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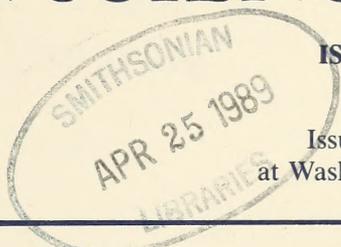
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Skeletal Biology of Prehistoric Ecuador: An Ongoing Research Program

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In 1973, excavation and analysis of a large Late Integration Period cemetery at the site of Ayalan on the southern coast of Ecuador resulted in the first detailed scientific glimpse at the complex biological variation and evolution of the prehistoric inhabitants of Ecuador.¹ Since then, the Smithsonian Institution and the museums of the Banco Central del Ecuador in Guayaquil and Quito launched a long term program of collaboration in the excavation and analysis of key prehistoric mortuary sites. With Banco Central support of Ecuadorean and foreign archeologists and Smithsonian support for human skeletal analysis, considerable progress has been made.

Our understanding of prehistoric biology has been enriched by published reports of culturally modified teeth,^{2,3} skeletal effects of activity-induced posture,^{4,5} and of the general skeletal biology of samples from the pre-ceramic site of OGSE-80 on the Sta. Elena Peninsula⁶, the highland site of Cotocollao dating from about 540 B.C.,⁷ the Jambeli coastal site of San Lorenzo del Mate in Guayas Province⁸ and the coastal Guangala site (100 B.C.) of OGSE-MA-172.⁹ These

published reports allowed in 1984 the first synthetic review of biological temporal trends within prehistoric Ecuador.¹⁰ At that time the data suggested a general temporal increase in certain pathological conditions, and other indicators of population stress.

Articles within this volume of the Journal of the Washington Academy of Sciences report on recent analysis of human remains from three additional important Ecuadorean coastal sites, La Libertad (OGSE-46) dating from the Engoroy Period, 900 B.C. to 200 B.C.; Agua Blanca (OMJPMN180) representing the Mantefio culture of the Late Integration Period, 800 A.D. to 1500 A.D.; and the northern coastal site of La Tolita, dating from 200 B.C. to 195 A.D. These three reports result from analysis conducted in Ecuador during the summer months of 1986 and considerably augment the previously available information on Ecuadorean prehistoric biology. The new data confirm many of the temporal correlations suggested in 1984, but also suggest more variation and complexity than previously thought. New evidence is suggested for cranial deformation involving

the use of a band at La Libertad, the occurrence of metatarsophalangeal alterations (kneeling facets) on both males and females (previously known in South America only in females from Ayalán), greater living stature at La Libertad and La Tolita than previously known from prehistoric Ecuador and the highest reported frequencies of trauma, infectious disease, and alveolar abscesses from La Tolita. Lack of porotic hyperostosis in the three newly reported samples, low frequencies of dental hypoplasia and caries at La Tolita and absence of carious lesions at Agua Blanca clearly show that temporal correlations of at least these pathological conditions are much more complex than previously suspected.

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Human Remains from OGSE-46 La Libertad, Guayas Province, Ecuador

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ABSTRACT

Excavations conducted in 1984 at Site OGSE-46, La Libertad Ecuador, produced 13 burial features dating from the Engoroy Period, circa 900 B.C. to 200 B.C. Analysis of the human remains in 1986 suggests the sample was biased against immature individuals, but otherwise indicates a population with tall stature, high frequencies of infectious disease and rapid dental attrition, but low frequencies of dental caries and no examples of trauma or porotic hyperostosis.

From July 16 to July 31, 1984, excavations were conducted by Karen Stothert in one section of a large site called OGSE-46, in the present town of La Libertad in Guayas Province, Ecuador. The excavation was sponsored by the Museo Antropológico of the Banco Central del Ecuador, Guayaquil and was concentrated in an area known as La Florida, near the Colegio Sta. Terecita and the Hotel Samarina. According to Stothert (Pers. Com.), this portion of the site contains refuse from Valdivia and Machalilla cultures with some Engoroy and Guanga material from the upper levels. Thirteen burial features were located and removed in the excavation. The few cultural associations present suggest with one possible exception that all of the bur-

ial features relate to the Engoroy period of cultural development and thus date from about 900 B.C. to 200 B.C. The exception may be the extended primary skeleton of Feature 14 that may date to the historic period.

In July of 1986, human remains from these 13 burial features were transported to the author's makeshift laboratory outside of Quito for analysis. After arrival, the plastic bags of bones were removed from the cardboard cartons, and sorted by feature. The human remains were then washed using water and a soft brush, dried, inventoried, analyzed, photographed, and repacked into the original cartons. Most of the procedure outlined above was conducted between July 20, 1986 and August 4, 1986. Following anal-

ysis, the cartons were transported back to Guayaquil for permanent storage and curation.

The following is a discussion of the results of that analysis, including a detailed description of the contents of each burial feature. Information on positions and associations observed in situ was graciously provided by Stothert. Note that all measurements are in mm unless otherwise indicated. Methodology employed and the measurements and observations utilized follow those outlined by Ubelaker.^{1,2}

Feature 1: This secondary feature was located at Cut A at a very superficial level. The material had been moved prior to excavation and was possibly associated with a broken vessel.

Human remains present consist of one right humerus, one left and one right ulna, one right scapula, one left temporal, one right maxilla, three left and two right mandibles, one lumbar vertebra, and one left hand navicular.

All three of the individuals present here appear to represent females. The left temporal shows a very small mastoid process and the three left mandibles all show female characteristics.

Two of the mandibles show considerable antemortem loss of teeth with the probable associated bones showing porosity and thinning of the cortex, suggesting an age at death of between 45 and 55 years. A third mandible shows considerable anterior dental wear, but little attrition on the posterior teeth. An age at death of between 35 and 40 years is suggested. No estimates of stature could be made from these fragmentary remains. No evidence of disease was noted.

For the cranium and first mandible, only five maxillary teeth are present while all of the mandibular teeth had been lost antemortem. One of the five teeth present is carious with loss of the distal half of the crown. No evidence of alveolar abscess was noted and calculus varied from slight to moderate.

The second mandible shows antemortem loss of the left premolars and molars.

The third mandible has six teeth with one molar missing antemortem. One carious lesion 1mm in length was noted in the occlusal surface of the left second molar. Alveolar abscesses are present in association with the left and right first molars. Calculus deposits are all slight.

Measurements and observations of one mandible are confined to height of ascending ramus, 50, minimum breadth of ascending ramus, 27; and corpal length, 76. Mylohyoid bridge is absent bilaterally and accessory mental foramen is present on the left but absent on the right.

Observations on another mandible consist of the presence of mylohyoid bridge on both sides, and the absence of accessory mental foramen, auditory exostoses, marginal foramen of tympanic plate and tympanic dehiscence.

Feature 3: This secondary burial of an incomplete skeleton was found in Cut A, 20 cm below the surface.

Human remains present consist of one left radius, one right ulna, both femora, the left tibia, one fibula fragment, both temporals, both maxillae, one right mandible, the first and second cervical vertebrae, the left hand navicular, the right calcaneus, and the left talus.

Male sex is suggested by large mastoid processes and general robusticity.

Age at death of about 35 to 40 years is suggested by well developed bone cortex and the extent of dental attrition.

The estimated length of a right femur of 375 suggests a living stature of about 151 cm (4 feet 11 inches) using the formulae of Genoves.³

No evidence of disease was noted, but the incomplete cranium shows lambdoidal deformation. The occipital is very flat with a slight depression extending around the upper superior surface of the occipital perhaps indicating the use of a band.

Twelve teeth are present with two missing antemortem. None are carious, but evidence for alveolar abscesses is present

bilaterally at the sites of the maxillary second and third molars. Calculus varies from slight to large.

The following measurements and observations were recorded: nasal breadth, 25; maxillary alveolar length, 42; maxillary alveolar breadth, 65; palatal length, 31; palatal breadth, 40; minimum breadth of ascending ramus, 29; height of mandibular symphysis 31; corpal length, 86; absence of mylohyoid bridge, accessory mental foramen, infraorbital suture, squamoparietal synostosis, auditory exostoses, and tympanic dehiscence; presence of marginal foramen of tympanic plate on the left but absence on the right.

Feature 4: This secondary burial of multiple individuals was found concentrated within a 50 x 45 cm area within Cut A at about 20 cm below the surface. The vertebral column, leg and foot regions were still articulated.

The following bones were present representing two individuals: two left and one right humerus, two left and two right radii, two left and two right ulnae, two left and two right femora, two left and two right tibiae, one left fibula, one left and two right clavicles, two left and two right scapulae, two left and two right maxillae, two left and two right mandibles, two left and one right innominate, one left patella, one first and one second cervical vertebrae, four other cervical vertebrae, 14 thoracic vertebrae, six lumbar vertebrae, one sacrum, one right lunate, one right capitate, two left and two right hamates, the following metacarpals; one left first, one left and one right second, one left and one right third, one left and one right fourth, one left and one right fifth; six proximal hand phalanges, five middle hand phalanges, one left calcaneus, one left and one right first metatarsals, and 16 ribs.

