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Nimbus IV View of the Major Structural Features of Alaska

An exceptional satellite picture of Alaska and western Canada shows regional geologic features.

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The Nimbus program of the National Aeronautics and Space Administration is an experimental program to support research and development needs in the atmospheric and environmental sciences by daily global coverage of Earth's atmospheric structure from spacecraft. Both Nimbus III and Nimbus IV satellites carried the Image Dissector Camera System (IDCS) experiment for daytime cloud mapping in the wavelength range from 0.45 to 0.65 micron (the visible part of the electromagnetic spectrum) (*1*). On 29 March 1971, a rare, cloud-free day in Alaska, an impressive IDCS image was obtained by Nimbus IV, showing most of the state and adjacent parts of Canada (Fig. 1). This image was examined to determine whether features significant in interpreting the geology of Alaska and surrounding areas could be identified. Linears (straight or gently curved physiographic features) representing the topographic expression of many of the large strike-slip faults known or suspected through ground mapping are either clearly discernible or locally suggested on the image (Fig. 2). Linears that coincide with the trends of known faults and folds in the Brooks Range, the Porcupine, Ogilvie, Mackenzie, and Kenai-Chugach mountains, and the Aleutian Range are also evident. Also visible are several linears of regional extent that may have geologic significance. Many of the linears conform to an orthogonal pattern trending north-northeast and east-southeast that may reflect a conjugate system of crustal structures. It is apparent that synoptic views with even relatively low image resolution are of value in the interpretation of regional geologic features in tectonic belts and that greater image resolution will enhance their usefulness.

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Characteristics of the IDCS Image

The IDCS is not a camera in the ordinary sense but consists of a shutterless electronic scan and step tube mounted behind a wide-angle lens. Scanning and stepping occur continuously while the satellite is orbiting; hence, the image is not exposed instantaneously from a single point in space. Scanning proceeds at right angles to the line of flight; stepping (800 steps per image) proceeds parallel to it. Scanning, stepping, and the orbital motion of the satellite are designed to achieve a length-to-width ratio of the image of a ground feature that is nearly the same as that of the ground feature itself (a 1 : 1 aspect ratio) for the polar circular orbit of the Nimbus IV satellite. An interval of 200 seconds is required to complete an IDCS image. The ground resolution obtained from the IDCS at an altitude of 600 nautical miles (1100 kilometers) is approximately 2 nautical miles (3.7 km) over most of the field of view, but near the edges it decreases to about 5 nautical miles (9 km). The light-response characteristics of the system are such that a given albedo observed in the lower central portion of the image will appear brighter than the same albedo observed along the margins or in the corners of the image. The data are telemetered to Earth's surface and displayed on 70-millimeter film negatives (*1*).

The IDCS image for 29 March 1971 (Fig. 1) shows most of Alaska and adjacent parts of Canada. Snow cover was heavy and has accentuated the contrast between uplands and lowlands. The uplands appear white because vegetation is nonexistent or too low to conceal the snow. The lowlands appear relatively dark because trees and brush have obscured the snow. In consequence, the major physiographic elements—mountain ranges, high plateaus, and lowlands—are readily apparent, as are much of the courses of many of the major rivers. Ice-free bodies of water also appear black on the image, and this enhances the contrast between areas of high and low relief. This is especially significant in coastal waters, particularly in the fjord-land areas of southern and southeastern Alaska.

At the time the picture was taken (approximately 10 a.m. local time), the sun angle was low, ranging from about 40° in southern Alaska to about 15° in northern Alaska. In view of the average resolution of the system, only features which have topographic relief exceeding about 10,000 feet (3 km) in the south and 2000 feet (600 m) in the north and which trend generally easterly would cast shadows long enough to be discernible on the image. The dark area along the north front of the Brooks Range may be such a shadow, as there is insufficient tall vegetation in this area to effectively obscure the snow cover, and the relief ranges from as little as 2000 feet (600 m) in the western part to as much as 5000 feet (1.5 km) in the eastern part.

