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# A Graphic Approach to a Compleat Anatomy*

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## LEONARDO'S CONCEPT

MORE than 450 years ago, in 1489, Leonardo da Vinci, the greatest genius of the Renaissance and one of the most gifted minds the world has known, began to work upon a comprehensive human anatomy. It was to be an encyclopedia of man illustrated with exhaustive completeness. His copious notes show the general plan of the work, which he had hoped to complete in 1510.

> "This work should begin with the conception of man and describe the nature of the womb, how the child inhabits it, to what degree it resides therein, the manner in which it is vivified and nourished, its growth, what interval elapses between one degree of growth and another, what expels it from the body of the mother and why sometimes it is expelled from the belly of its mother before the proper time. Then you will describe what members are those that grow more than the others after the child is born, and give the dimensions of a child of one year. Then describe the grown man and the woman and their measurements, the nature of their complexions, colors and physiognomies. Then describe how he is composed of veins, nerves, muscles and bones. This you will do at the end of the book.
>
> "Then represent in four histories four universal conditions of men, to wit: Joy, with various acts of laughing, and represent the cause of laughter; weeping, in various manners with its cause; quarrels, with various movements of killing, flight, fear, ferocity, homicides and all things pertaining to such cases. Then represent fatigue from dragging, pushing, carrying, stopping, supporting and similar things. Then describe the attitudes and movement.
>
> "Then perspective through the agency of the eye and hearing. You will speak of music and describe the other senses. Then describe the nature of the five senses."

In another place he wrote:

> "Commence your anatomy with the perfect man, then make it on an old and muscular one; then go on removing (parts) by degrees up to the bones. And you will then do the child, with a drawing of the womb." (AnA, 16.)

Artist as well as scientist, Leonardo was the first great champion of the superiority of pictorial representation over verbal description as a means of conveying accurate information. He proposed to represent all parts of the body from several aspects.

> "The true knowledge of the form of any body will be from views of it from different aspects. And so to give knowledge of the true form of any member of man, *prima bestia infralli animali,* I shall observe this rule, making of each member four representations from the four sides. And in the case of the bones I shall make five, cutting them through the middle and showing the cavity of each of them." (AnA, Iv.)[1]

Leonardo's notes show that, as planned, his treatise would consist of 120 books covering the anatomy of man from conception to death, from head to sole, and would include physiology and comparative anatomy. Like many other valuable works to which this extraordinary man set his hand, Leonardo's anatomy was never completed, but he did make over 800 drawings for it. For the preparation of these he himself dissected 30 cadavera and used injections into veins, liquid wax in cavities and gross serial sections. Had even the drawings and notes which he had made become available, instead of lying unknown until very recent years, the science of anatomy would have been advanced by centuries.[2,3]

The totality of Leonardo's concept as formally expressed in the initial notes of 1489 is the more remarkable because none of the basic medical advances which might have fostered such perspective had been made. More than half a century was

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 Third of a series of articles for this journal on aids and approaches to the study of anatomy.

