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The last two decades have seen a great increase in the application of scientific methods of investigations in the problems of fire of undetermined origins. During the same period new emphasis has been laid on the medical aspects of sudden and violent deaths. The experts in this field can contribute much in arson investigations. In any fire in which there is a death, problems are apt to arise in two principle categories. These are the identification of the deceased and the cause of the death.

IDENTIFICATION OF BURNED BODIES

The application of anthropological techniques to the problems of identification of partly destroyed bodies will frequently yield an unexpectedly large amount of information. The post mortem examiner not only has available these techniques but in the course of a complete autopsy may come upon scraps of clothing or other tiny bits of evidence of great value to the investigator of a fire.

Determining the Sex of the Remains. At first approach the examiner must seek carefully for remnants of clothing. The finding of fragments, even a few inches in diameter, may be of real importance because of the differences in clothing between the two sexes. In this regard, attention should be paid to the scene at the time the body is removed since, if there are two or more bodies, it is important to relate any clothing or other fragments removed from the scene to the proper body.

It is uncommon for the body of an adult human to be completely destroyed during the burning of a dwelling or office building. The head and extremities may be absent but the pelvis, spine, and not infrequently soft tissue structures of the lower abdomen remain. Careful pathological examination of these may reveal recognizable portions

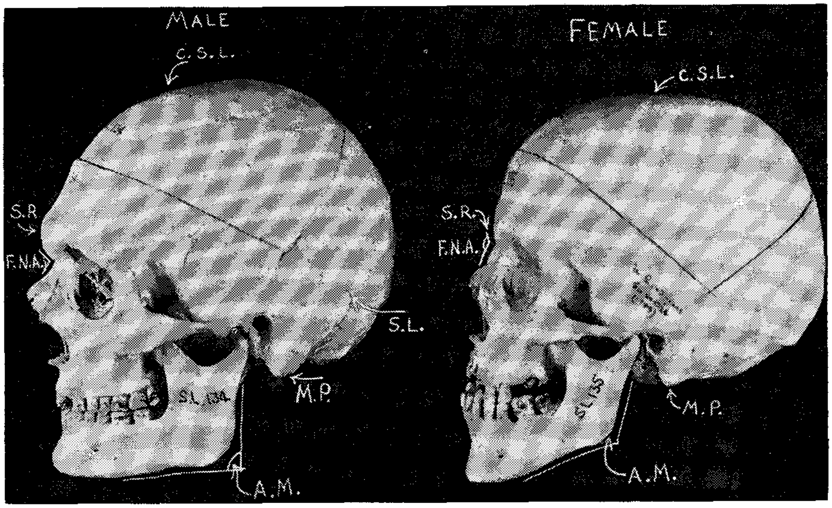

Figure 1.

Adult skulls showing characteristic sex difference. AM—Angle of mandible. C.S.L.—Coronal suture line. F.N.A.—Frontonasal angle. M.P.—Mastoid process. S.R.—Supraorbital ridge.

of reproductive organs which determine the sex of the body. There may still be considerable portions of bone, and these may be sufficient to characterize the individual. A few of the generalizations useful in determining sex from skeletal remains follow.

The bone weight of the male is generally heavier and the muscular insertions in the long bones coarser than in the female. Figure 1 presents a male and female skull for comparison, and it may be seen that the supraorbital eminences or ridges of bone over the eyes are heavier in the male. The frontonasal angle is more acute in the male than is its female counterpart. The angle of the mandible is ordinarily less than 125 degrees in the male while the opposite is true in the female. The mastoid processes are more massive and prominent in the male than in the female, and the orbital openings tend to be rectangular in the male whereas they are oval in the female. The male forehead is rounded and slopes backwards in sharp contrast in the erect frontal bones of the female skull. Many other characteristics of the skull speak clearly to the anthropologist of the sex of remains under study.