Because of the above factors and the small scale of the image, only those regional physiographic linears resulting

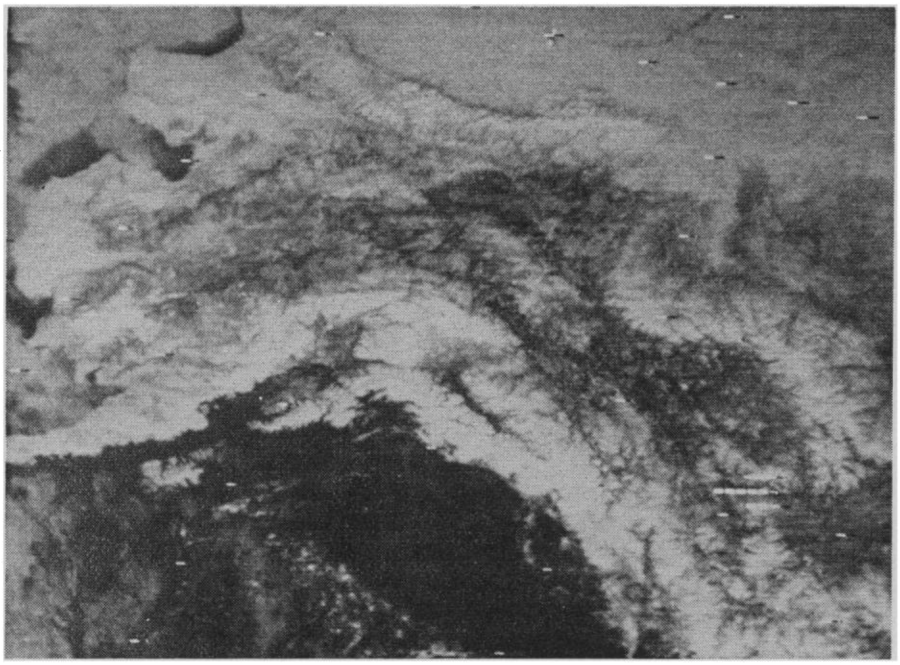

Fig. 1. Nimbus IV Image Dissector Camera System picture on 29 March 1971. [National Aeronautics and Space Administration photograph]

from major structural control will be seen. Further, a major regional feature may appear discontinuous where it neither follows a linear belt of vegetation nor casts a shadow long enough to be seen on the image. As a consequence, even a major feature may not be seen where it passes through a broad area in which little change in vegetation occurs. On the other hand, a less significant feature may be more apparent because of a sharper change in vegetation or because it casts a long shadow. Also, a linear that coincides with a scan line of the image may not reflect geologic control but rather electronic variations within the camera system, whereas a linear that lies at an angle to the scan lines and hence appears on many scan lines represents a feature that is topographically and perhaps geologically controlled.

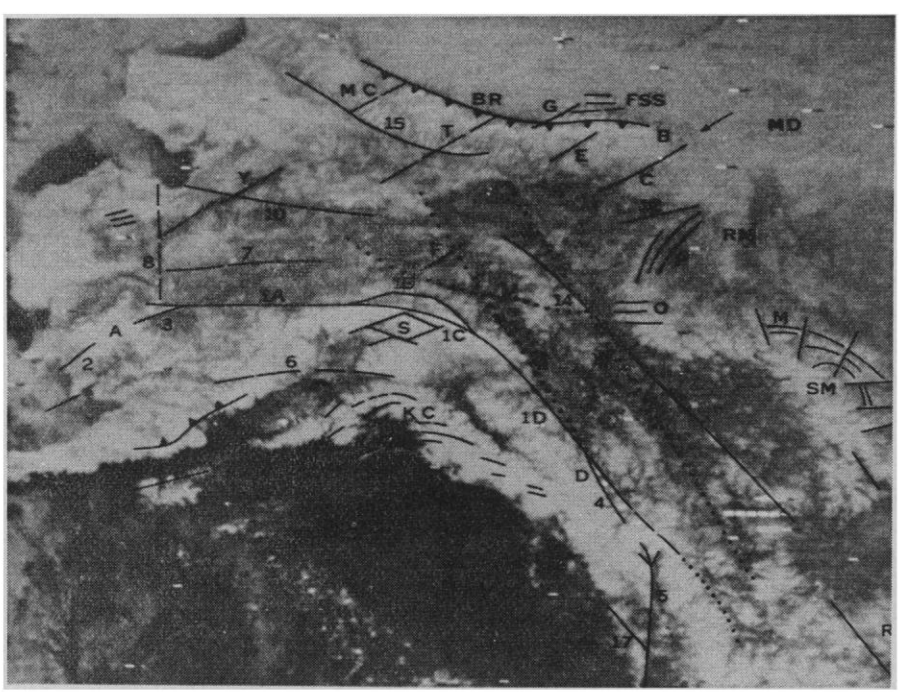

Fig. 2. Linears known or suspected to be controlled by geologic structure. (See Fig. 3 and text for explanation of symbols.) The scale varies but is approximately 1 : 19,000,000.