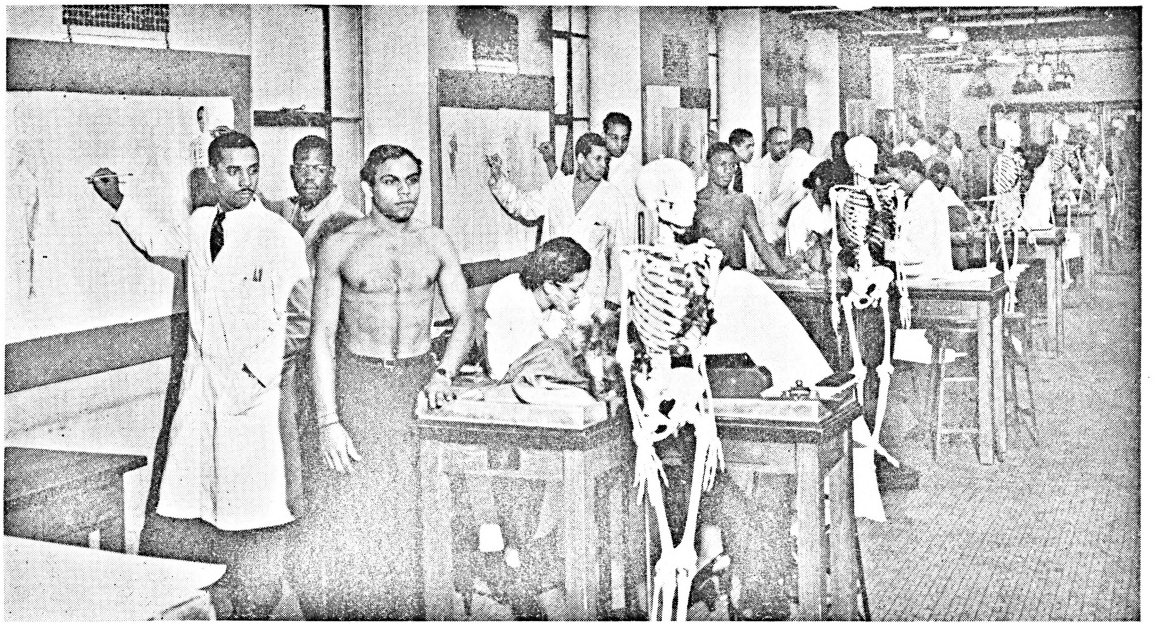

Fig. 1—Students at work in Howard University laboratory, showing use of outlines of figure for drawing-in structures as uncovered in course of dissection.

to elapse before Vesalius' anatomy, the foundation of modern medicine, would appear in 1543. The observed facts about the heart and blood vessels were not to be integrated by Harvey to establish the reality of the circulation until 1628. It would be two centuries before the medical uses of the microscope would be demonstrated by Leeuwenhoek in 1673, three and a half centuries before microscopic study would advance far enough to permit Schwann and Schleiden in 1838 to affirm that the cell was the biological unit of which all living organisms were composed, and two decades more before Virchow would make in 1858 his epochal contribution that the basis of all disease must be sought in pathology of the cell. Cuvier would not lay the foundations of systematic comparative anatomy and paleontology until the first of the nineteenth century, Darwin would not present "The origin of species," until 1859, and Mendel's pioneer researches in genetics would not be published until 1866.

It was the essence of Leonardo's genius, however, that he always searched beyond the immediate applications of a science into the fundamental principles of that science. On the practical side he has to his credit as an anatomist such items as observation of the correct inclination of the pelvis, discovery of the frontal and maxillary sinuses, of the moderator band of the heart, of the bronchial arteries and of arterial sclerosis. Of possibly greater interest is the fact that his speculations upon fundamentals led to conclusions startlingly current in the light of modern knowledge. Life was a matter of nutrition, but more than that, where there was life there was heat, the original source of which was the sun, and particularly apropos in the atomic age, "Motion is the cause of all life."

Acquaintance with his thinking, therefore, enables one to understand how Leonardo could perceive a need for an all-inclusive anatomy and how competently he could plan such a work centuries in advance of basic facts it would eventually have to include.

## CURRENT KNOWLEDGE AND NEEDS

Today we have nearly all the basic collateral materials Leonardo lacked. Embryology and histology are complete sciences. Comparative anatomy and paleontology have conclusively established man's place and relationships in the animal kingdom. Physical anthropology has brought a knowledge of human prehistory, of variation in all its aspects, and of growth and development. Genetics is on a solid foundation. Physiology, biochemistry and pathology have tremendously improved our

Fig. 2—Other side of laboratory. Note simultaneous use of skeleton, living subject, and cadaver, the three vital essentials in the study of anatomy.

understanding of vital processes and their derangements. And new advances continue without interruption.

So numerous and complex at present are known facts about human structure and function, that even more than in Leonardo's day are synthesis and simplification indicated, not on philosophical grounds alone, but on behalf of the thousands of students of varying interest who now and hereafter will require or desire a comprehensive grasp of human anatomy. This would include students of medicine, dentistry, physical anthropology, clinical anatomy, art, physical education and music, as well as those independent thinkers who, without professional motive would enhance their understanding of how our bodies are made and function.

For the special needs of these various classes of students there has developed a multiplicity of textbooks, and of difficulties. Professional anatomists have well realized the necessity of finding ways for the student to acquire more easily, more and better associated facts with broader perspective. The recent methods of Grant[3] and of Mainland[4] are examples of excellent efforts in this direction. Regimentation or excessive standardization in teaching method are neither feasible nor desirable in anatomy, however, and the way for new or different approaches may still be considered open.