The bones of the pelvis show even more prominent sex differences than the skull. Nature intended the female pelvis to be the passage way for the off-spring without which the race would vanish from the earth. A summary of the anatomical differences reflecting this intent may be cited. The pubic arch or angle below the pubic bones is generally narrow and frequently less than 60 degrees in the male whereas it

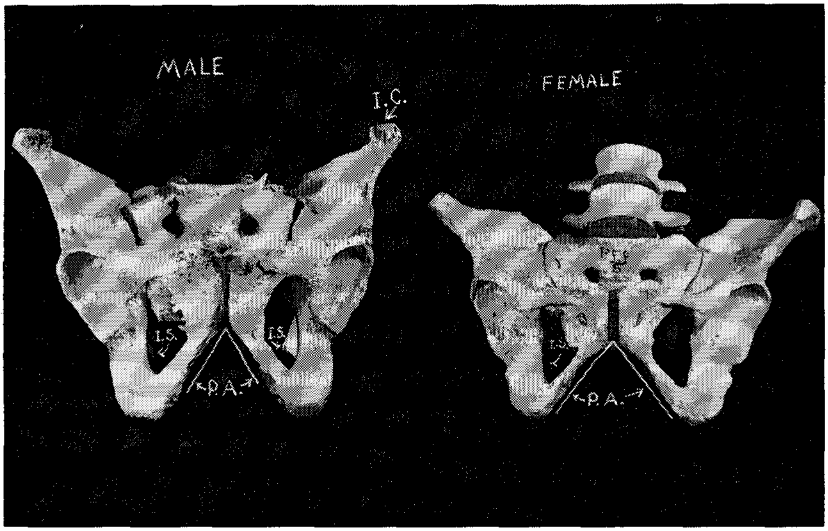

Figure 2.

Adult pelvis showing characteristic sex differences. I.C.—Iliac crest. I.S.—Ischial spine. P.A.—Pubic angle.

averages well over 70 degrees in the female (Fig. 2). The internal size of the pelvis as determined by the distance between the spines of the ischial bones averages 15 to 30 percent greater in the female pelvis despite the smaller size of the entire structure. The hip sockets of the male pelvis are larger and face more laterally than those of the female. This is one of the explanations of the differences in gait between the sexes. The curve of the sacrum is much lower in the female pelvis than in the male with consequently greater room for the passage of the infant's head through the outlet of the pelvis.

Determining the Age of a Burned Body. The ravages of time are demonstrable in both the skeleton and the soft tissues of the body. The developing of hardening of the arteries is one of the principle items by which the pathologist estimates the age. Thus, the finding of extensive hardening accompanied by calcium deposition in the walls of blood vessels of the heart may usually be interpreted as indicating an age over 50. The prostate gland enlargement prone to occur in men past the 5th decade of life occasionally gives useful information by its presence.

The skull undergoes a well defined sequence of changes with increasing age. If it is present in a burned body, an estimate of age accurate to plus or minus 5 years may frequently be reached. The individual bones which comprise the skull in youth unite in later years to form a single continuous bony skull in the very old. The lines of juncture between the individual bones are known as suture lines, and the degree of closure or disappearance of these suture lines is a basis for estimating age. The midline (sagittal) suture for example, begins closing at about 22 years of age and is usually obliterated by 35. The suture between the frontal and parietal bones (CSL in Fig. 1) follows the sagittal closure by two to five years. The sutures around the ear begin to close in the early 30's but even in the 80's are rarely completely closed.

In the case of skeletons under 25 years of age fusion of the ends of the long bones with their shafts progresses at rates that have been carefully determined by X-ray (1) and study of the skeleton. In addition the points in which bone formation occurs in the largely cartilaginous skeleton of the new born are well defined in relation to age. Study of these elements of a skeleton, under 22 years of age in the female and 25 in the male, will ordinarily allow an anthropologist to estimate the age within a year or two. Another characteristic which speaks of age, particularly in the young, is the dentition. Almost every school boy feels he has outgrown his infancy when his six year molars erupt and that he is nearing manhood when his 12 year molars appear. The medicolegal pathologist will frequently enlist the aid of a dentist when estimating the age of an individual. Once the full dentition is obtained, wearing of the occlusal surfaces of the teeth and the degree of shrinkage of the mandible in cases where teeth have long been absent may yield some information regarding the age.