Morphology of the pubic bones suggests that the older individual is probably female. The innominates show wide sciatic notches, rough auricular areas, deep preauricular sulci, and a wide right

pubis. Sex cannot be estimated reliably for the other younger individual.

Epiphyses are not yet attached on the distal left radius, distal right ulna, distal femur, proximal tibia, and proximal right first metatarsal. The left ischium is not united to the ilium. The second molars have erupted, but show roots only 75 percent formed. Collectively, these data suggest an age at death of about 10 years. The extent of dental attrition and other factors suggest an age at death for the adult of between 30 and 35 years.

An estimated length of the right femur of 398 suggests a living stature of about 153 cm or 5 feet 0 inches, using the formulae of Genoves.³

No observations of disease were made for either individual.

Twenty-seven teeth of the adult are present with none absent antemortem. Two of the teeth are carious with lesions 4mm in length on the occlusal surface of the mandibular right third molar and 2 mm in length on the occlusal surface of the left mandibular third molar. No alveolar abscesses are present, but eight of the teeth show hypoplastic defects (Figure 1). The positions of the defects on the crown surfaces suggest they were formed at about the ages of two and six years. Calculus deposits ranged from absent to moderate deposits.

Twenty-six permanent teeth are present belonging to the immature individual. Only the mandibular third molars are absent antemortem, probably reflecting congenital absence. One carious lesion was located on the buccal crown surface of the mandibular right second molar. Calculus varied from absent to slight.

The following measurements and observations were recorded for the adult: upper facial height, 71; nasal height, 52; nasal breadth, 26; orbital height, 34; orbital breadth, 38; minimum breadth of ascending ramus, 33; height of mandibular symphysis, 31; presence of mylohyoid bridge and supraorbital foramina; and absence of accessory mental foramen and infraorbital suture.



Fig. 1. Hypoplastic defect on left maxillary canine of adult from feature four.

Feature 5: This apparently represents a primary burial from Cut C that had been disturbed prior to excavation. The skeleton had flexed legs and was facing east.

Bones consisted only of the following: one radius fragment; one ulna fragment; one left femur; one left clavicle; one left and right innominate; one lumbar vertebra; one right fifth metacarpal; various hand phalange fragments; one left talus; one right fifth metatarsal; and various rib fragments.

A narrow sciatic notch and flat auricular area on the innominates suggest male sex.

The appearance of the bone cortex, lack of degenerative change and extent of fusion and remodeling of the iliac crest epiphysis suggest an age at death between 20 and 30 years.

No measurements were possible and no evidence of disease was noted.

Feature 10: A secondary burial located at Cut E between 15 and 55 cm below the

surface. This collection of bones was located on top of a shell spoon in association with a green bead of serpentine. The long bones were positioned vertically in the soil.

The following bones of two adults are present: one left and one right humerus; one left and two right radii; one left and one right ulna; two left and two right femora; two left and one right tibia; one left and one right fibula; one left and one right clavicle; one left and one right scapula; one left and one right temporal; two left and two right innominates; one left and two right patellae; one first, one second and four other cervical vertebrae; eight thoracic vertebrae; one right hand navicular; one left greater multangular; one left capitate; one right second, third, and fourth metacarpal; eight proximal hand phalanges; two middle hand phalanges; one left and right calcaneus; one left cuboid; one right first metatarsal; one left second metatarsal; one right third metatarsal; and ten ribs.

Morphology of the bones suggests that one male and female are present.

The female skeleton lacks a cranium and mandible, but considerable porosity within the long bone cortex and other degenerative changes suggest an age at death between 45 and 55 years.

An age at death for the male skeleton of between 45 and 50 years is suggested by the extent of cranial suture closure and metamorphosis of the pubic symphysis.

Measurements of the left radius (237), right radius (236), left ulna (256), left ulna (256), and left clavicle (159) suggest a living stature of about 166 cm (5 feet 5 inches) for the male using the formulae of Trotter and Gleser.⁴

Both tibiae and fibulae of the female show porosity within the cortex and periosteal apposition (well remodeled) over most of their shafts (Figure 2). The distal femora show slight indications of well remodeled periosteal apposition as well. In addition, a right third metatarsal has a bony extension 7 mm long on its medial proximal border.

The male cranium shows occipital flattening with a slight depression extending around the superior posterior portion of the occipital (Figure 3). The nature of the depression suggests a band may have been held against the skull with pressure for a considerable time while the individual was immature.

Only nine teeth are present on the male skull and mandible. No carious lesions are present but alveolar abscess was present in the area of the mandibular left second molar. Nine teeth were absent antemortem and calculus ranged from slight to moderate.

The following measurements and observations were collected: auricular height, 136; porion-bregma, 132; cranial length, 160; cranial breadth, 156; minimum frontal breadth, 93; bigonial breadth, 102; height of ascending ramus, 53; minimum breadth of ascending ramus, 28; height of mandibular symphysis, 35; absence of mylohyoid bridge, accessory mental foramen, frontal grooves, wormian bones, parietal process of temporal squama, squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence; presence of supraorbital foramen on the left but absence on the right.

One immature right femur is also present. An estimated maximum length of 90 mm suggests an age at death of about six months.

Feature 11: This secondary burial with some articulated parts was found in Cut B, 50 cm below the surface. Human remains present consist of the following: one left humerus; one left radius; one left ulna; one left and one right femur; one

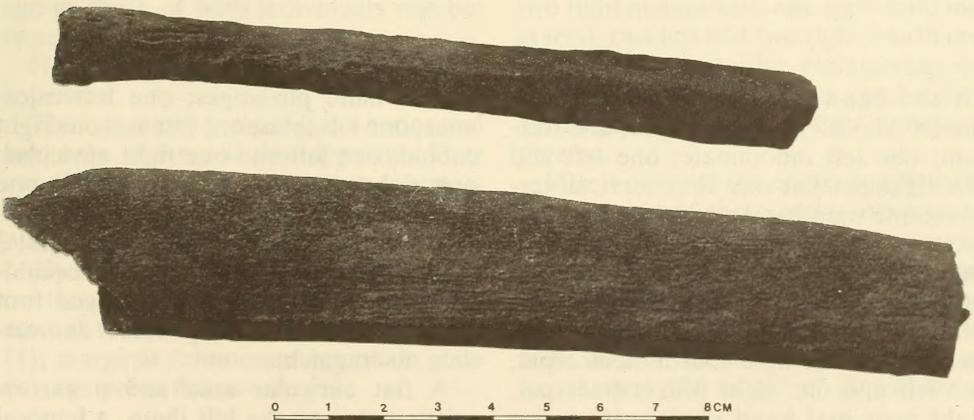


Fig. 2. Remodeled periosteal bone apposition on tibia and fibula of female from feature 10.



Fig. 3. Deformed male cranium from feature 10.

left and one right tibia; one left fibula; one left clavicle; one mandible; one sternum; one left innominate; one left and one right patella; one first cervical vertebra; one right hand navicular; one right lunate; one right triquetral; one right capitate; one right and one left hamate; one left and one right first metacarpal; one left second metacarpal; one right third metacarpal; one right fourth metacarpal; one left and one right fifth metacarpal; eight proximal hand phalanges; seven

middle hand phalanges; one left calcaneus; one left talus; one left and one right cuboid; one left and one right navicular; one right cuneiform; one left and one right second cuneiform; all 10 metatarsals; two proximal first foot phalanges; 3 other proximal foot phalanges; three middle foot phalanges; one first distal foot phalanx; one other foot phalanx; and various rib fragments.

A flat auricular area and a narrow sciatic notch on the left ilium, a femoral

head diameter of 45 mm and other observations suggest male sex.

The extent of dental attrition suggests an age at death between 25 and 30 years.

The estimated length of the left ulna (268) suggests a living stature of 170 cm (5 feet 7 inches) using the formulae of Trotter and Gleser.⁴

Fourteen teeth are present showing no carious lesions. No teeth are absent antemortem and no alveolar abscesses were noted. Calculus deposits varied from slight to moderate.

Feature 14: This primary skeleton was found in extended position in Cut K, at 15 cm below the surface. The cranium was separated from the skeleton by a distance of 30 cm. Bones present consist of two mandibles and the following other bones: one left humerus; one left and one right femur; fragments from a tibia and fibula; one left clavicle; one left scapula; one left and one right temporal; one right patella; one left second metacarpal; three proximal hand phalanges; two middle hand phalanges; two distal hand phalanges; one right talus; two proximal foot phalanges.

Both individuals appear to originate from adult females.

One mandible shows dental attrition with some dentin exposure and both show loss of teeth. The cranial sutures are still open on the skull present and the long bones show a robust cortex with no porosity. These data collectively suggest that age at death of both individuals was between 30 and 35 years.

No evidence of disease or deformation is present.

The one tooth present lacks caries and has only slight calculus deposits. Four mandibular teeth were absent antemortem on one mandible and seven on another. No alveolar abscesses were noted.

The following observations were noted on the mandibles: absence of accessory mental foramen (4); auditory exostoses (1); marginal foramen of tympanic plate (1); tympanic dehiscence (1).