Traces of Known Strike-Slip Faults

The location and distribution of known and suspected strike-slip faults in Alaska (Fig. 3) and the evidence indicating their probable age and amount and direction of movement have been summarized by Grantz (*2*).

Many of the faults and linears that Grantz recognized can be clearly identified on the IDCS image (see Fig. 2): the Hines Creek (1B) and McKinley (1C) strands and the Shakwak Valley (1D) segment of the Denali fault, the Kobuk (15) and Tintina (14) trenches, and the Chatham Strait (5) and Peril Strait (17) faults. Less obvious but locally discernible are the Farewell segment (1A) of the Denali fault; the Kaltag (10), Castle Mountain (6), Iditarod–Nixon Fork (7), Togiak-Tikchik (2), Holitna (3), and Aniak–Thompson Creek (8) faults; the northern end of the Rocky Mountain trench (R); and a straight linear that includes part of the Chilkat River fault (4) on the southeast and the Duke depression (D), a well-known thrust fault zone, on the northwest.

The Yukon-Porcupine lineament (13 on Fig. 3), considered by many to be the northeastern extension of the Kaltag fault (*2–4*), cannot be recognized where it traverses the dark area of the Yukon Flats. To the east, however, two linear disruptions in the arcuate pattern of the mountain ranges can be seen. The southerly one (12) is undoubtedly the Porcupine River part of the Porcupine lineament, across which no major discontinuity has been reported (*2*, p. 34). The northerly linear (C) traverses up the lower reaches of the Coleen River and crosses into Canada just north of latitude 68°. If extended to the northeast, the linear would pass between the British (B) and Richardson (RM) mountains of Yukon Territory and out to sea beneath the Mackenzie Delta (MD). This linear follows a more northerly course than that previously suggested (*3*) (Fig. 3). However, strong facies differences in the rocks on either side of a fault in the Coleen River area favor this position for the northeasterly part of the Yukon-Porcupine lineament (*5, 6*). Further, the regional distribution of tectonic and stratigraphic elements in Yukon Territory (*3, 7*) permits a northeast-trending throughgoing structure in one or another of the northeast-trending throughgoing valleys in this area, but such structures have not, as yet, been reported.

Structural Linears in Mountain Belts

Strong physiographic linears reflecting the trends of folds and faults can be seen in many of the mountain belts. The most notable are in the Mackenzie Mountains (M), where arcuate linears, convex to the north and east, probably reflect the zone of folding and eastward thrust faulting (*3, 8*). These arcuate linears are transected by a series of short but remarkably straight linears that radiate eastward and northward from the Selwyn Mountains (SM). The radial linears coincide, from south to north, with parts of the channels of the South Nahanni River, with tributaries of the Keele River, and with the Mountain, Arctic Red, and Snake rivers, respectively. Their straightness and radial pattern suggest that they reflect tear faults, which are common in thrust-fault belts. Geologic maps of this area at scales of 1 : 250,000 or larger do not show faults in most of these positions, which are occupied by glaciated valleys; hence, movement along the faults was probably not large. The location of these tear faults may have been determined by older faults, such as those along which vertical or transcurrent movement of basement blocks has occurred (*8*).

Little detail is visible in the area where the south-trending structures of the Richardson Mountains (RM) impinge on the east-trending structures of the northwest Mackenzie Mountains (*8*). In the Porcupine Mountains (P), however, westerly convex linears paallel to known folds and west-dipping thrust faults strike into the Ogilvie Mountains (O), in which vague east-trending linears that coincide with the trends of known folds and faults are on strike with structures in the northwest Mackenzie Mountains (*8*).

In Alaska, the bold northern front of the Brooks Range (BR), which is largely controlled by massive Paleozoic rocks in the upper plates of south-dipping thrust sheets, is discernible through most of its extent. The major faults which bound the Franklin, Sadlerochit, and Shublik mountain blocks (FSS) that lie to the north of the main thrust front in the northeastern Brooks Range (*9*) are equally distinct. In the Kenai-Chugach (KC) mountains in southern Alaska, a series of short linears reflects the known westward to southwestward change in strike of folds and south-directed reverse faults in this area. These structures are associated with the northwest-trending Fairweather (16) strike-slip and the west-trending Chugach–St. Elias (16A) thrust fault systems to the east (Fig. 3) (*3, 10*), which are not visible on the image.