Height of the Body. There is available a series of formulae developed by Karl Pearson (2) over 50 years ago which allow the arson investigator to estimate the height of a burned body even though much of the body is missing. Typical is the following applicable to the dry bone of a male:

$$S = \frac{81.31 + 1.88\ F}{2.54}$$

Where S is height in inches and F is the length of the thigh bone (femur) expressed in centimeters. Other formulae based on the length of the arm bone (humerus), the leg bone (tibia), and the forearm bone (radius) are available. There are also composite formulae which make use of two or more bone lengths and are slightly more accurate than the single bone calculations. While not valid in the case of children or those rare individuals with abnormal stature due to glandular disease the general application of these formulae will yield results accurate to within one inch of the true height of the subject.

Determining the Racial Origin of Skeletal Remains. Obviously the presence of even small fragments of unburned skin yield valuable evidence in regard to their racial origin. In the absence of these recourse must be had to the skeletal remains for this important identifying data. The three great racial groups, yellow or mongoloid, white or caucasoid, and black or negroid in their pure occurrence are differentiated with ease. Admixtures, especially of the latter two, however are common in our country and tax the skill of the most expert anthropologist at times. Some of the more easily recognized differences in the white and negro races may be enumerated. The skull of the latter tends to be longer and of lower height than does the caucasoid cranium. Thus, the height index which is the quotient of height divided by length averages 0.75 or above in the white and below 0.70 in the negro race. The long bones of the extremities usually exhibit a distinctive ratio in the two racial groups, in that the quotient of length of tibia to length of femur is greater than 0.80 in the negro and less than this figure in the white race. Similarly, the quotient of radius to humerus is less than 0.75 in the caucasoid and greater than 0.80 in the negroid skeleton. The pelvis shows two points of racial difference—the white is wider in proportion to its thickness than is the colored. This is expressed in the formula:

$$\frac{\text{Anteroposterior diameter of pelvic brim}}{\text{Width of pelvic brim}}$$

The quotient averages over 0.90 in the negro and less than 0.80 in the caucasoid pelvis. The other difference is one of shape rather than a numerical index and concerns the configuration of the hip bones (iliac crests). In the white race, these are generally flaring and relatively horizontal whereas the negroid characteristic is for the width between the iliac crests to be narrowed, due to more erect configuration of these bones in relation to the remainder of the pelvis. Curiously this peculiarity of the pelvis is a strongly dominant one and may be well developed and give strong evidence of some intermingling of racial origin even though the skin, hair, and other features of the skeleton do not reveal clear cut evidence of negroid ancestry.

Cause of Death of Bodies Found in Fires

The pathologist who examines a burned body recognizes several important sources of evidence concerning the existence of life in the body during the fire. The oldest and most easily conducted study is that for carbon monoxide in the blood or tissue of the deceased. The ancients were aware that a fire burning in a closed room or under any but the most favorable conditions of combustion produced a poisonous gas. Livius, at the time of the second Punic war, about 200 B.C., stated "The commanders of the allies and other Roman citizens were suddenly seized and fastened in the public baths for guarding where the glowing fire and heat took away their breath and they perished in a horrible manner." Again the death of Seneca in 68 A.D. is described in the terms "committed suicide by the coal vapors." Diocletian in 300 A.D. seems to have reached the ultimate in the use of this knowledge and is given credit for killing many of the Christian martyrs by using "the greenest possible most smoke producing wood for this purpose."

