distances indicated. Nitrogen molecules are more than 3 times as numerous as oxygen. In the inset a schematic sketch is given of just one strand of the flagellum, and even so only the hydrogen atoms on the near side are indicated. Otherwise the representation would become unintelligible, as the other atoms behind them are not placed in regular rows as they are in the salt crystal. Total width of the protein molecule including the amino acids which are bound to the strand is indicated (5).

1 cm. in picture = 10^{-7} cm. = 0.001 micron. Scale = 10,000,000:1 = 10^{7}



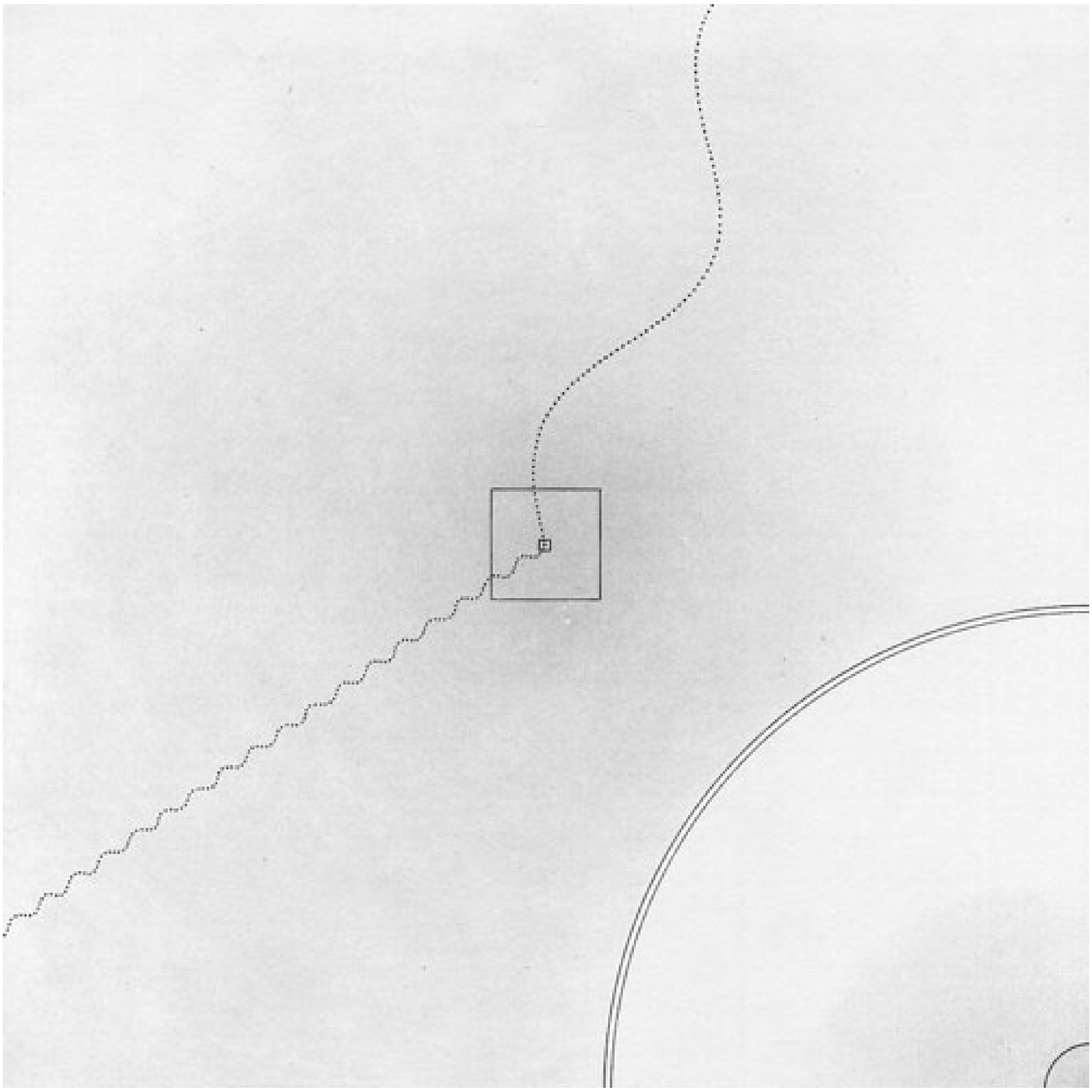
—8 The sodium (1) and chlorine (2) atoms of the salt crystal are clearly indicated. The shading here and in later pictures has only a symbolic value: a darker grey only means that the probability is greater that an electron will be found there than in a place that is more lightly shaded. As to the oxygen molecules (3) moving in the air, their average speed at a temperature of 10° Centigrade (= 50° Fahrenheit) would be 470 meters per second (= 1,000 miles per hour) in reality. In the image that speed would be 10^8 times greater, that is, more than 100 times the speed of light! In the inset the helical structure of the flagellum which could be recognized in —7 can no longer be seen, as again only hydrogen atoms are indicated, and all other atoms behind them (oxygen, carbon, and nitrogen) are left out. In the corner is one quarter of a hydrogen atom.