## PRESENT APPROACH

The present approach to synthesis and simplification in the presentation of anatomy has taken three forms. The first was a scheme for the organization and fixation of anatomical facts, in which the ovum, the seven week embryo and the erect adult as 'master keys' were used as focal points for associations.[6] The second was the development from classical sources of a canon of proportions with which any student might prepare for himself outlines of the human figure with skeleton, from ventral, dorsal and lateral aspects, and use these outlines for personal portrayal and review of specific anatomical features.[7] The third was the use of these basic outlines of the figure as a common frame of reference for the successive presentation of the detailed anatomy of all parts and regions, introducing variations and clinical, developmental or other features of special interest as marginal items around the basic outlines detailing the subjects with which they belong. It is believed that through presentation in this manner, information imparted can be greater in amount, more quickly acquired and better retained than is possible through other means.

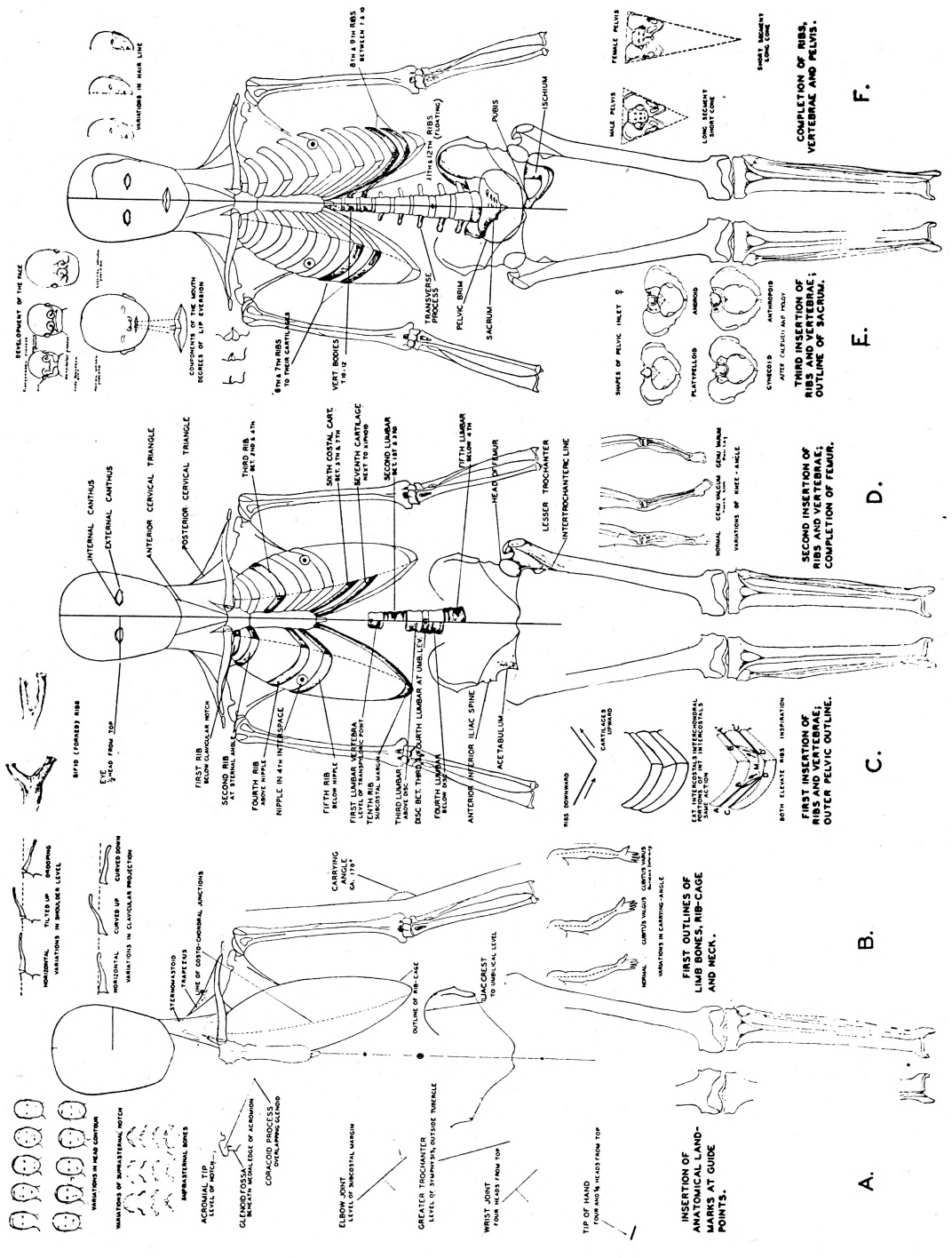


Fig. 3—Construction of ventral outline of figure. For explanation see text.



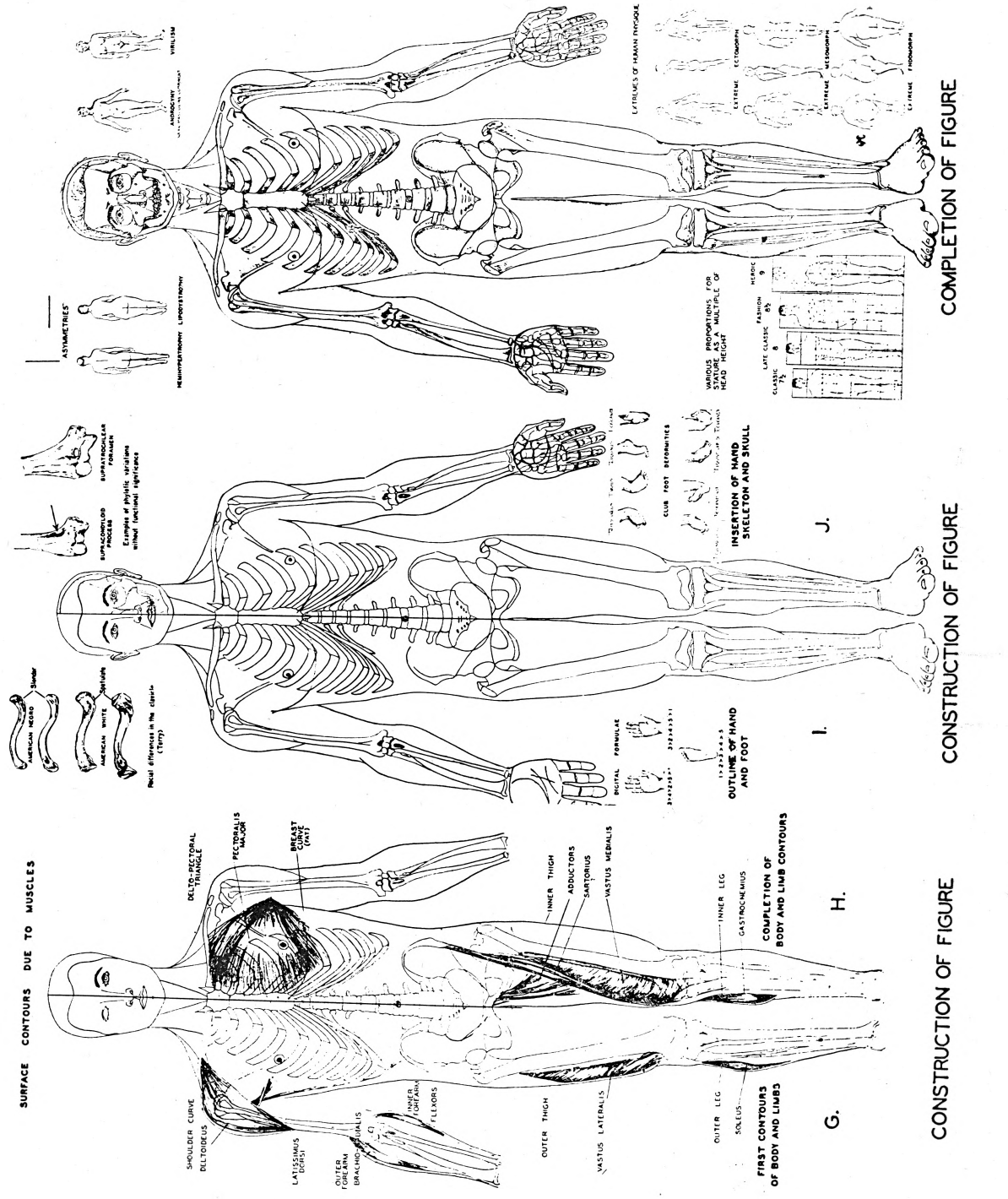


Fig. 4—Construction of ventral outline of figure. For explanation see text.