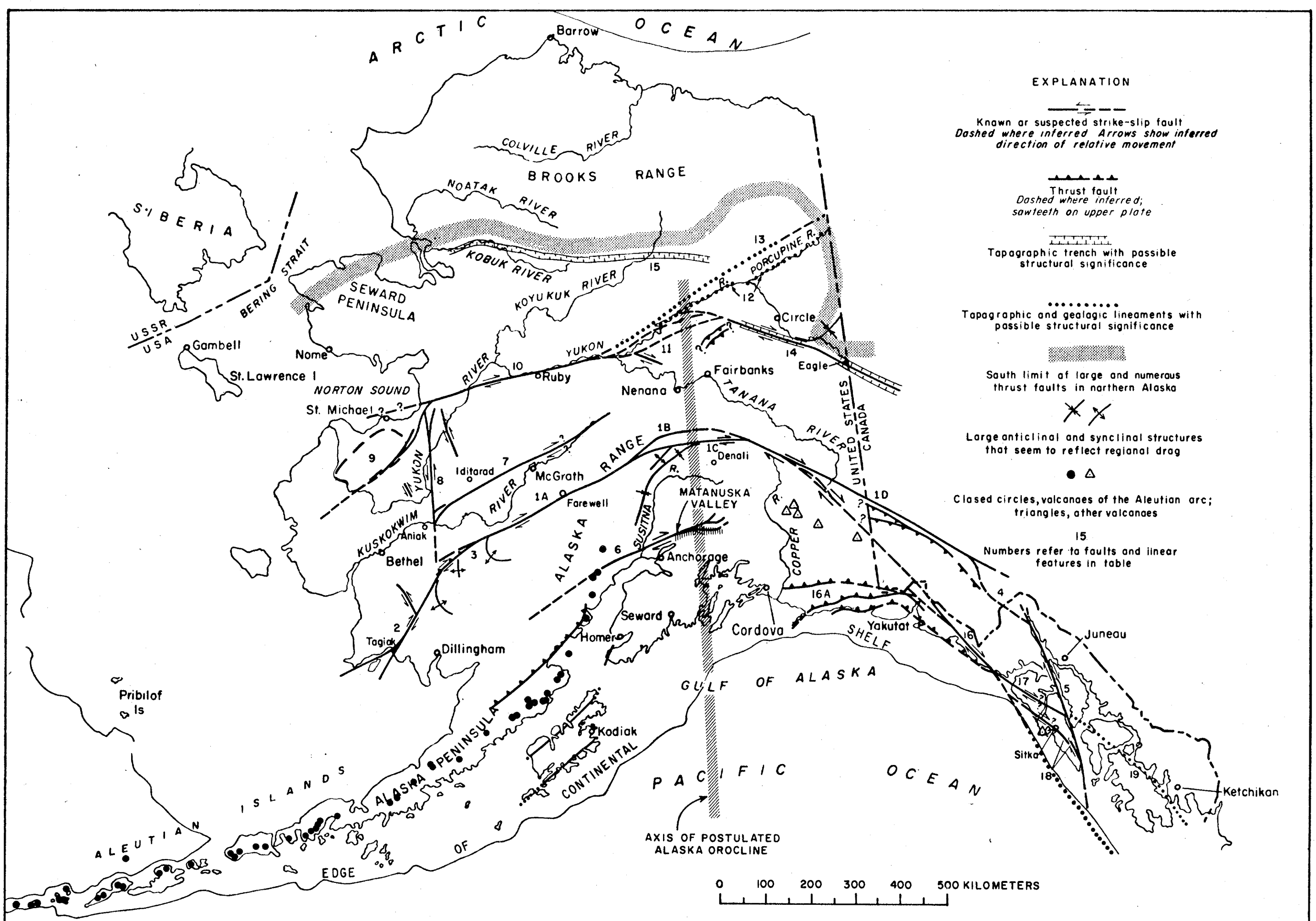

Fig. 3. Map of Alaska showing known and suspected large strike-slip faults and selected linear features [from Grantz (*2*)]. Denali fault (1) [including Farewell segment (1A), Hines Creek strand (1B), McKinley strand (1C), and Shakwak Valley segment (1D)], Togiak-Tikchik fault (2), Holitna fault (3), Chilkat River fault zone (4), Chatham Strait fault (5), Castle Mountain fault (6), Iditarod–Nixon Fork fault (7), Aniak–Thompson Creek fault (8), conjugate wrench faults in the Yukon Delta region (9), Kaltag fault (10), Stevens Creek fault zone (11), Porcupine lineament (12), structural discontinuity in northern Yukon flats (13), Tintina fault zone and trench (14), Kobuk trench (15), Fairweather fault (16), Chugach–St. Elias thrust fault system (16A), Peril Strait fault (17) Chichagof-Sitka and Patterson Bay faults (18), and Clarence Strait lineament (19).

Possible Structural Linears

In several areas additional linears, which may or may not be structurally controlled, can be seen. North of the northern end of Chatham Strait fault (5) there is a faint suggestion that the Shakwak Valley segment (1D) of the Denali fault, rather than following the Chilkat River fault (4) to join with the Chatham Strait fault (5), may continue on to the southeast, into or east of the Coast Range in British Columbia. In the Brooks Range, near longitude 157°, a northeast-trending linear (MC) appears to separate two areas of different image contrast. This linear lies near the position of the northeast-trending Makpik-Cula Creek transcurrent fault (*11*). To the south the straight northeast trend of the Yukon River and lower Koyukuk River (Y) suggests structural control. Surface mapping in the lower Koyukuk River area indicates that this part of the linear (Y) is structurally controlled (*12*). Eastward in the Brooks Range is a faint linear of similar northeast strike (T); Brosgé and Tailleur (*6*) note a linear at about this position that may reflect a change in the basement north of the range but exhibits left-lateral offsets in surface beds in the southern Brooks Range and in the upper Koyukuk River area. A parallel linear (G) forms or lies near the western boundary of the Franklin, Sadlerochit, and Shublik mountains. Many workers have noted that in the northeastern Brooks Range Paleozoic and older strata are exposed only east of this linear; to the west the older strata are covered by deposits of the Mesozoic Colville geosyncline. The East Fork of the Chandalar River (E), the northeastern part of the Yukon-Porcupine lineament (C), short linears along the upper Susitna River (S), one (F) northwest of Fairbanks, and the Togiak-Tikchik fault (2) all also reflect this trend.