1 cm. in picture = 10^{-8} cm. = 1Å(angstrom unit). Scale = 100,000,000:1 = 10^8



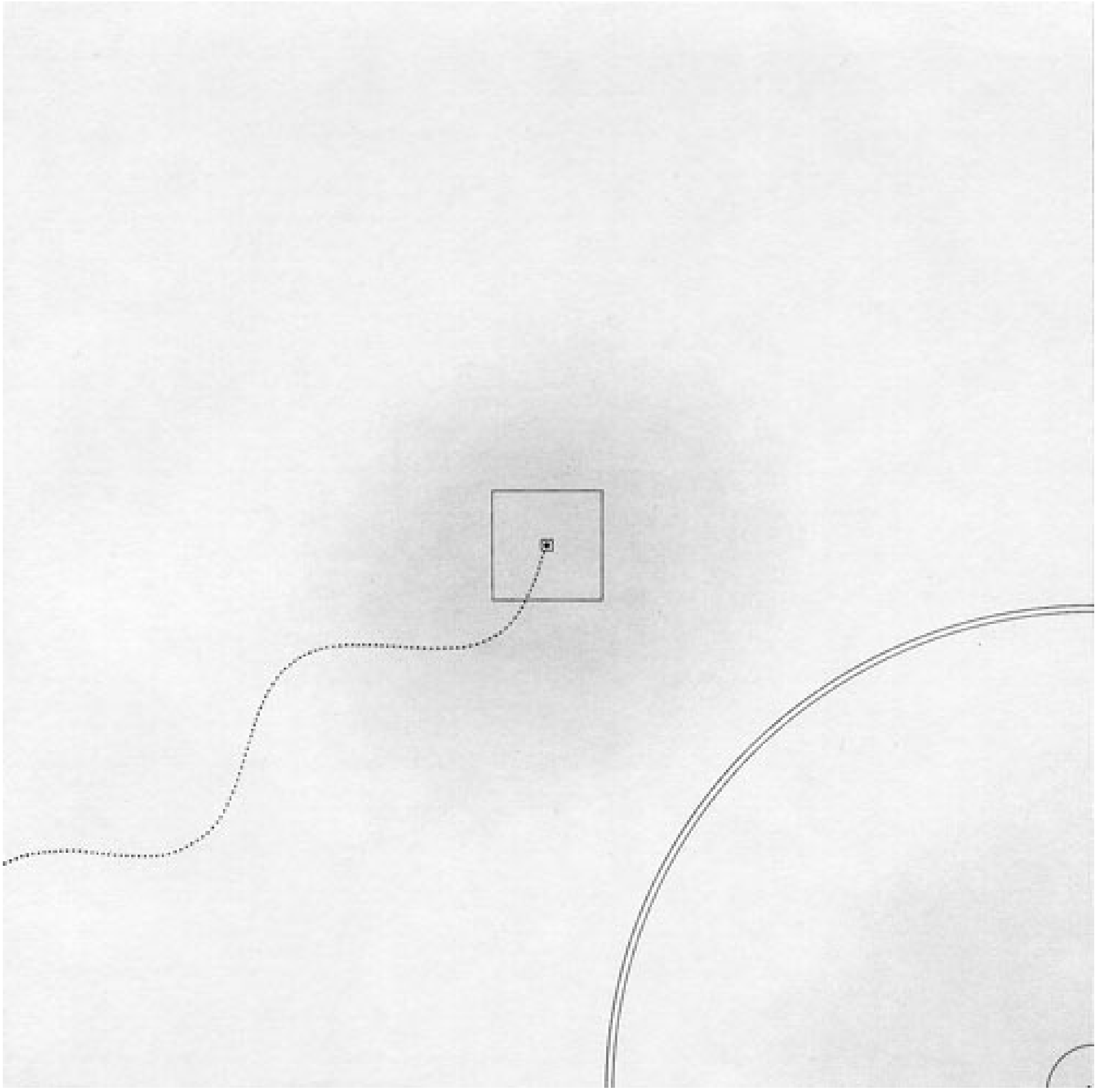
—9 Again in this picture darkness of tone denotes the probability that an electron will be found in a certain place. As the sodium atom is here drawn at a 10 times larger scale, the area depicted in it is only $(\frac{1}{100})^{th}$ that of —8. The probability that an electron will be found there will be that much smaller and the shading in consequence is made lighter. The same holds for the hydrogen atom in the inset. The nucleus of the sodium atom is in the center. Its size on this scale is only 7 microns. Twelve electrons are whirling around this nucleus at speeds of about 1,000 kilometers per second in reality, or a thousand million times more on this imagined magnified image. The sinusoid drawn shows the wave length of the finest X-rays on this scale. In the inset a quarter of a hydrogen atom is visible.