The present communication is in the nature of a progress report to show (1) greater detail than in a previous report[7] as to the manner in which the ventral outline of the figure is constructed and the use of marginal insertions; (2) the way in which medical and dental students may work upon their own charts in the dissecting laboratory; and (3) examples of student work done under supervision in the laboratory and free-hand under pressure in an examination.

### THE VENTRAL OUTLINE

Our canon of proportions uses conventionally the height of the head as its unit. Stature and shoulder breadth are given the classical values of 7½ and 2 heads respectively. A rectangular frame 7½ by 2 reads subdivided into heads and half heads is prepared. Any dimension may be used as the head height, depending upon the size of the figure desired. On this frame ten guide points, the locations of which must be memorized, are plotted. Six are called primary, because they are axiomatic assumptions. These are (1) suprasternal notch, 1⅜ heads from top; (2) nipples, 2 heads from top, 1 head apart; (3) umbilicus, 3 heads from top; (4) top of symphysis pubis, 3¾ heads from top, in center of body; (5) knee joint, 5½ heads from top; and (6) tip of medial malleolus, 7 1-5 heads from top. The remaining four points are called secondary, because they are derived from the primary. The transpyloric level is marked as midway between suprasternal notch and symphysis. As this plane is also midway between sternoxiphoid junction and umbilicus, the former (7) is now indicated by a mark the same distance above transpyloric as umbilicus is below it. Subcostal margins (8) lie slightly above umbilicus and outside nipple lines; anterior superior iliac spines (9), slightly below midpoint between umbilicus and symphysis and outside nipple lines; and tubercles of iliac crests (10) slightly above and lateral to anterior superior spines. These points and the manner of their utilization in the construction of the three views of the figure have been topically described.[7] In Figs. 3 and 4 the construction of the ventral view is shown in greater detail, but attention is particularly directed to the marginal insertions and their significance.

In Figs. 3 and 4, the letters A through J represent progressive construction through ten successive halves of the body, each half showing an advance over the preceding. The marginal insertions are designed to reinforce basic facts shown and add as much collateral information as possible. The stages shown by the respective sections are as follows:

Fig. 2, A. Here the actual anatomical landmarks represented by the ten guide points have been drawn in, acromial tip added and elbow, wrist, and tip of middle finger levels marked. The marginal insertions illustrate the phenomenon of variation in respect to two features, the contour of the head and the suprasternal notch.

B. First outlines of limb bones, rib-cage and neck have been added. Sternomastoid and trapezius muscles drawn from the living demonstrate the production of surface contours by muscles. Marginal insertions show two additional kinds of variation, one, the slope of the clavicle, which may be due either to inclination of the whole bone or curvature of the bone itself, the other, the angulation which bones of adjacent limb segments must have with each other. Such bones must lie either in the same straight line, or bend noticeably inward (valgus, 'knock-knee,' position) or outward (varus, 'bow-leg,' position). The normal cubital (carrying) and pathological (cubitus valgus and varus) angles are shown.

C. First insertion of ribs, vertebrae and pelvic outline according to a strategem previously described[7] is made. Marginal insertions show basic direction of ribs downward and medialward, and cartilages upward and medialward, demonstrating that external intercostals and interchondral portions of internal intercostals have same direction and costal relationships, and therefore the same action, as muscles of inspiration. Forked ribs are shown as a variation.

D. The insertion of ribs and vertebrae is continued according to plan and femur is completed. Lower limb angulation is illustrated marginally by the normal and genu valgum and varum deformities.

E. Third insertion of ribs and vertebrae is made, sacrum and pelvic brim are outlined and mouth is added. Marginally, descriptive types of female pelvic inlet are shown, the embryology of the face is depicted to emphasize the topographical features of the mouth, and variations in degree of eversion of the lips outlined.