Stothert (Pers. Com.) believes this feature may represent a more recent historic burial, that could relate to an early Christian cemetery dating to the 16th or 17th century A.D. that was located nearby.

Features 15 and 22: Originally feature 15 referred to an articulated skeleton, buried seated and facing south, and feature 22 to a secondary bone assemblage located immediately above the former in Cut K. Apparently during and after excavation the bones of the two features were intermixed to the point that the two features can no longer be differentiated. Accordingly, data collected from the bone assemblages labeled as the two features were merged to produce the following adult totals: one left and two right humeri; two left and one right radius; one left and two right ulnae; four left and three right femora; one left, one right and one side undetermined tibia; one right fibula; two left and one right clavicle; one left scapula; three left and three right temporals; three left and three right maxillae; one mandible; one sternum; one left innominate; one right navicular; one right capitate; two left and one right first metacarpal; one left second metacarpal; one left third metacarpal; one left and one right fifth metacarpal; one proximal hand phalanx; two right calcanea; one left and two right tali; one left navicular; one right first cuneiform; one left and one right metatarsal; two right metatarsals; one right third metatarsal; two left and two right fourth metatarsals; two left fifth metatarsals; one first proximal foot phalanx; and various rib fragments. Parts of four crania are present.

Morphology of the crania suggests that one female and three males are present.

Age at death of the female appears to be from 28 to 33 years. Two of the male skulls are between 20 and 25 years and age at death of the remaining male skull is 28 to 35 years. These estimates are based upon the extent of cranial suture

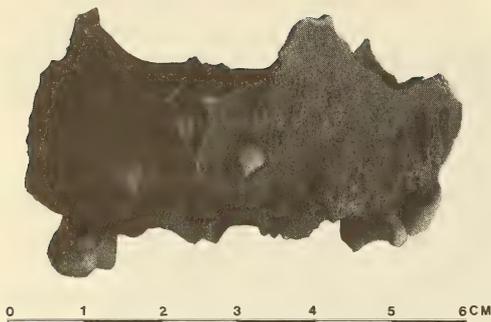


Fig. 4. Unerupted canines of young adult male from feature 15.

closure, dental attrition, and other observations of the skeleton.

Estimate of living stature is possible for only one male. Measurements of the left radius (238) and right ulna (250) suggest a living stature of about 165 cm (5 feet 5 inches).

No evidence of disease or trauma was noted, however, both maxillary canines of one of the young males have not erupted. They remain in the middle of the maxilla, still in correct anatomical orientation (Figure 4).

For the female cranium, only one maxillary right third molar is present which displays no carious lesions and only slight calculus deposits.

One of the young adult male crania has 8 teeth present with no carious lesions. One maxillary right third molar was absent antemortem and no alveolar abscesses were noted. Calculus deposits vary from slight to moderate.

The other young adult male has 17 teeth present with one 3mm carious lesion on the proximal root of the maxillary left first molar. One maxillary right third molar and one mandibular right third molar were absent antemortem, but no alveolar abscesses are present. Calculus deposits vary from slight to moderate.

The third male cranium has only two teeth present which lack caries and have slight calculus deposits. One maxillary left second premolar was absent antemortem. No alveolar abscesses were present.

The female cranium shows some occipital flattening. The following measurements and observations were recorded: cranial length, 147; minimum frontal breadth, 92; orbital height, 33; orbital breadth, 38; absence of frontal grooves, supraorbital foramina, wormian bones, auditory exostoses, marginal foramen of tympanic plate; presence of squamoparietal synostosis, and tympanic dehiscence.

Measurements and observations on the first male cranium are as follows: minimum frontal breadth, 95; orbital height, 34; orbital breadth, 37; absence of supraorbital foramina, infraorbital suture, squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence.

Measurements and observations on the male mandible are as follows: minimum breadth of ascending ramus, 30; height of mandibular symphysis, 34; absence of mylohyoid bridge, and accessory mental foramen.

Observations of another male cranium are as follows: absence of squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence.

Immature remains from these combined features consist of one left ulna, one left tibia, one right temporal and the right half of one thoracic vertebra. The length of the bones suggests the individual died between one and six months of age.

Feature 16: A secondary interment located above a large concentration of shells in Cut K. Bones present consist of the following: two left and one right humerus; one left and one right radius; one left and one right ulna; two left and two right femora; two left and one right tibiae; three fibulae; two left and two right clavicles; one left scapula; two left and two right temporals; two left and two right maxillae; two left and one right mandible; gladiolus; right innominate; right patella; one first cervical vertebra; two second cervical vertebrae; six other cervical vertebrae; 10 thoracic vertebrae; six lumbar

vertebrae; one sacrum; one right hamate; one left and one right first metacarpal; one second left metacarpal; one left and one right third metacarpal; one right fifth metacarpal; six proximal hand phalanges; one middle hand phalanx; one left and one right calcaneus; one left and one right talus; one left cuboid; one left and one right navicular; one left and one right foot navicular; one left and one right first cuneiform; one second left cuneiform; one left and one right first metatarsals; two left and one right second metatarsals; one left third metatarsal; one left and one right fourth metatarsal; one left and one right fifth metatarsal; two proximal first foot phalanges; one other proximal foot phalanx; and six ribs.

A narrow sciatic notch and flat auricular area on the right innominate, and the size and appearance of the other bones suggest male sex for both individuals.

The right pubic symphyseal face shows a complete ventral rampart, no distinct rim formation and no vestigial billowing which in consideration of the extent of dental attrition and other data suggest an age at death of between 40 and 45 years for one of the males. The second male appears to be slightly younger, between 30 and 35 years.

The maximum length of the right radius (230) suggests a living stature of 162 cm (5 feet 4 inches) for one of the individuals.

No evidence of disease was noted.

The cranium and mandible from one adult male have 13 teeth present with no caries, none missing antemortem and no alveolar abscesses. Calculus deposits range from slight to large.

Another mandible from the older male shows six teeth were absent antemortem on the left side. No teeth were present for examination. The younger male cranium displays marked occipital flattening (Figure 5) with a band indentation located approximately 25 to 30 mm below lambda. Measurements are as follows: auricular height, 122; porion-bregma, 119; cranial length, 162; cranial breadth, 143;

minimum breadth of ascending ramus, 29; absence of accessory mental foramen, wormian bones, parietal process of temporal squama, squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence. Mylohyoid bridge is present on the left and absent on the right.

The older male also displays marked occipital flattening with a band indentation located about 25 mm below lambda. Measurements and observations are as follows: auricular height, 128; porion-bregma, 124; cranial length, 158; cranial breadth, 145; height of mandibular symphysis, 36; absence of supraorbital foramina, wormian bones, squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence; presence of accessory mental foramen and frontal grooves.

Feature 19: Field notes describe this feature as a primary burial of one skeleton buried seated and facing west. The presence of two adults in this feature is confirmed by the occurrence of two right tibiae. Other bones present consist of a left and right humerus, left and right radius, left and right ulna, left femur, left tibia, left and right fibula, left and right clavicle, left and right scapula, left and right temporal, left and right maxilla, left and right mandible, left and right innominate, left and right patella, one first, one second and three other cervical vertebra, one thoracic vertebra, one left and one right hand navicular, one left and one right lunate, one right greater multangular, one left and one right capitate, one left hamate, one left and one right first, second, third, and fifth metacarpals, 10 proximal hand phalanges, 4 middle hand phalanges, 3 distal hand phalanges, one left and one right calcaneus, one left and one right talus, one right cuboid, one right navicular, one left first cuneiform, one left and one right first, second, fourth and fifth metatarsals, the right third metatarsal, two first proximal foot phalanges, six



Fig. 5. Deformed younger male cranium from feature 16.

other proximal foot phalanges, and one distal first foot phalanx.

Male sex is suggested by a narrow sciatic notch and a flat auricular area on the innominates, and other data.

The morphology of the pubic symphysis, extent of dental attrition and cranial suture closure as well as other factors suggest an age at death of between 33 and 38 years.

An estimated maximum length of a left tibia of 320 suggests a living stature of about 156 cm (5 feet 1 inch), using the formulae of Genoves.³

No evidence of disease was noted, although the skull present shows some occipital flattening.

Fourteen teeth are present that lack caries and have calculus deposits ranging from absent to large. Eleven teeth were missing antemortem and two alveolar abscesses were noted, at the sites of the mandibular first molars.

Measurements and observations on the slightly deformed male cranium are as follows: auricular height, 122; porion-bregma, 121; cranial length, 162; cranial breadth, 155; minimum frontal breadth,

94; orbital breadth, 41; bicondylar breadth, 125; bigonial breadth, 97; height of ascending ramus, 53; minimum breadth of ascending ramus, 31; height of mandibular symphysis, 32, corpal length, 89; absence of mylohyoid bridge, accessory mental foramen, frontal grooves, supraorbital foramina, wormian bones, squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence.

Feature 20: Concentration of disarticulated human bone and debris between Cuts I and K. Only a few long bone fragments from an adult are present. One maxillary third molar is also present. The extent of attrition on the tooth and the condition of the fragments suggest an age at death of between 28 and 40 years. No estimate of sex or stature can be made. The tooth lacks caries and has no calculus deposits.