1 cm. in picture = 10^{-9} cm. = 0.1 ÅScale = 1,000,000,000:1 = 10^{9}



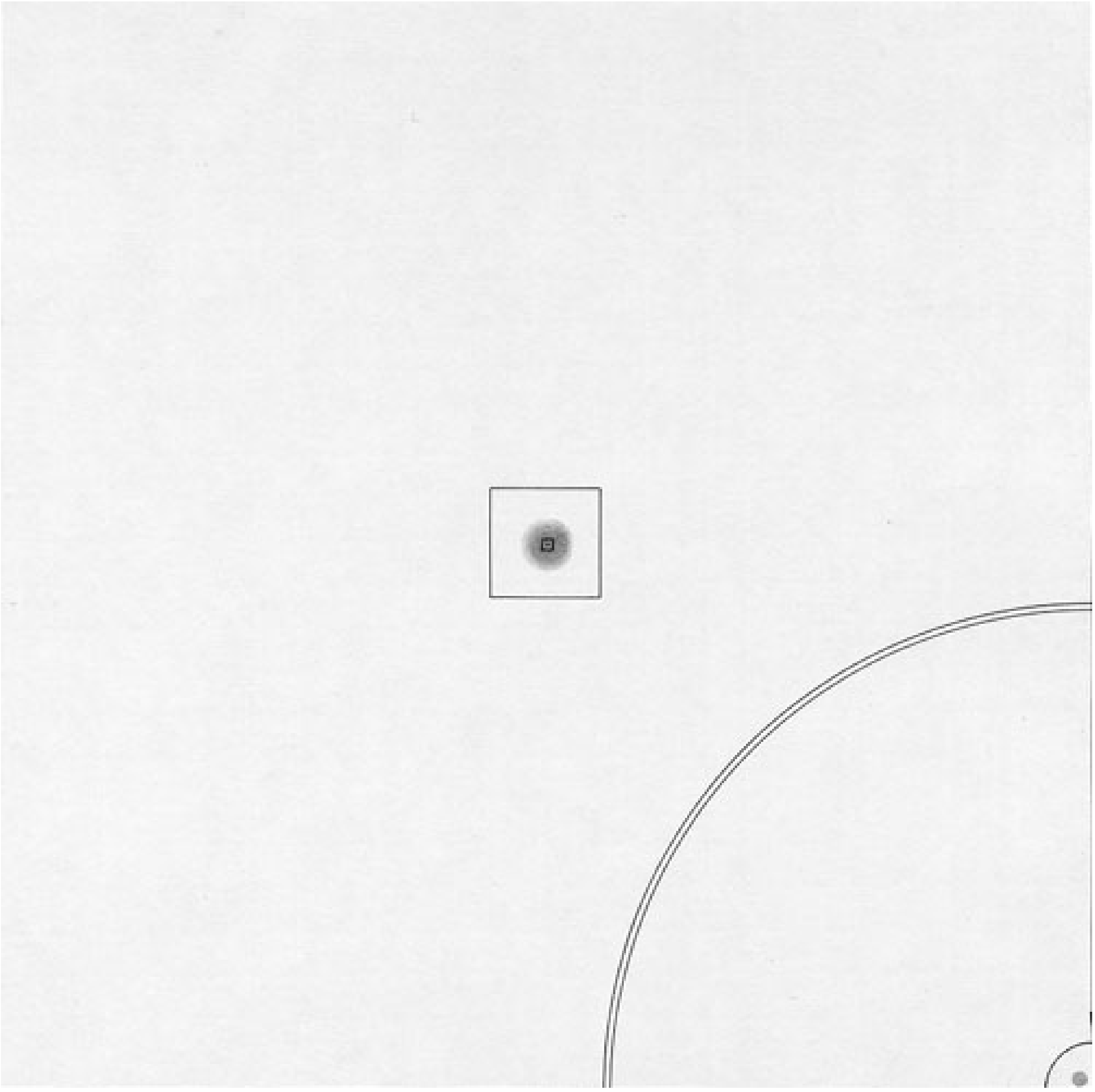
—10 It will be noticed that the tone that symbolizes the probable presence of an electron is again a lighter grey than that of the previous drawing, because the actual area depicted in the square is here again reduced to $(\frac{1}{100})^{th}$. The sinusoid coming from the left shows the wave length of a typical gamma ray (wave length here 5 millimeters) such as is emitted from a radium-dial watch. The girl of picture 1 would on this scale have a length of about 15 million kilometers! The salt crystal would now be more than 3000 kilometers high. The sodium nucleus would be 0.0333 millimeter, the hydrogen nucleus (a proton) 0.01 millimeter.

