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GEOGRAPHY

How You Can Prove Columbus' Theory

Next Wednesday, October 12, we celebrate the 435th anniversary of the discovery of the New World by Christopher Columbus. To most of us, the name of Columbus automatically suggests the idea that the earth is round, which was the basic theory on which his voyage was undertaken. In our early school days we were taught that at the time the great admiral found a new continent everybody in Europe thought the earth was flat and that if you sailed far enough you would fall off into outer space. Like many of our childhood notions, this is not correct. Centuries before Columbus discovered America and before Magellan proved that the earth was round by sailing around it, students of the subject quite generally believed in the earth's rotundity. They did think, however, that the earth was at the center of the universe and that the sun revolved around it. After Copernicus published his book on "The Revolution of the Celestial Orbs" in 1546 his ideas naturally came into wide acceptance, and now like him we believe that the sun is at the center and the earth revolves around it. In the time of Columbus there may have been people who thought that the earth was flat, but they were not the scientists of the day.

We now know that the earth is a figure that the mathematicians call an oblate spheroid. This is a figure approximately the shape of a door knob or an onion. However, for practical purposes the earth is a sphere, because its diameter at the equator is only a few miles greater than that from pole to pole. The slight additional distance at the equator is due to the earth's rotation. When you swing a stone on the end of a string around your head it tries to fly away. In the same way the part of the earth at the

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COLUMBUS' NAVIGATING INSTRUMENTS would be considered crude nowadays; but they were the latest word in 1492, and in using them the great discoverer plotted out his course on the assumption that the earth is a sphere

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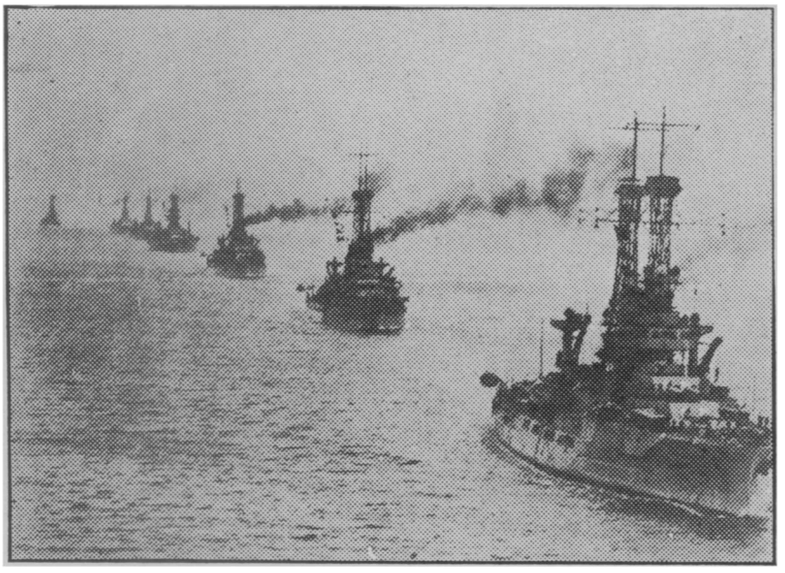

WHEN THE FLEET COMES IN the ships seem to climb a low, round hill, for the masts and smokestacks rise over the horizon before the hulls appear

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equator tries to fly away from the center as it is swung around once every day.

But what are the proofs that the earth is round and that it is rotating? Of course one was furnished by the navigator Ferdinand Magellan when he sailed around it, but if the earth were flat, and large enough, it is conceivable that a boat might sail in a large circle and yet the captain would think he was sailing in a straight line. That might have have been true at the time of Magellan, but with the modern sextant, radio and other means by which modern sailors determine their position when at sea, such a mistake is hardly possible.

Recent achievements in aviation have furnished striking proof. When Commander Byrd flew straight from New York to France despite almost constant fog he again demonstrated the accuracy of modern navigation. Again, when Maitland and Hagenberger flew to the Hawaiian Islands, where only a slight deviation from the path would have carried them beyond their goal to possible death, they also showed how trustworthy are our ideas of the shape of the earth.

Proof By The Great Circle

The very routes taken by the trans-Atlantic and trans-Pacific flyers depend upon the rotundity of the earth.