Feature 23: A few disarticulated human bones found in the wall of Cut A. Bones present consists of one lumbar vertebra, one left cuboid, one left first cuneiform, the left and right first and third metatarsals, second left metatarsal, right fourth metatarsal, right fifth metatarsal, and one proximal first foot phalanx. The bones are those of an adult, but a more accurate estimate of age and sex is not possible.

Burial Features

Of the twelve burial features reported here, field notes suggest that five consisted of secondary bone assemblages, one primary burial of a single individual, one primary burial with an extra mandible, two primary burials with associated secondary deposits and one secondary burial with some bones in articulation. Information is not available for two of the features, but very few bones were present, strongly suggesting secondary burial. Most of the secondary burials were very

incomplete, lacking especially the small bones of the extremities, suggesting that many of these bones were lost during the transfer from primary repository to secondary burial. Obviously, this suggests that bones were selected from the primary repository for burial rather than a complete transfer of all remains in the original wrappings or container.

The variety of type of interment and burial position suggests marked complexity in funerary behavior. Multistage treatment was involved for most individuals and even the primary burials were of both sexes and one of these included an extra mandible.

Individuals Represented

At least 24 individuals are represented in the 12 features. Five features contained only one individual (all adults) while at least five were represented in the large combined features of 15 and 22. Of these 24 individuals, 21 (88 percent) are adults, while only three are immature. Such an age distribution can only be explained by sampling problems, since normally one would expect a prehistoric Ecuadorean cemetery sample to show a high proportion of infant and other immature deaths.² In this sample, only the incomplete remains of two infants of about six months and one ten year old child are present. The sex distribution of the adults is fairly uniform with 10 males, 8 females, and 3 of undetermined sex.

Age at death of adults varies from 20 to about 55. The upper age limit is especially difficult to assess due to the fragmentary nature of the remains. Those ages suggested here represent the best estimates possible, but certainly do not rule out the possibility of even older ages for some individuals. The mean age at death for all adults is 35 years. The value is slightly higher for females (39) than for males (32).

Stature

Estimated living stature for males varied from 151 cm (4 feet 11 inches) to 170 cm (5 feet 7 inches) with a mean of 162 cm. The only female value is 153 cm (5 feet 0 inches). Both the male and female values are within the upper range of those previously reported from Ecuador.⁵

Cultural Modifications

Four of the adult crania present displayed deformation while only one adult female cranium lacked deformation. The deformed skulls were from three males and one female. All consisted of occipital flattening, although one male also showed evidence that a narrow band may have been used in the upper occipital area.

No artificial dental alterations, metatarsophalangeal alterations or other cultural indicators were detected.

Disease

Evidence of non-dental disease is confined to the well-remodeled periosteal lesions of feature 10, and the unusual bony extension on the right third metatarsal of that same feature. This suggests a ratio of adult bones with evidence of infectious disease to the number of adults in the sample of .29. In comparison with other samples from prehistoric Ecuador, the value is high, but short of the .44 figure from the Guangala site of OGSE-MA-172.⁶ No examples of trauma or porotic hyperostosis were noted. The only other abnormalities noted were the unerupted canines in the young adult male from features 15 and 22.

Dental Data

Eighteen individuals were complete enough to allow dental observations. A total of 166 permanent teeth were examined from individuals ranging in age

Table 1.—Cranial and mandibular measurements (mm).

Measurement	Males				Females			
	No.	Mean	S.D.	Range	No.	Mean	S.D.	Range
auricular height	4	127	6.6	122-136				
porion-bregma	4	124	5.7	119-132				
cranial length	4	161	1.9	158-162	1	147	0.0	147-147
cranial breadth	4	150	6.7	143-156				
minimum frontal breadth	3	94	1.0	93-95	1	92	0.0	92-92
upper facial height					1	71	0.0	71-71
nasal height					1	52	0.0	52-52
nasal breadth	1	25	0.0	25-25	1	26	0.0	26-26
orbital height	2	38	4.9	34-41	2	33	0.7	33-34
orbital breadth	1	37	0.0	37-37	2	38	0.0	38-38
maximum alveolar length	1	42	0.0	42-42				
maximum alveolar breadth	1	65	0.0	65-65				
palatal length	1	31	0.0	31-31				
palatal breadth	1	40	0.0	40-40				
bicondylar breadth	1	125	0.0	125-125				
bigonial breadth	2	100	3.5	97-102				
height ascending ramus	1	53	0.0	53-53	1	50	0.0	50-50
minimum breadth asc. ramus	5	29.4	1.1	28-31	2	30	4.2	27-33
height mandibular symphysis	5	33.6	2.1	31-36	1	31	0.0	31-31
corpal length	2	87.5	2.1	86-89	1	76	0.0	76-76

from 10 to about 50 years. Sixty-eight teeth were absent antemortem compared with 295 observations on the presence or absence of teeth, a ratio of .23. The figure is below that of the Guangala site of OGSE-MA-172, but higher than most other samples.⁵

Only six carious teeth were found, a frequency of only four percent. This figure also falls into the low range for Ecuador, compared with three percent from Cotocollao and Sta. Elena, eight percent from Ayalan non-urn component and OGSE-MA-172 and 11 percent from the Ayalan urn sample.⁵

Nine examples of alveolar abscesses were detected in the sample. Observations on abscesses were possible at 203 tooth locations on the alveolus, a ratio of about .04. This figure falls nearly in the middle of the range of values reported from other sites.⁵

Observations of dental calculus were made on 145 permanent teeth. On the buccal surface, 25 teeth (17 percent) lacked calculus, 79 (54 percent) had slight calculus, 37 (26 percent) moderate deposits, and four (3 percent) large deposits. On the lingual surface, 27 (19 percent) lacked calculus, 97 (67 percent) showed slight deposits, 20 (14 percent) moderate deposits, and only one (1 percent) with heavy deposits. The data suggest that cal-

culus is slightly more concentrated on the buccal surface than on the lingual surface.

A Pearson Correlation matrix revealed a positive age correlation, significant at the .05 level for teeth absent antemortem. This indicates that the frequency of teeth lost before death increases with increasing age. The matrix also revealed significant negative correlations of age at death with the absent and slight calculus categories. Obviously, this means that the greater frequencies of low calculus scores are concentrated in the lower age groups. The size of calculus deposits increases with age except in those mostly older individuals where excessive dental attrition has destroyed most of the crowns and the associated calculus.

Measurements and Observations

Measurements and observations are summarized in Tables 1-2. The male crania appear very broad headed in relation to other Ecuadorean samples, but this could be influenced by artificial cranial deformation.

Summary

The twelve burial features culminating from complex mortuary procedures con-

Table 2.—Frequency of non-metric cranial and mandibular observations.

Observation	Male		Female	
	Absent	Present	Absent	Present
mylohyoid bridge	7	1	4	3
accessory mental foramen	10	1	4	1
frontal grooves	4	2	2	0
supraorbital foramen	7	1	2	1
infraorbital suture	3	0	1	0
wormian bones	8	0	2	0
parietal process of temporal squama	3	0	0	0
squamoparietal synostosis	13	0	0	1
auditory exostosis	14	0	3	0
marginal foramen tympanic plate	13	1	2	1
tympanic dehiscence	14	0	2	1

tained at least 24 individuals, primarily adults. Adult mean age at death was about 35 years with some individuals living at least into the 50's. Estimated mean living statures of 170 cm for males and 153 cm for females fall within the upper limits of values reported from prehistoric Ecuadorean samples. Some artificial cranial deformation was noted and consisted of the occipital flattening as well as a form of indentation suggesting the use of a band.

The frequency of infectious disease was relatively high in the sample, although no examples of trauma or porotic hyperostosis were noted. The frequency of carious lesions (four percent) is relatively low, while frequencies of alveolar abscesses and teeth lost antemortem are within the established range. The population had a relatively rapid rate of dental attrition which produced dentin exposure before the age of 20 and loss of most of the crown by age 50.

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A Preliminary Report of Analysis of Human Remains from Agua Blanca, a Prehistoric Late Integration Site from Coastal Ecuador

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ABSTRACT

Analysis of human remains recently excavated at the Coastal Ecuadorean site of Agua Blanca revealed seven individuals were present, representing both sexes and a high percentage of infants and children. The data suggest a comparatively healthy population, in spite of the late date of the site.

Agua Blanca represents a large multi-component archeological site located about 8 km inland from the coastal towns of Puerto Lopez and Machalilla in Manabi Province, Ecuador. The vestiges of several hundred stone walled structures are visible on the surface and these appear to represent the Manteño occupation of the Late Integration Period (800 A.D. to Spanish Contact).

Survey and mapping conducted by Colin McEwan in 1979 and 1981 revealed a pattern of public architectural complexes which form the nucleus of the site and are surrounded by an array of satellite settlements comprising mainly domestic structures.

Excavations in 1985 and 1986 directed by Colin McEwan and sponsored by the Museo Antropologico del Banco Central, Guayaquil and the British Museum, London, have located several burial features in one of these satellite settlements which underlies the present community of Agua Blanca.