Extensive linears can be seen that may be structurally controlled, although geologic mapping showing evidence of such control is not yet available. These are the east-trending linear (U) south of Fairbanks and the two southeast-trending linears (V and W) that bracket the Yukon-Tanana Upland in the northwest and, if extended southeasterly with no change in strike, would bracket the Coast Range batholithic complex in the southeast. Better image resolution and further geologic mapping are necessary to determine their geologic significance. The latter two linears (V and W) may bracket a continuous belt of dominantly crystalline rocks in the Yukon-Tanana Upland, which was uplifted or tilted, or both, in late Tertiary and Holocene time (*13*). These linears may also reflect faults in the Precambrian basement along which transcurrent or vertical movement has taken place.

Another possible lineament, even more faintly suggested on the image (indicated by arrows), extends from the Yukon-Porcupine lineament (C) southwestward entirely across Alaska. This lineament passes northwest of Fairbanks, northwest of the front of the western Alaska Range, and southeast of the Ahklun Mountains (A), and divides Alaska in two parts. As there are no indications of a throughgoing fault in Mesozoic and younger rocks along this lineament, this feature, if it exists, is an old one, largely concealed by the younger strata. It is interesting to note that along this lineament a narrow belt, characterized lithologically by a thin shelf facies representing continuous deposition from Cambrian through Silurian time and possibly separating differing facies to the northwest and southeast, has been noted in the Coleen River area (5) and from Fairbanks southwest to the lower Kuskokwim River area (*14*). Rather than a fault, this lineament may reflect an old hinge line, possibly a linear segment of an outer carbonate platform (*15*), that exerted varying control over sedimentation after the early Paleozoic. Extended northeasterly through Canada, this lineament would roughly coincide with the trend of Paleozoic shelves and depositional troughs in the Canadian Arctic Archipelago (*16*).