On a flat earth the shortest distance between two points would be a straight line. To everyone familiar with ordinary maps, it would seem that the quickest way to get from New York to Paris would be to fly almost directly east. Most of us were surprised when Lindbergh, instead of going by this apparently direct route, went first from New York to Newfoundland and followed a track along a great northward-curving arc. The shortest distance between two points on a

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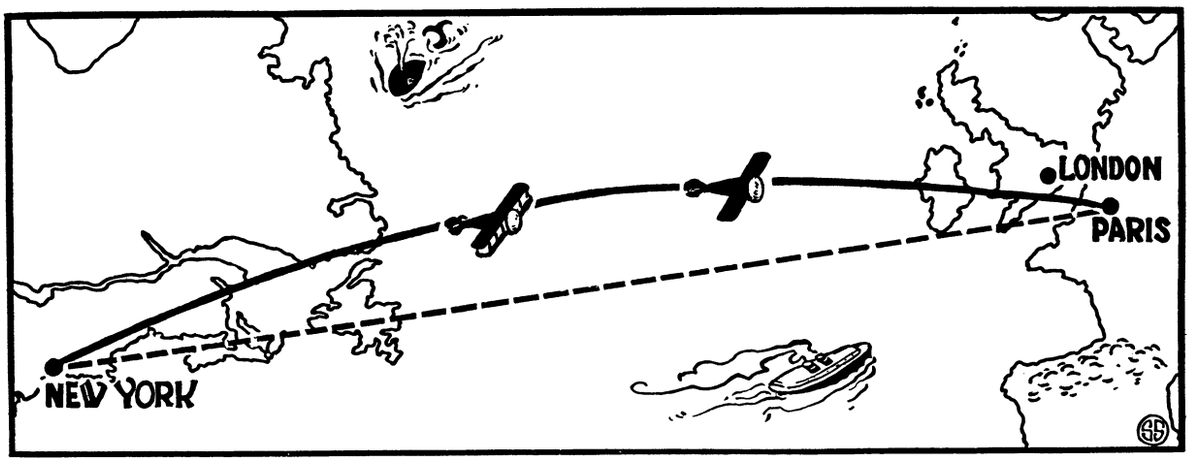

THE PARADOX OF THE GREAT CIRCLE: If the earth were flat, a "ruler line" would be the shortest distance between two points, but on the surface of a globe a curved line is. Hence the northward swing of Lindbergh and the other trans-Atlantic fliers

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sphere is what the navigators call a segment of a great circle.

Any one can test out the "great circle" idea for himself. It requires merely a globe and a tape measure or a piece of string. If a regular geographical globe is not available any large sphere—a basketball for example—will serve fairly well. Of course, the bigger your sphere the better your results will be. Just hold down one end of your string at New York, and stretch it to Paris, pulling it tight, to make the span with the shortest length possible. You will find that it automatically lays itself out along the curious curved path followed by Lindbergh and all the other fliers who have followed him. If you try to lay the string along a "ruler line" such as could be drawn on a flat map (or a flat earth) you will find that it lies slack, and is noticeably longer than the "great circle" line. The only place on the globe where a straight east-and-west line is also the shortest way to get there is right on the equator.

Stars Prove Rotundity

There are other proofs that the earth is round. One of the most striking is that afforded by the changes in the stars as we go south. The Great and Little Bears, the Pole Star, and the familiar big "W" in Cassiopeia are all conspicuous objects in our night sky.

But if we were living in South Africa or New Zealand we would never see these stars. In their place we would see such constellations as the Southern Cross, the Southern Triangle and the Centaur. None of these are visible at all from the northern part of the United States and only a few of them can be seen low in the south at certain seasons of the year from the southern part of our country. At a point on the equator both the southern and northern constellations are visible at certain times, but the pole star is never more than barely above the northern horizon.

This could not possibly be the case if the earth were not round. The stars are scattered around the earth in all directions as if they were located on the surface of a huge sphere. We know of course that they are not, but instead are at distances ranging from relatively close to infinitely far away. However, for convenience the astronomer often considers them as if they were all on a huge celestial sphere. If the earth stood still in space we would only be able to see about half of the stars from any one place because the rest would be continually below the horizon. As it is the movement of the earth brings certain constellations into view at various times of the year which are not seen at others. The farther north they are the more continually are they visible.

The Little Bear, of which the Pole Star is a member, never sets below the horizon for people in the United States. Like all the stars it appears to revolve around the north pole of the heavens, but even when it is lowest it is still above the horizon. A star group such as Orion which is approximately on the celestial equator, and is always over some point on the equator of the earth, is visible in the evening for about half of the year.

A group still farther south may only be visible in the evening for a month or two. Such a constellation is the Southern Fish. The bright star of this group, called Fomalhaut, is seen low in the south in the early winter evenings. Still farther south are the constellations which revolve within about forty degrees of the south pole of the sky. These never rise high enough to be seen in the United States. If the earth were flat we would see the same stars in the sky above us whether we were at one side of it or another.