It is an observed fact that carbon monoxide, an odorless colorless gas, is produced in dangerous amounts in practically every building fire. It has an affinity for the red blood cell pigment hemoglobin that is in excess of two hundred times that of oxygen, the normal combining agent of the hemoglobin. Therefore, the inhalation of as little as 1% of carbon monoxide in inhaled air along with twenty percent oxygen leads in a minute or two to displacement of nearly 90% of the oxygen from the hemoglobin. Such a "90% saturation of the blood with CO" is, of course, immediately fatal since the tissues throughout the body depends on the hemoglobin to bring its oxygen supply from the lungs and exchange it for the waste products of tissue metabolism. One half of one percent of carbon monoxide in the air will lead to fatal asphyxia of persons exposed for less than one half hour.

Mine explosions with fire have been known to yield as high as 8% of carbon monoxide; locomotive smoke averages 2% of the lethal gas. The amounts found in house fires vary but are usually in the range 0.1 to 5.0%. A simple calculation will elucidate the danger of carbon monoxide production in such an insignificant conflagration as a bed fire. One ounce of CO gas occupies about one cubic foot at ordinary pressure and temperature. This one ounce of CO would be equivalent of 1% of the gas in 100 cu. ft. of air. The production of one pound of CO would give the rapidly lethal 1% concentration in a 10 x 16 x 10 feet room. Now CO is actually only 43% carbon, so the carbon equivalent is but seven ounces. Further, the average carbon content of wood or cotton fiber is about 35%. In other words, 20 ounces of cotton contains 7 ounces of carbon. Finally, if one assumes that combustion is not totally choked and only one fourth of the carbon becomes carbon monoxide, a common sequence in smoldering fires, it would require the combustion of four times as much wood or cotton, i.e.

80 ounces or only five pounds to produce a lethal concentration of carbon monoxide in a room as large as 10 x 16 x 10 feet.

The union of carbon monoxide with blood produces a bright pink coloration of the blood, and this pink tint in the skin or organs is often so well developed in bodies found in fires that the investigator can state with only casual examination that the victim was alive for some time during the fire. More accurate and sensitive laboratory techniques are available and should be used in testing for CO in the blood or tissue of every victim of arson. Failure to demonstrate concentrations of over 10 percent CO saturation of the victim's blood should immediately arouse the suspicion that the body was dead before the fire started. The usual finding, even where burning is the true cause of death of a fire victim, is of a 20 to 50 percent or greater CO saturation. Many fire victims whose bodies are not seriously burned are found to be dead of CO poisoning. In such cases, the CO saturation is usually from 40 to 70 percent.

Another sign of life during the fire is the presence of smoke or soot inhalation. The lining membranes of the windpipe and bronchial tubes are moist and will trap soot particles from inhaled smoke. These are readily observed at autopsy, and their absence may usually be taken to indicate that breathing had ceased before much smoke was present in the air, hence that death had occurred before the fire. Still another sign of life during a fire is the presence of true blistering and reddening of the skin. The typical blister of a burn forms because fluid rich in protein escapes from capillaries injured by the heat and accumulates within the skin. This phenomenon requires that the capillaries be distended with blood under the pressure of the circulation. In severe shock and at death this pressure is no longer extant, hence blisters will not form in burned skin after death. The localized redness seen around the edges of a burn is due to increased blood content in blood vessels dilated because of injury by excessive heat. As with blistering, this requires an active circulation of blood under pressure, and it will not occur unless life exists after the injury is sustained.

A pathological examination of a fire victim is not complete unless an alcohol determination is made. Our studies have shown (3) that one-third of the victims of conflagrations are under the influence of alcohol at the time of their death. The significance of such findings, both in regard to the cause of death and the cause of the fire, is evident.