In July of 1986, the author was invited by the archeological team to analyse human remains recovered by that time from the site. The four burial features were packed and transported from Agua Blanca to the author's laboratory outside of Quito for analysis. There the remains were carefully unpacked and washed with water and a soft brush. The remains were

then dried, reconstructed, inventoried, and analyzed by the author.

The remains are relatively well preserved, although fragmentary. Some bone surfaces show erosion, bleaching and other evidence of surface exposure. Most however, suggest they were in a relatively protected soil environment with minimal exposure to those factors of extreme moisture, acidity or temperature shifts which can cause rapid fragmentation.

Burial 1 (Site MN-C4-54 Structure 2)

Burial 1 was found 2 meters south of the southwest corner of site MN-C4-54, Structure 2. The burial and the associated Burial 2 (Figure 1) were accidentally discovered by villagers excavating a trench for the installation of a water supply.

When first exposed, the burial was covered by a large everted funerary urn.

The remains represent an adult and an infant. The adult is fragmentary, but nearly complete, lacking only the left scapula, and several vertebrae, ribs, hand and foot bones. The position of the ventral arc, a flat medial portion of the ischio-pubic ramus and the lack of a subpubic concavity on a left pubis all strongly suggest male sex. The mastoid processes and the general skeleton are small for a male, but deep grooves posterior to the mastoids and the muscle markings are well within the male range. Maximum diameters of heads of the femur and humerus of 41 mm are small for a male.

The ventral rampart of the left pubis is completely formed, with no rim formation and some vestigial billowing, suggesting an age at death between 36 and 42 years. This estimate is supported by lack of union of the sutures of the cranial



Fig. 1. Burials 1 (human remains within ceramic urn) and 2 (concentration of human remains outside of urn in upper left of photograph), site MN-C4-54 Structure 2.



Fig. 2. Superior view of reconstructed crania from Burial 1, showing flattening on the right occipital.

vault, solid bone cortex with no visible porosity and slight extensions on the sternal ends of the ribs.

Bone measurements of maximum length are left clavicle, 142 mm; left humerus, 290 mm; left radius, 212 mm. Using Trotter and Gleser's formulae for Mongoloids and Mexicans,¹ these measurements suggest a living stature of about 157 cm.

No evidence of disease was observed.

The reconstructed skull revealed a marked flattening on the posterior right side. The deformation appears to have been intentional and produced a very asymmetrical shape (Figure 2), with the right petrous portion of the temporal displaced markedly inward and upward. Because of the deformation, measurements of the cranial vault were not taken. Overall however, the deformed skull was very small. Cranial and mandibular measurements taken are as follows: nasal breadth, 26 mm; bigonial breadth, 104 mm; minimum breadth of ascending ramus, 33

mm; and corpal length, 87 mm. Observations included the bilateral absence of mylohyoid bridge, accessory mental foramina, frontal grooves, infraorbital sutures, squamoparietal synostosis, auditory exostosis and marginal foramen of tympanic plate; and bilateral presence of wormian bones. Supraorbital foramina and tympanic dehiscence occurred on one side but not the other.

Three cervical, eight thoracic and three lumbar vertebrae display stage one osteophytosis, while two thoracic vertebrae show stage two.¹ No arthritic lipping was observed on the head of a humerus, proximal tibiae, distal tibiae, patellae and the cuboid facet of a calcaneus. Similarly no breakdown was observed on the proximal and distal tibia, distal fibula, two facets of the calcaneus, distal humerus, proximal and distal radius, proximal and distal ulna, and distal femur. Spicule formation was absent on the tibia, patellae, and calcaneus. These observations are compatible with the age estimate of between 36 and 42 years and further suggest that long term physical stress was greater at the individuals back (bending, lifting) than at the joints of the shoulder, elbow, wrist, knee or ankle.

Metatarsophalangeal alterations were lacking on the metatarsals, but present on the foot phalanges suggesting that habitual work and/or rest posture included at least some hyperdorsiflexion of the toes (bending of the toes while in a kneeling or squatting posture).

All teeth were present except the right maxillary third molar, and the following mandibular teeth: right lateral incisor, right canine, right third molar, left incisors and canine and left second and third molars. The mandibular third molars had been lost antemortem. Many of the teeth showed some dentin exposure due to attrition, and slight to moderate calculus deposition, especially, on the buccal surface. No carious lesions or hypoplasia was observed.

The infant of Burial 1 is represented only by a few cranial fragments, both hu-

merii, a right femur, both temporals, a left mandible, a right ilium, three ribs and one sacral vertebra. No teeth are present but the size of the spaces for the teeth within the mandible suggests they were not yet with calcified crowns. The length of the left humerus suggests the individual was either a very small newborn infant or a fetus approaching term.

Burial 2 (Site MN-C4-54 Structure 2)

This burial feature contains the fragmentary remains of an adult and an infant. It was found in association with Burial 1 and excavated on July 5, 1986. The adult is represented by a fragmentary skull, both humeri, radii, ulnae, femora, tibiae, and fibulae, the left clavicle, both temporals, right mandible, first cervical, one thoracic and one lumbar vertebra, the left hamate, both first metacarpals, the right second metacarpals, both fourth metacarpals, five proximal hand phalanges, six medial hand phalanges, three distal hand phalanges, the left talus, right cuboid, two cuneiforms, six metatarsals, two foot phalanges and several ribs.

Small mastoid processes on the temporals and general gracility of the skeleton strongly suggest female sex.

The extent of dental attrition, vertebral osteophytosis and long bone cortical thickness suggest an age at death of between 30 and 35 years. The mandibular premolars and canine show some dentin exposure. Three thoracic vertebrae and one lumbar vertebra show stage one ver-

tebral osteophytosis. The cervical vertebra lacks osteophytic involvement.

The length of the left clavicle (122 mm) and the right humerus (260 mm) suggest a living stature of about 151 cm using Trotter and Gleser's formulae for Mongoloids and Mexicans.¹

One large fragment (170 mm) representing most of the shaft of a right tibia shows well remodelled periosteal apposition on two areas of the medial surface (Figure 3). The two areas measure 45 mm and 42 mm in length respectively and represent a deposit of several mm. The lesions appear to have been produced by localized infectious disease, probably many months before death. The disease was not active at the time of death and was not observed in any other bones.

The cranium was too fragmentary to reconstruct. It lacked auditory exostoses, marginal foramina of the tympanic plate and tympanic dehiscence on both sides.

The proximal radii lack breakdown as well as osteophytic involvement. The metatarsals and foot phalanges lack alterations.

The following teeth were present: maxillary right lateral incisor, second and third molars, maxillary left lateral incisor, mandibular right lateral incisor; canine and premolars, and mandibular left premolars. The maxillary incisors show slight hypoplasia at the base of their crowns. This suggests a developmental disturbance at about the age of four. No carious lesions were observed. Dental calculus was slight for both surfaces of most teeth, although the mandibular right lateral incisor displayed large deposits on most sur-

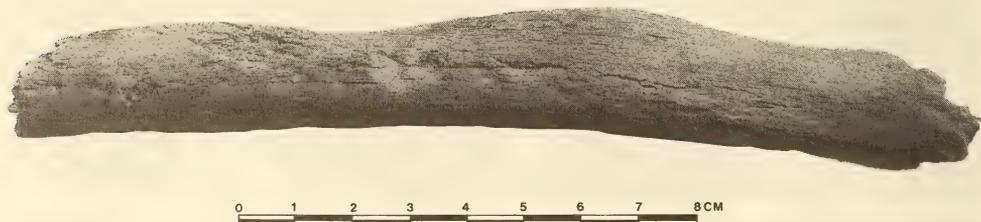


Fig. 3. Areas of periosteal apposition on right tibia from Burial 2.



Fig. 4. Burial 3, Site MN-C4-54 Structure 1.

faces, perhaps indicating that the adjacent central incisor had been lost long before death.

The following infant remains were found mixed with those of the adult: both humeri, right radius, left ulna, both femora, left scapula, both temporals, right mandible, and several ribs. No teeth were present. The following bone measurements suggest the individual was either a very small newborn or fetus approaching term: maximum lengths of left femur, 63 mm; right humerus, 57 mm; right radius, 47 mm; and breadth of left scapula, 28 mm.

Burial 3 (Site MN-C4-54 Structure 1)

Burial 3 was accidentally uncovered very close to the present ground surface approximately 20 meters east of the east wall of MN-C4-54 Structure 1 (Figure 4). Ma-

terials consist of several fish vertebrae and the remains of two infants. The larger infant is represented by a left humerus (maximum length 95 mm), left frontal orbit, left ilium (maximum length 53 mm), right femur (maximum length 120 mm), right temporal, right ulna, right humerus, right radius (maximum length 74 mm), basilar (maximum length 21 mm), left radius and left pubis (maximum length 24 mm). Two deciduous maxillary lateral incisors show crowns completely formed and roots 75% formed. The crown of the permanent maxillary first molar is 25% formed. Collectively, these data suggest an age at death of about nine months.