Regional Significance of Linears

Grantz concluded, on the basis of his analysis of the evidence of strike-slip faulting, that two main trends of surface faulting are present: east-northeast in western and central Alaska and east-southeast in eastern Alaska (*2*, p. 50). The traces of these faults on the IDCS image substantiate this conclusion. However, a number of additional lineaments seen on the IDCS image in western and central Alaska, along many of which no surface faulting has yet been reported, display a north-northeast trend not seen on Fig. 3—a trend that is more nearly orthogonal to the trend of the faults in eastern Alaska. Grantz also suggested, as an alternative to oroclinal bending, that a conjugate system of faults or lineaments may lie within the crust of Alaska, disguised by Mesozoic and Cenozoic formations and deformations along which large blocks have moved differentially, and that the present bending of the surface faults could result from selective trailing of suitably situated older faults or other structures by younger "rotational" strike-slip movement (*2*, pp. 72–73). The orthogonal east-southeast and north-northeast pattern of linears shown on the IDCS image may reflect the conjugate system of crustal structures Grantz proposed, a system that has governed the lateral translation of gross terranes of Alaska, disrupting normal facies patterns (*14, 17*).

If the east-southeast and north-northeast set of linears noted on the IDCS image does indeed reflect a pattern of fractures within the crust, it may represent part of the global "regmatic shear pattern" (*18*), one of the two sets of fractures Katterfel'd and Charushin (*19*) and others have noted not only on Earth but on other planets as well. Fractures of the dominant planetary set trend northeast and northwest; fractures of the subordinate set trend north and east. These sets of fractures are believed to have formed from stresses originating in the lithosphere of a planet in response to changes in the rotational regime of the planet and are most apparent on small-scale maps. Structures of differing trends resulting from local tectonic movements are believed to be superimposed on the planetary fractures; on large-scale maps local tectonic effects obscure the fundamental global fracture pattern. However, in the absence of data it is not possible at this time to evaluate the nature of the linears or the stresses that have produced them.

Summary

Notwithstanding the relatively low degree of ground resolution, many of the major structural features of Alaska can be identified on the Nimbus IV IDCS image, exposed at an altitude of 600 nautical miles (1100 km). In addition, linears of regional extent that may be structurally controlled can be seen, many of which have not yet been recognized in surface mapping. The synoptic view provided by the image brings into focus an orthogonal set of fractures trending north-northeast and east-southeast and not heretofore apparent in regional maps of Alaska. This orthogonal fracture set may reflect a conjugate set of fractures within the crust, which has exerted significant control over the geologic history of the state. Increased resolution in other images from space platforms, such as the resolution of 200 to 650 feet (60 to 200 m) planned for the satellite television cameras of the ERTS program (*20*), will permit the discernment of finer detail and a greater accuracy in identifying and locating geologic features.

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Measurement Structures and Psychological Laws

Measurement of psychological variables is closely linked to the testing of qualitative psychological laws.

David H. Krantz

Measurement is employed in two quite different ways in scientific research. Usually, the investigator searches for quantitative laws, relying on previously established physical measurement. This is what chemists do, for example, in weighing various products of reactions. Such weight measurements led ultimately to the periodic table and to the chemical theories suggested by it. Similarly, physiologists and psychologists measure variables such as pupil diameter in order to discover laws of functioning of the visual system and the brain.

The second use for measurement is to represent an empirical structure by an analogous or homomorphic numerical structure. It is this second use that leads to construction of measurement scales de novo. For example, the weight measure was originally introduced because the properties of numerical weights gave a convenient representation to qualitative empirical observations. Objects can be compared qualitatively in a pan balance and the resulting empirical ordering is represented by the numerical ordering of the scale values (weights) assigned to them. Similarly, putting two objects together is represented by adding their weights. A set of empirical relations that leads to construction of measurement scales in this fashion is called a measurement structure.

In physics, measurement structures are very common. In most other sciences, previous physical measurement is used to generate new empirical relations. The laws satisfied by these latter relations lead to formulation of theories, but they do not lead to introduction of new measurement, that is, the empirical relations do not constitute measurement structures, even though they were generated by use of previously established physical measures. In psychology, however, the program of introducing new numerical functions, to measure such variables as intelligence, utility, or sensation magnitude, has long been attractive. In some cases, appropriate qualitative psychological laws do lead to such new, nonphysical measurement.

In this article I review some kinds of lawful structures that lead to measurement, briefly first in physics, then more thoroughly in psychology. I conclude by emphasizing that many areas of psychology should and do operate in the same way as biology or chemistry, so that previously established physical measures are used to discover new psychological theory, but not to establish new measurement scales. In still other areas, psychological measurement structures seem quite promising.

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