The complete post mortem examination of a fire victim may disclose evidence that death or at least severe injury preceded the fire. The

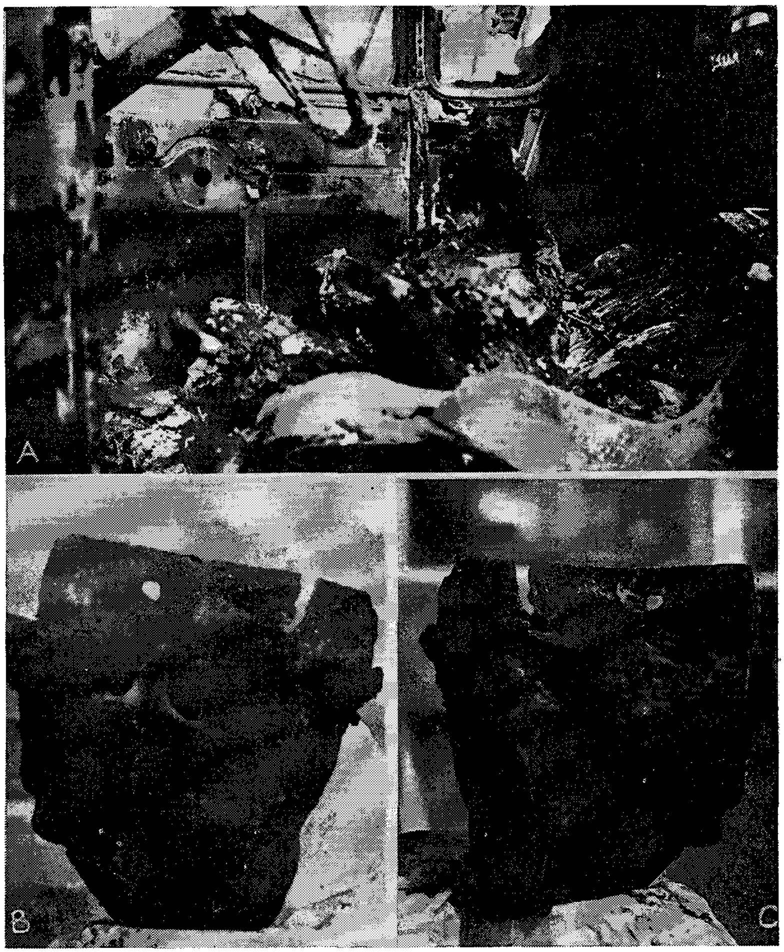

Figure 3.
Burned body of a murder-arson victim. *A*. Body as discovered in burned automobile. *B* and *C*. External and internal views of skull showing bullet hole. Despite the apparent extensive destruction of the body as found in the car, a careful post mortem examination disclosed the evidence of homicide.

finding of antemortem injuries such as bullet or stab wounds or blunt injuries is of greatest importance in an arson investigation (Fig. 3). That such injuries may be concealed by extensive burning of a body makes the task of the pathologist more difficult in dealing with burned bodies than in almost any other type of case. The X-ray is an invaluable tool in the search for fractures or bullets in a burned body. In regard to fractures, mention must be made that fire and heating "per se" may cause severe fractures of the long bones and skull. This is due to the explosive effect of steam generated within the confined narrow space or cranial cavity by the overheating of the fluid content of

Figure 4.

"Fire fractures" in the vertex of the skull. This individual had not sustained any blunt injury to the head before the fire nor did he fall during the fire.

these cavities. In the skull especially, multiple radiating fractures through the entire thickness of the bone may develop before the scalp is completely destroyed (Fig. 4). This leads to escape of boiling bloody fluid from the brain cavity to the region under the scalp where it spreads out widely within and beneath the muscle layers. If burning ceases at this stage, the picture can easily be misinterpreted by the inexperienced autopsy surgeon as antemorten skull fracturing with bleeding into the scalp giving rise to the false allegation of blunt injury to the head of the victim.

In occasional cases where only small bits of tissue or bone remain of a body removed from the scene of a fire, the question may be raised of their identification as of human origin. The answer can usually be had with great certainty by the use of specific agglutination tests using serum known to react only with human material. Microscopic examination of tissue fragments coupled with the serological procedures will practically always allow recognition not only of the fact that the tissue is human but also of the specific part of the body represented by the fragment.

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