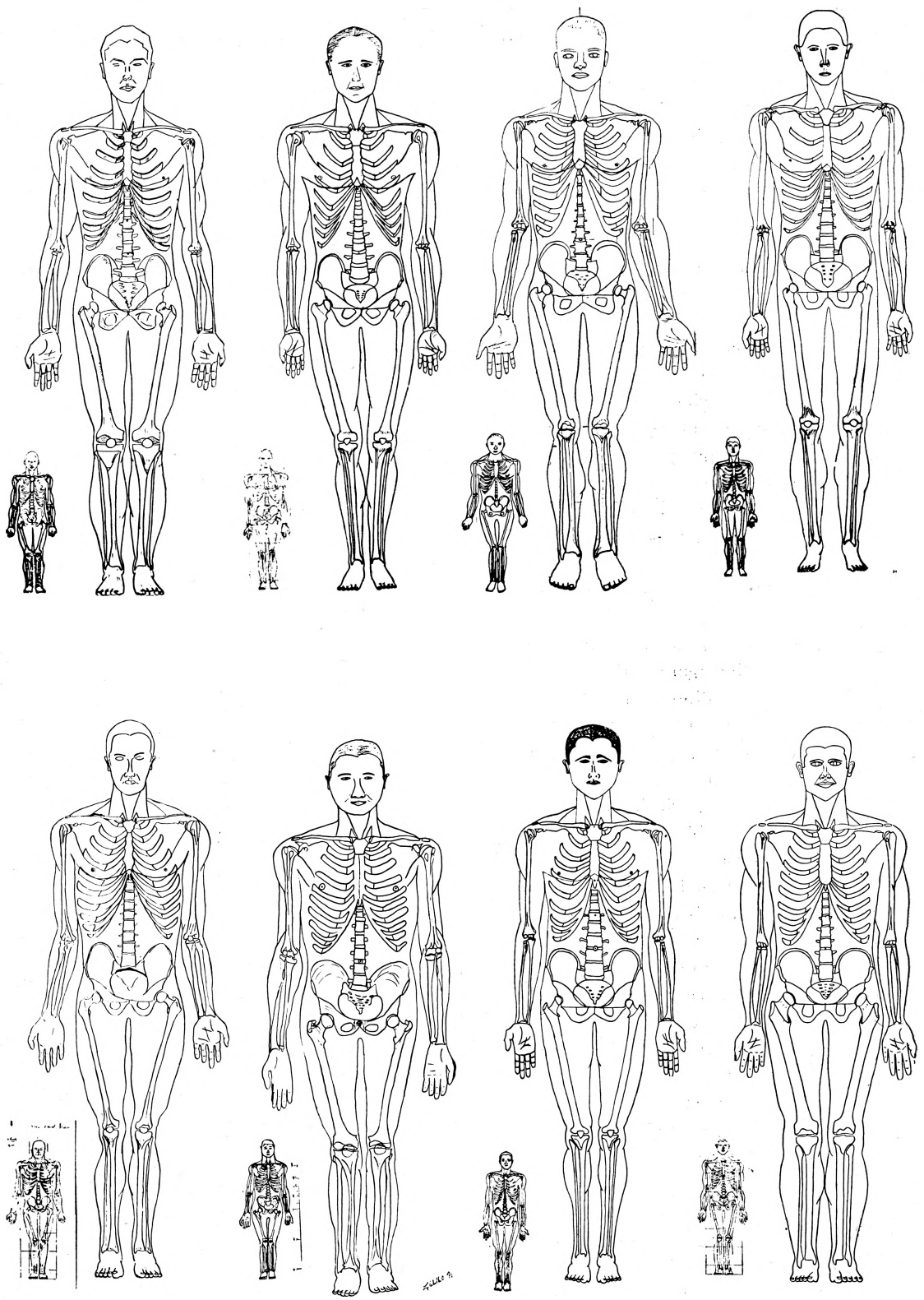

Fig. 5—Examples of basic outlines prepared by students. Large figures were made in laboratory under supervision. Insets were made on blank paper in an examination.

F. Ribs, vertebrae and pelvis are completed. Addition of pubic arch permits sex differences in pelvic facade to be shown marginally, the male as a long segment of a short cone and the female as a short segment of a long cone.