1 cm. in picture = 10^{-10} cm. = 0.01 Å. Scale = 10,000,000,000:1 = 10^{10}



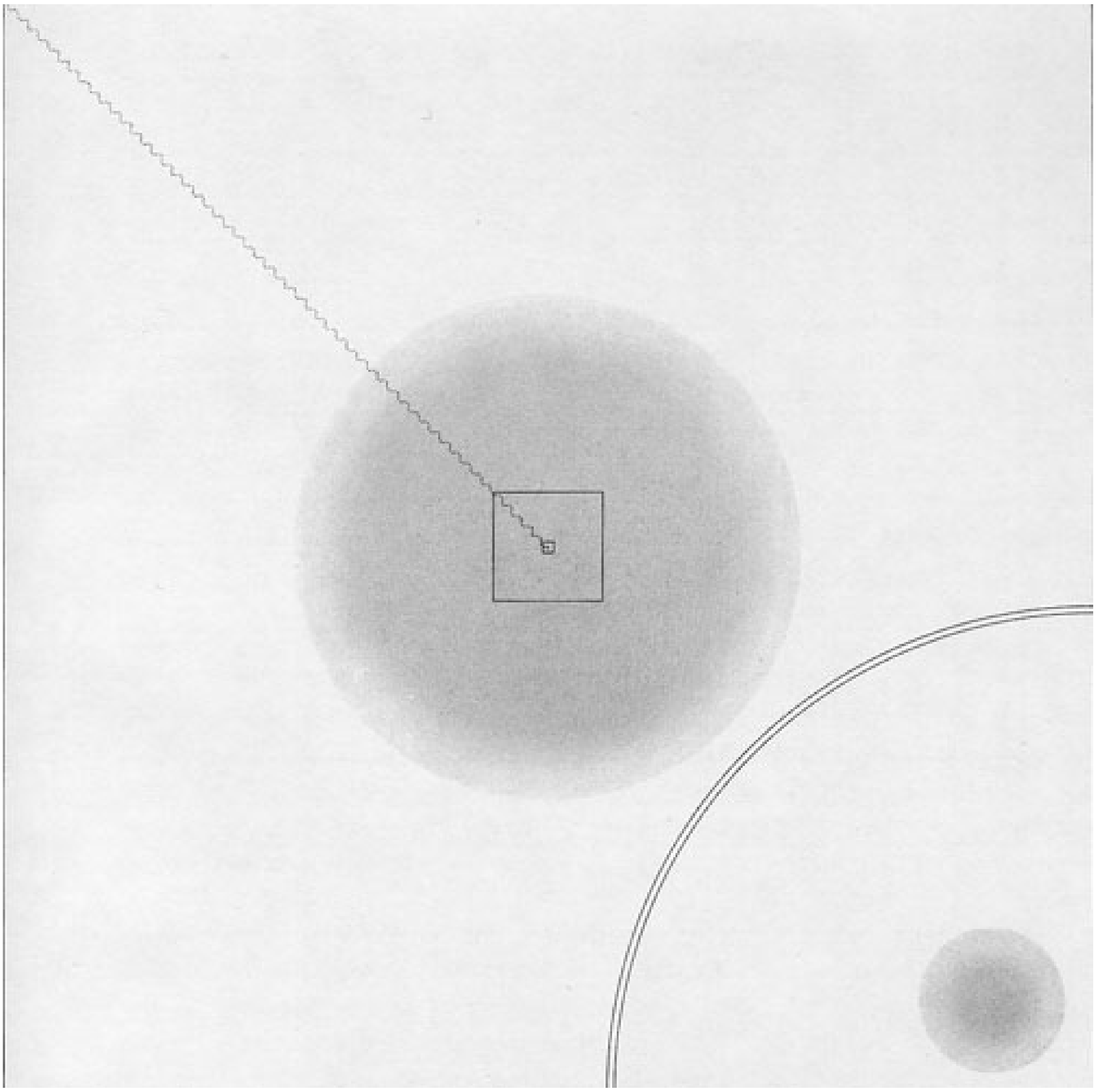
—11 This is already the third jump we have made since we saw the atom from the outside in —8 and we are still in the seemingly endless emptiness of the inside. The chance of our meeting an electron has again become a hundred times smaller. The color in consequence is again a lighter grey. The wave length of the gamma ray has increased to 5 centimeters. The grain of salt which was only half a millimeter when we saw it in actual size on the girl's hand has now become an unthinkably huge cube with sides of more than 50,000 kilometers. The nucleus of the sodium atom is 0.7 millimeters and of hydrogen 0.2 millimeters.