The smaller infant is represented by a left and right femur (maximum length 70 mm), a right frontal orbit, a right tibia (maximum length 63 mm), right humerus (maximum length 62 mm), right and left ulna (maximum length 58 mm), left radius (maximum length 51 mm), left tibia (maximum length 62 mm), left mandible, left scapula (maximum breadth 27 mm, height 34 mm) basilar, and a fibula (maximum length 56 mm). No teeth are present but the size of the bones suggests the individual was either a very small newborn or a fetus approaching term.

No evidence of disease was observed in either individual.

Burial 6

This disturbed burial was found during the surface collection of the lower terrace of the west sector of site MN-C4-1 (a terraced mound).

The remains consist of the very fragmentary cranial and post-cranial bones and teeth of a child of between 10 and 11 years of age. Bones present include a right temporal and various fragments of the skull and skeleton. Permanent teeth present include a right second incisor, both maxillary first molars, a maxillary canine, both mandibular first molars, the four

mandibular premolars, and two mandibular canines. All of the teeth show slight attrition on their occlusal surfaces. The molars all lack distal facets suggesting the second molars had not yet erupted. A deciduous maxillary second molar was present showing considerable attrition. The presence of the deciduous tooth and the stage of formation and eruption of the permanent teeth, collectively suggest an age at death of between 10 and 11 years.

No evidence of disease was observed and no measurements were possible due to the extreme fragmentation.

Obviously, conclusions about the Agua Blanca population and comparison with others are limited by the small sample size and must await additional excavation. Several preliminary observations can be made however.

The four burial features from Agua Blanca produced seven individuals: three large fetuses or small newborns, one infant age nine months, one child age 10–11 years and two adults. The features reveal that individuals of different ages and sexes were buried in a variety of combinations rather than in a fixed, predictable pattern.

The presence of both sexes and the wide distribution of ages suggests that the sample may be randomly drawn from the population, and not subjected to obvious cultural segregation. The large sample from the Late Integration site of Ayalán² also from the Ecuadorean coast also produced adults of both sexes and a high percentage of infants and children (38% below the age of five).

Of the 44 teeth recovered, only two (5 percent) show hypoplasia and none were carious. This compares with Ayalán frequencies of hypoplasia 6 percent and caries 11 percent. The lack of caries at Agua Blanca is surprising considering its late date, but may only reflect the small sample size. Three permanent teeth (molars) were lost prior to death. This represents six percent of the total number of observations on the presence of teeth (52). Fifteen percent of the Ayalán sample were

lost. No alveolar abscesses were observed at Agua Blanca, while four percent of the Ayalán teeth showed associated abscesses. Dental calculus appears to have occurred in a pattern similar to Ayalán. The Agua Blanca data tentatively suggest superior general dental health over Ayalán.

Non-dental disease at Agua Blanca is confined to the inactive periosteal lesions on the tibia from Burial 2. The ratio of the number of bones showing infectious lesions to the number of individuals in the sample is .14. In the Ayalán urn sample the ratio was .08. The Ayalán sample also contained numerous examples of trauma, porotic hyperostosis, cribra orbitale, and congenital disorders which are lacking entirely in the small Agua Blanca sample.

Ten of the 15 deformed skulls in the Ayalán sample displayed the same type of asymmetrical flattening as present in the Agua Blanca male from Burial 1. Both males and females had this deformation at Ayalán.

The slight presence of metatarsophalangeal alterations in the foot bones of the male and not in the female stands in marked contrast to Ayalán where the trait seemed to occur exclusively in females. This may suggest cultural variations in resting patterns or differing sex roles.

The two adults from Agua Blanca had living statures of 151 cm (female) and 157 cm (male). For the late Ayalán sample, females averaged 149 cm and males 159 cm.

The small Agua Blanca sample reported here offers a very preliminary glimpse of biocultural adaptation at this important site. Hopefully, continued excavation will produce a large sample that will enable more definitive conclusions.

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Prehistoric Human Biology at La Tolita, Ecuador, A Preliminary Report

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ABSTRACT

Recent archeological excavations at La Tolita in Ecuador produced 22 human skeletons that mostly date from the "La Tolita Clasico" Period, 200 B.C. to 90 A.D. Biological analysis suggests a population of high stature and high frequencies of trauma, infectious disease and alveolar abscesses, but low frequencies of dental caries and tooth loss, and absence of porotic hyperostosis.

Recent excavations at La Tolita, Esmeraldas Province, coastal Ecuador directed by Francisco Valdez of the Banco Central del Ecuador, Quito have produced a small but well documented collection of human remains from that site. In the past, this well known but heavily vandalized site has produced only isolated crania which for the most part have not been reported in the literature. Because of the importance of the Tolita site in trade, metal-working, and general cultural development of prehistoric Ecuador, these human remains offer a highly desirable and unique look at prehistoric health and other biological factors.

According to Valdez,¹ the skeletons from La Tolita date from two chronological periods. Those recovered from the "Tola del Pajarito Sector" all correspond to the "La Tolita Clasico" Period, dated

between 200 B.C. and 75/90 A.D. Others were recovered from a sector termed Mango Montano. All but one of the features from this sector date from the "La Tolita Tardio" Period with associated radiocarbon dates from 90 A.D. to 195 A.D. Feature 9 from this sector was found at a greater depth than the others and probably dates from the Classic Period.

By August, 1986, the remains had been transported to Quito, and cleaned by project personnel. In early August, the remains were packed and transported to the author's makeshift laboratory outside of Quito for analysis. All remains from each feature were inventoried, photographed and studied in detail for evidence of disease and other comparative biological data. The results of that analysis are presented here. Note that burial features were recovered from excavations at the

two areas mentioned above; Tola del Pajarito and Mango Montano. Descriptions of the individual features from these two areas are presented separately, however summary data group features of the same date. Note also that all measurements are presented in mm unless indicated otherwise. Methods used in analysis are summarized by Ubelaker.^{2,3}

Area La Tola del Pajarito.

Feature 1a. (RQ2-714cm).

This child skeleton is generally complete with excellent preservation. Nearly all bones are present with minimal fragmentation. The stage of dental formation suggests an age at death of between 4.5 and 5.0 years. The cranial occipital shows some flattening, suggesting deformation. No reliable estimate of sex can be made and no evidence of disease is present. The teeth lack evidence of caries, but do show a blackish stain. The crowns of the maxillary canines show buccal pitting which appears to represent a form of hypoplasia. Slight dental calculus occurs on one maxillary molar and one mandibular molar. Maximum lengths of the following bones were recorded: left ilium, 76; right ilium, 76; left femur, 203; left tibia, 166; left radius, 109; left humerus, 150; left ulna, 122; left clavicle, 73; right clavicle, 74. Other measurements are height of the ascending ramus of the mandible, 37; corpal length, 60; minimum breadth of the ascending ramus, 28; height of the mandibular symphysis, 21; bigonial diameter, 79; and bicondylar diameter, 99.

One adult premolar tooth is also present. The tooth lacks dental caries, but shows large calculus deposits on its buccal surface and moderate deposits on its lingual surface. The occlusal surface of the tooth shows some initial dentin exposure due to attrition.

Feature 2a. (RQ2,3-760cm).

This adult skeleton is generally complete and well preserved. Maximum diameters of the heads of the femora and humeri of 48 as well as morphological data on the pubis and skull strongly suggest male sex.

Maximum lengths of the left ulna (260), right ulna (264), and left radius (240) suggest a living stature of about 167 cm (5 feet six inches). Muscle markings on the bones further suggest the individual was quite robust.

Morphology of the pubic symphysis, extent of dental attrition, closure of cranial sutures, and extent of osteophytosis and joint changes collectively suggest an age at death of between 33 and 36 years.

Evidence of skeletal disease is confined to the cervical vertebrae (Figure 1). Slight degenerative pitting is present on the inferior body surface of the third cervical vertebra, the superior body surface of the fourth cervical vertebra, and the superior body surface of the seventh cervical vertebra. Marked destruction and remodeling occurs on the inferior body of the fifth cervical vertebra and the superior surface of the sixth cervical vertebra. Although the thoracic and lumbar vertebrae appear normal, the bony changes in the cervicals produce a marked kyphosis in that area. The appearance of the bony changes both in the gross bone and in radiographs suggest a traumatic origin, at least several years before death.

The 25 teeth present lack dental caries, but show moderate to large calculus deposits. Some dentin exposure resulting from attrition occurs on most teeth. A large well-remodeled depression on the lingual alveolus in the area of the missing mandibular right lateral incisor and canine probably results from alveolar abscess at that site. No hypoplastic teeth are present, however, the maxillary right first molar appears anomalous, rounder than normal with a slight division through its longitudinal axis.



Fig. 1. Degenerative pitting and kyphosis of cervical vertebrae from feature 2a, La Tola del Pajarito, probably induced by trauma.

The skull lacks evidence of disease and deformation. The following measurements were recorded: auricular height, 113; porion-bregma, 112; cranial length, 183; cranial breadth, 145; minimum frontal breadth, 97; bicondylar breadth, 111; bigonial breadth, 96; height of ascending ramus, 64; minimum breadth of ascending ramus, 29; height of mandibular symphysis, 34; and corpal length, 80. A mylohyoid bridge was present on the right but not on the left. The following features were all absent: accessory mental foramen, frontal grooves, supraorbital foramen, wormian bones, parietal process of temporal squama, squamoparietal synostosis, auditory exostoses, marginal foramen of the tympanic plate and tympanic dehiscence.