G, H. Production of surface contours by muscles having been demonstrated in the neck, the muscles producing the remaining body contours are illustrated so as to add those contours. Body is now complete except for hands and feet.

I. Hands and feet are added. In the margin, human digital formulæ for relative lengths of fingers and toes are given and a racial osteological difference is illustrated by modal specimens of the clavicle in Negro and white.

J. Skull and hand and foot skeletons are inserted to complete the figure. The addition of feet provided opportunity for marginal representation of the club-foot deformities. Continuing the illustration of variations, two of phyletic nature without functional importance are shown, the supracondyloid process and septal aperture of the humerus.

The final panel of Fig. 3 shows the completed ventral outline of the figure with skeleton. The marginal illustrations afford perspective on the rather stockily built male norm developed through our canon of proportions, as a man among men. At lower left are shown other canons of 8, 8½ and 9 heads for stature, which may be used if figures of more fashionable or heroic proportions are desired. Opposite are the familiar lean, muscular and obese extremes of human physique, while above right are shown bodily variations due to gonadal dystrophy as represented by weak masculine component in the male and virilism in the female. Last of the variations of the body as a whole, the asymmetries are shown. Vertical asymmetry is represented by hemihypertrophy, in which the right or left half of the body is larger than its mate, and horizontal asymmetry by a lipodystrophy in which the upper half of the body is of a different build from the lower.

## A COMPLEAT ANATOMY

In the same manner in which the preparation of the ventral outline was illustrated in steps of logical sequence, with appropriate marginal insertions, it will be obvious to the reader that the preparation of dorsal and lateral outlines may be similarly shown, and additional collateral facts presented with new marginal insertions. The reader will further see readily that reproductions of the ventral, dorsal and lateral outlines so prepared, may be made in indefinite number; that these reproductions may be used to present the anatomy of every region, system or desired grouping of structures in the body; and that by proper marginal insertions nearly every known cognate fact may be introduced.

What does one have when an anatomy constructed on this plan is completed? He has Leonardo's dream come true, a compleat anatomy. More than that, he has an anatomy which every student of the subject, artistically gifted or not, may learn to reproduce for himself in his formal first course, and improve and revise as his proficiency grows and yet newer knowledge becomes available.

Such a work is in an advanced stage of preparation, the method and many plates have been demonstrated to the assembled American anatomists, and physical anthropologists,[8,9] and it is hoped that publication will be possible as soon as circumstances permit. It is believed that an atlas of this kind will make it possible for a teacher, on the one hand, to present anatomy to any group of students from the same work, without having to use one text for medical students, another for nurses, a third for physical anthropologists, etc., and for students, on the other, no matter what their anatomical interest, to find what they need under one cover.

## STUDENT WORK AND RESULTS

Figs. 1 and 2 illustrate the manner in which students are encouraged to learn their anatomy graphically in the author's laboratory. Skeleton, living subject and cadaver, the vital indispensables to the learning of anatomy, are in evidence in the best Vesalian tradition.* Fiber wall-boards are convenient to every table, where structures may be drawn in on self-prepared outlines.

It has been previously indicated[7] that drawing is a primitive and natural form of human expression. The contention of many students that they cannot draw can almost invariably be easily proved a delusion. Fig. 5 shows eight examples of student

* Cf. frontispiece of the first edition of the Fabrica.

work in the Howard University laboratory. The large figures are of basic outlines, using a scale of four inches to the head, prepared by the class under supervision during scheduled sessions. The course opened on January 4, 1946 and the drawings shown were submitted as completed on January 18, two weeks later. On the same day an examination was given on which one of the questions was, "Draw on a blank sheet of paper an outline of the ventral aspect of the male human figure with skeleton in correct proportions." The inset figures are the response of the same students to the examination question. None of these freshman students, except the craftsman of the upper left hand figure, had had any particular artistic aptitude or training. In our experience, natural gift for drawing has negligible relevance to the quality of work done on these anatomical drawings, a fact which serves to emphasize the tremendous mental disciplinary value of the graphic method in compelling thorough, analytical and accurate observation, a habit invaluable to a physician.

## FINALE

A progress report on an anatomical *vade mecum* designed for the student in the atomic age has been rendered, in testimony of the fact that Leonardo's goal of a compleat anatomy may yet be aspired to and possibly some day realized.

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