But there are still further astronomical proofs that the earth is round. If we could get on the moon we would see the earth from such a distance that it would look round. Of course this is not possible, but the earth does cast a shadow out into space. At the time of an eclipse of the moon the earth's shadow falls upon the lunar disc. At such times we can actually see the outline of the earth and we can see that it is always round.

Sea Shows Curvature

A more familiar proof is accorded by watching ships going to sea. When the ship is close by, it is seen in its entirety. Then as it reaches the horizon the lower part of the hull vanishes over the edge of the horizon even if we have a telescope to watch it. Gradually the whole hull vanishes. Finally only the upper part of the smokestack or mast is left and then the ship has disappeared completely and only the smoke shows its location. But if one then quickly climbs a hill or ascends a high tower, the ship again becomes visible, because the greater height of the observer enables him to see over the curve of the earth.

With the sextant the sea captain finds the height of the sun above the horizon at noon and from this figure he calculates his position.

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STARTING THE FOUCAULT PENDULUM in the building of the National Academy of Sciences and the National Research Council at Washington; this instrument demonstrates the rotation of the earth

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Because the bridge may be as much as 30 or 40 feet above the surface of the water the horizon is a trifle lower than it would be if he were right at the surface or standing in a lifeboat. This difference is quite small. If the sextant is 36 feet above the water the horizon would only be about six minutes of angular distance lower than if it were at the surface. Six minutes is about one-fifth of the apparent diameter of the full moon. At sea the captain uses tables of the dip that have been prepared according to the generally accepted figures and ideas of the shape and size of the earth. If these were in error it is inconceivable that ships could be navigated as accurately as they are.

The Earth Rotates

The earth is more than a sphere floating in space. It is a rotating sphere. Once in twenty-four hours the earth revolves from west to east. This causes the heavens to move apparently from east to west and brings us sunrise and sunset. But how can this be proved? Before the time of Copernicus men believed that the earth stood still and that the heavens revolved around it. The only argument that Copernicus could bring in favor of the rotating of the earth was that it would be much simpler to have the relatively small earth revolve instead of the vast sphere of stars. However, all the phenomena that had been observed up to that time could be equally well explained if the earth or the heavens turned around.

Proof of the Pendulum

The first experimental proof that the earth actually turned was performed in 1851 in Paris by the famous physicist Foucault, with a pendulum consisting of a heavy ball hung on a long wire. This has been repeated in many places, and today at Washington, in the new building of the National Academy of Sciences, a Foucault pendulum is kept in regular operation.

The principle is this. If a pendulum is arranged to swing freely in any direction, unlike the pendulum of a clock which is designed to swing in one place only, it will continue to swing in the same direction even if the support is turned around. If such a pendulum were suspended over the North Pole and started swinging it would continue to swing in the same direction even though the earth were turning under it. To a person standing beside the pendulum, not aware of the motion of the earth, the plane in which the pendulum swung would seem to turn from east to west. Actually it would be the pendulum that was standing still, however, and the observer that was turning.

If the pendulum were set up at the equator, the effect would not be the same. The pendulum would not work because the earth would not be turning under it. The whole pendulum would be carried around in a circle. At a point any place between the equator and the north pole the pendulum would seem to turn around, taking more than a whole day. The one in Washington takes about 36 hours. It moves in the direction of the hands of a clock, in the same direction as the shadow of an upright stick moves during the day. At a point in the southern hemisphere as far south of the equator as Washington is north of it, the pendulum would also turn once in about 36 hours. Here, however, the movement would be in a counter-clockwise direction.

Pendulum Easily Duplicated

The Foucault experiment is an easy one to duplicate. Anyone with a little ingenuity can set up a pendulum so that it will swing freely in any direction. The longer the wire or cord supporting the weight is, the better. In Paris Foucault used a wire over two hundred feet long. A shorter wire can be used, however, and if a heavy weight is used the effect can be noted. In order to start the pendulum without giving it a push to one side or the other, Foucault pulled it to one side with a thread. Then he burned the thread with a match. This allowed it to swing without any tendency of its own to turn. To tell how it seems to turn by the motion of the earth he attached to the bottom of the ball a metal point. Each time the pendulum swung to one side, this point plowed through a ridge of sand. Each time the groove left in the sand would be a little farther in a clockwise direction than the previous one. Such a system might be used in a home-made Foucault pendulum, and if it is kept free from draughts of air, one will be able actually to watch the earth turning.