Feature 3a. (PO3-725cm).

This secondary deposit consists of the following adult bones: right humerus, both radii, left ulna, both femora, right tibia, one fibula, right clavicle, both scapulae, both innominates, two lumbar vertebrae, the skull and mandible and the left calcaneus.

Female sex is suggested by femoral

head diameters of 42 mm, a wide sciatic notch on one innominate and general gracility of the long bones.

An age of death of between 27 and 32 years is suggested by the lack of union of the cranial sutures, lack of osteophytosis, and the presence of some dentin exposure of the teeth due to dental attrition.

An estimated length of the left femur of 394 suggests a living stature of about 152 cm (5 feet 0 inches) using the formulae for females provided by Genovés.⁴

The fibula shows a well remodeled periosteal lesion at the mid-shaft. A slight, well-remodeled depressed fracture is located on the midline of the frontal, about 40 mm below bregma. There is also a small reactive lesion about 11 mm in diameter on the right parietal 15 mm from the sagittal suture and 70 mm from the coronal suture.

The nine teeth present lack dental caries and show slight to medium deposits of calculus. No examples of hypoplasia or alveolar abscess were observed.

The following measurements were recorded from the undeformed skull and mandible: cranial length, 170; cranial breadth, 141, minimum breadth of the ascending ramus, 31. The following features

were absent: mylohyoid bridge, accessory mental foramen, frontal grooves, supraorbital foramen, infraorbital suture, wormian bones, parietal process of temporal squama, squamoparietal synostosis, auditory exostosis, marginal foramen of tympanic plate, and tympanic dehiscence.

Feature 4a. (QR1-760cm).

This large secondary deposit contains the skeletal remains of at least five adults, as suggested by the presence of five left femora, and five left scapulae. Other bones are present in the following numbers: four left and three right humeri, four left radii, four left and four right ulnae, two right femora, three left and four right tibiae, at least six fibulae, two left and one right clavicle, two right scapulae, two left and two right temporals, three mandibles, three left and two right innominates, one left and one right patella, three first cervical vertebrae, three other cervical vertebrae, 13 thoracic vertebrae, 15 lumbar vertebrae, one sacrum, one right second metacarpal, one proximal hand phalanx, three right calcanea, and several rib fragments. Note the almost complete lack of small bones of the feet and hands, and irregular representation of the larger bones of the skeleton.

All of the five individuals represented here appear to be female. The five left femora are all gracile. The innominates show wide sciatic notches, deep pre-auricular sulci, and elevated auricular areas. Female sex is also supported by femoral

head diameters of 39, 40, and three of 42, and by humeral head diameters of 38, 38, 38, 39, and 39.

Data from long bone cortical thickness, pubic symphysis morphology, cranial suture closure and dental attrition suggest that one of the females was elderly, probably between 45 and 50 years, one was between 38 and 45 years, two were between 25 and 35 years and one was between 20 and 25 years.

Only one long bone was complete enough to allow an estimation of living stature. The maximum length of a left radius of 234 suggests a living stature of about 163 cm (five feet four inches).

Several of the bones show evidence of disease. One right tibia fragment shows a well remodeled periosteal lesion at the lateral surface of the mid-shaft. Another right tibia shows an area of remodeled periosteal apposition on the medial surface of the shaft about 45 mm from the distal end (Figure 2). In addition, two fibular shaft fragments show areas of well remodeled periosteal apposition.

One of the crania present was sufficiently intact to enable some measurements and observations. Those from one undeformed skull are as follows: auricular height, 121; porion-bregma, 120; cranial length, 184; cranial breadth, 146; orbital height, 33; orbital breadth, 37; bigonial breadth, 103; height of ascending ramus, 54; minimum breadth of ascending ramus, 25; height of mandibular symphysis, 31; corpal length, 86; absence of mylohyoid bridge, accessory mental foramen, frontal

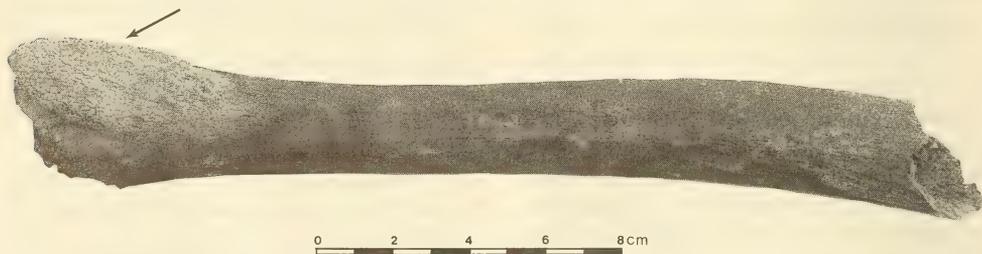


Fig. 2. Area of remodeled periosteal apposition on the medial surface of a right tibia from feature 4a, La Tola del Pajarito.

grooves, wormian bones, parietal process of temporal squama, squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate and tympanic dehiscence, and presence of supraorbital foramen.

Measurements and observations of a mandible and additional skull are as follows: bicondylar breadth, 118; bigonial breadth, 80; height of ascending ramus, 54; minimum breadth of ascending ramus, 29; height of mandibular symphysis, 33; and corpal length, 80. Absent were mylohyoid bridge, auditory exostoses, marginal foramen of tympanic plate and tympanic dehiscence. Accessory mental foramen and supraorbital foramina are present on the left but not on the right.

One mandible shows antemortem loss of 12 teeth with only the left second molar remaining and alveolar abscesses at the sites of the three right molars and the left second molar.

Another mandible shows five teeth present. The left second premolar has a carious lesion 5 mm in length on the mesial root. All teeth show slight calculus deposits.

Area El Mango Montano.

Feature 1. (CD2,3,4-60cm).

This feature was labeled "decapitado" (Figure 3) since the post-cranial skeleton was largely articulated, but the skull was separate. The following bones are present: the right humerus, both radii, ulnae, femora, fibulae, clavicles, the left scapula, the sternum, both innominates, both patellae, the first, second and four other cervical vertebrae, 12 thoracic vertebrae, five lumbar vertebrae, the sacrum, both hand naviculars, lunates, triquetrals, capitates, hamates, the left greater and lesser multangulars, all metacarpals, 11 proximal hand phalanges, 6 middle hand phalanges, 8 distal hand phalanges, both calcanea, the left talus, both



Fig. 3. View "in situ" of the skeleton of feature 1, area El Mango Montano. Note the articulated cranium and mandible out of normal anatomical position between the legs.

cuboids, the right foot navicular, both first and second cuneiforms and the left third cuneiform, both first, second, third, and fifth metatarsals, two proximal first foot phalanges, two other proximal foot phalanges, and one distal first foot phalanx.

Morphology of the pubic bones and other aspects of the skeleton suggest male sex.

The extent of cranial suture closure, dental attrition, morphology of the symphyseal face of the pubis and other factors suggest an age at death of between 33 and 38 years.

The maximum length of the right tibia of 367 mm suggests a living stature of about 167 cm. or five feet six inches.

No evidence of disease was detected on the skeleton.

All teeth are present except the maxillary right third molar, missing post-mortem. Only the mandibular right third molar shows a carious lesion, 2 mm in diameter on the occlusal surface. Calculus deposits vary from small to medium.

The skull shows some frontal flattening (Figure 4). Measurements are as follows: auricular height, 124; porion-bregma, 120; cranial length, 171; cranial breadth, 142; basion-bregma, 140; basion-porion, 18; minimum frontal breadth, 104; upper facial height, 76; facial width, 141; nasal height, 54; nasal breadth, 27; orbital height, 37; orbital breadth, 42; maxillary alveolar length, 55; maxillary alveolar breadth, 64; palatal length, 32; palatal breadth, 38; bicondylar breadth, 124; bi-

gonial breadth, 98; height of ascending ramus, 54; minimum breadth of ascending ramus, 34; height of mandibular symphysis, 33; total facial height, 124; corpal length, 87. The following traits were absent: mylohyoid bridge, accessory mental foramen, frontal grooves, supraorbital foramen, squamoparietal synostosis, auditory exostoses, pharyngeal fossa, marginal foramen of tympanic plate, tympanic dehiscence. Wormian bones were present.

Feature 2. (C2,3,4-70/80cm).

This feature is from cuadro CD2.3.4., Nivel 2a at a depth of 60 cm. The feature also was labeled "decapitado" because



Fig. 4. Frontal flattening (deformation) of cranium from feature 1, area El Mango Montano.

the skull was found separated from the post-cranial skeleton (Figure 5). Bones present include the left humerus, both radii, the left ulna, both femora, both tibiae, both fibulae, both clavicles, both scapulae, the right temporal, the mandible, both patellae, all seven cervical vertebrae, 11 thoracic vertebrae, the five lumbar vertebrae, the sacrum, the left hand navicular, both triquetrals, the left greater and lesser multangulars, both capitates, the left hamate, the left second, third, fourth, and fifth metacarpal, three proximal, three middle and four distal hand phalanges, both calcanea, both tali, both cuboids, both foot naviculars, the first and second cuneiforms, the right third cuneiform, the left metatarsals, the right first, second and fourth metatarsals, two proximal first foot phalanges, four other proximal foot phalanges, three middle foot phalanges, one distal first foot phalanx.