1 cm. in picture = 10^{-11} cm. = 0.001 Å. Scale = 100,000,000,000:1 = 10^{11}



—12 Now the nucleus of sodium has become of appreciable size, and also in the inset the nucleus of the hydrogen atom (a proton) is clearly "visible". As was pointed out in —4, there is no question of the objects themselves being "visible", as we are dealing here with dimensions which are a hundred million times smaller than the wave lengths of light. Light functioned only up to that drawing. So did color, which could play an appreciable role in only 14 domains of scale (10 to —3); 11 to 26 could give no more than white spots on a black background.

1 cm. in picture = 10^{-12} cm. = 0.0001 Å. Scale = 1 million million:1 = 10^{12}



—13 In this final picture we see the nucleus of the sodium atom. We cannot even guess how the 12 protons and 11 neutrons in it are placed. This nucleus is not painted an even grey; its edge is of a somewhat lighter tone which gradually merges into the darker hue in the center. The meaning of this difference of tone is again different from that in drawings —7 to —11. Here a darker grey denotes greater density of electric charge. As a new element there is a gamma ray, full of astonishingly penetrating power, coming in from the left. Its wave length is only a millionth of an angstrom unit, which itself is a hundred millionth of a centimeter! Looking back on the whole series of 40 pictures we find that in only 10 of them (3 to —6) is life known to exist. In other scales there may, however, be forms of life we do not yet know.

1 cm. in picture = 10^{-13} cm. = 0.00001 Å. Scale = 10 million million:1 = 10^{13}

And so our journey ends at the nucleus of the atom, that mysterious, utterly small, and incredibly powerful center of energy which only recently has unveiled some of its mighty secrets to mankind. Whereas at the end of our first journey we stood in awe before the imposing greatness of the dimensions of the universe, and felt as nothing in comparison to their immensity, the conditions are now completely different. True, we feel as much awe and reverence when we attempt to think of the miracles of dynamic power that are hidden in these domains of the smallest existing entities, but our own dimensions are now indescribably colossal compared with what we see.

Thus on the scale of the last drawing, the height of the little girl would be about 15,000 million kilometers, that is, more than the diameter of the solar system! If we add the thought that man is beginning to control and use these limitless nuclear powers, it is clear that unthinkable possibilities are within his reach. When we thus think in cosmic terms, we realize that man, if he is to become really human, must combine in his being the greatest humility with the most careful and considerate use of the cosmic powers that are at his disposal.

The problem, however, is that primitive man at first tends to use the power put in his hands for himself, instead of spending his energy and life for the good of the whole growing human family, which has to live together in the limited space of our planet. It therefore is a matter of life and death for the whole of mankind that we learn to live together, caring for each other regardless of birth or upbringing. No difference of nationality, of race, creed, or conviction, age or sex may weaken our effort as human beings to live and work for the good of all.

It is therefore an urgent need that we all, children and grown ups alike, be educated in this spirit and toward this goal. Learning to live together in mutual respect and with the definite aim to further the happiness of all, without privilege for any, is a clear duty for mankind, and it is imperative that education shall be brought onto this plane.

In this education the development of a cosmic view is an important and necessary element; and to develop such a wide, all-embracing view, the expedition we have made in these “forty jumps through the universe” may help just a little. If so, let us hope that many will make it!