Male sex is suggested by a narrow pubis and a flat auricular area and general morphology of the skeleton.

Morphology of the symphyseal face of the pubis suggests an age at death of between 30 and 35 years. This age estimate is supported by the extent of cranial suture closure, dental attrition and other age indicators on the skeleton.

The maximum length of the left tibia of 364 suggests a living stature of 165 cm. or five feet five inches.

The fifth lumbar vertebra displays a separate neural arch. No other abnormalities or evidence of disease was noted.

No evidence of cut marks suggestive of intentional defleshing or decapitation was found on this skeleton or that of feature 1. In spite of this, the fact that the skulls and mandibles were articulated with each other but not with the rest of the skeleton argues for decapitation. If natural decomposition had advanced to the extent that

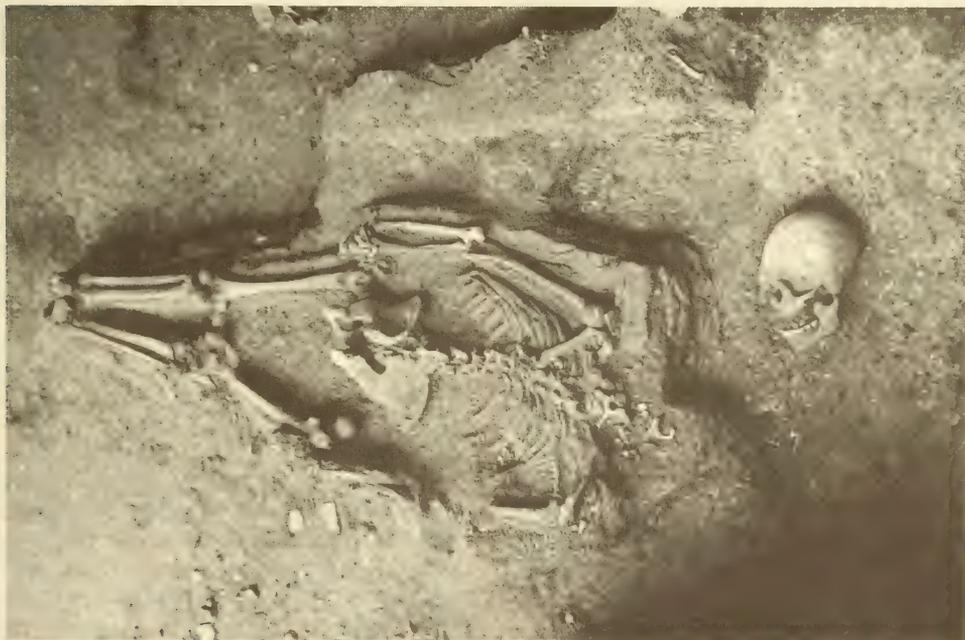


Fig. 5. "In situ" view of skeleton from feature 2, area El Mango Montano, also with articulated cranium and mandible out of normal anatomical position.

joints would have separated as well. It is possible that the heads were severed without the instrument used striking bone or that due to the poor preservation, the marks were not detected.

Twenty six teeth were present with only one mandibular right third molar absent antemortem. Only the maxillary right third molar has a carious lesion. This measures 2 mm in length and is located in the mesial root. No evidence of hypoplasia or alveolar abscess was noted but considerable alveolar resorption is present apparently resulting from periodontal disease. Calculus deposits vary from small to large.

The following measurements and observations were collected from the undeformed skull and mandible: auricular height, 103; porion-bregma, 98; cranial breadth, 137; bicondylar breadth, 123; bigonial breadth, 97; height of ascending ramus, 55; minimum breadth of ascending ramus, 28; height of mandibular symphysis, 30. The following features were absent: accessory mental foramen, frontal grooves, wormian bones, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence. Mylohyoid bridge was bilaterally present and supraorbital foramen was present on the left, but absent on the right.

Feature 3. (F5,6-70cm).

Most major bones of this adult are present. Absent are the sternum, left carpal bones, both calcanea, and the right talus. A second individual is represented by an additional first cervical vertebra, right fourth metatarsal and left fifth metatarsal.

A maximum diameter of the left femoral head of 43, a maximum diameter of the head of the left humerus of 42, a wide sciatic notch, irregular auricular area, and a large pre-auricular sulcus all suggest female sex.

A maximum length of the right radius of 243 suggests a living stature of 167 cm (5 feet 6 inches).

The vertebral bodies show little arthritic change. The basilar suture is well united and the bone internal cortex shows little porosity. The extent of dental attrition is extensive with considerable dentin exposure. Collectively, these observations suggest an age at death of between 32 and 38 years.

The distal end of the left radius diaphysis shows a well remodeled Colles fracture. Typically, this type of fracture is produced by forward falls, where the individual lands on his/her hands.

The 32 teeth present lack dental caries and show calculus deposits ranging from slight to moderate. Extensive attrition has produced alveolar abscesses through exposure of the pulp cavity in the maxillary right second premolar and second molar, and the six mandibular molars.

Unfortunately, the skull has been coated with preservative in situ and could not be reconstructed for detailed measurements. The following measurements were recorded: nasal breadth, 27; maxillary alveolar length, 56; maxillary alveolar breadth, 63; bicondylar breadth, 131; bigonial breadth, 107; height of ascending ramus, 55; minimum breadth of ascending ramus, 32; height of mandibular symphysis, 34; and corpal length, 88. The following features were all absent bilaterally; mylohyoid bridge, accessory mental foramen, parietal process of temporal squama, squamoparietal synostosis, auditory exostoses and tympanic dehiscence. Marginal foramen of tympanic plate was absent on the left, but present on the right.

Feature 4. (D2,3-78cm).

The disturbed primary burial consists of the following bones: one left and one right humerus, one femur fragment, one left and one right clavicle, one left and one right scapula, two skulls, one mandible, one right innominate, one right patella, one left and one right hand navicular, one left and one right lunate,

one right capitata, one right third metacarpal and various rib fragments.

Various morphological criteria suggest both individuals represented here are females. One skull and most other bones appear to belong to an individual aged between 40 and 50 years. The skull of this individual shows extensive cranial suture closure and obliteration, extreme osteoporosis on all bones, and extreme dental wear. The vertebral bodies are extremely compressed and porous. The head of the femur shows arthritic changes with extensive remodeling. Well remodeled periosteal apposition occurs on the posterior surface of the distal femur shaft.

The second skull is much younger. Very slight dentin exposure on the first two molars suggests an age at death of between 25 and 30 years. No evidence of disease is present.

The first older skull and mandible contain 19 teeth, which lack dental caries but show extensive wear and only slight calculus deposits. Lesions and deposits may once have been present and are not detected now since nearly all of the crowns have been destroyed by attrition. Alveolar abscesses are located at the sites of the maxillary right lateral incisor and canine, the maxillary left lateral incisor and the mandibular left first molar.

The following measurements and observations were recorded from the older skull: minimum frontal breadth, 97; nasal breadth, 27; minimum breadth of ascending ramus, 26; accessory mental foramen, absent; supraorbital foramen, present bilaterally; squamoparietal synostosis, absent; auditory exostoses, absent; tympanic dehiscence, absent.

The second younger skull contains 12 teeth which lack carious lesions and have calculus deposits ranging from small to moderate. No alveolar abscesses were present.

The following measurements were recorded on the undeformed skull: auricular height, 103; porion-bregma, 99; cranial length, 169; cranial breadth, 140; minimum frontal breadth 90; upper facial

height, 69; nasal height, 51; nasal breadth, 26; orbital height, 39; orbital breadth, 44; maxillary alveolar length, 51; maxillary alveolar breadth, 63. The following features were all absent: supraorbital foramen, infraorbital suture, squamoparietal synostosis, auditory exostoses, marginal foramen of tympanic plate, and tympanic dehiscence.

Feature 5. (CD2, D3)

This feature consists of an incomplete skeleton with an extra right humerus. Bones present consist of two right humeri, one left and one right radius, one left ulna, one left femur, one left tibia, one left and one right temporal, one left and one right maxilla, one right innominate, four thoracic vertebrae, one lumbar vertebra, and one right third metacarpal.

Morphology of the right ilium suggests female sex.

The extent of dental attrition and cranial suture closure suggests an age at death of between 30 and 35 years.

Maximum length of a left ulna of 243 suggests a living stature of about 159 cm or 5 feet 3 inches.

Fourteen maxillary teeth are present with only one right third molar showing carious lesions. Dental calculus varies from slight to moderate.

The following observations and measurements were recorded from the skull: auricular height, 102; porion-bregma, 105; cranial breadth, 137; absence of supraorbital foramina, parietal process of temporal squama, squamoparietal synostosis, marginal foramen of tympanic plate and tympanic dehiscence; presence of auditory exostoses.

The inside surface of the left temporal shows a small 6 mm × 4 mm bony nodule extending over a groove for a blood vessel. No other abnormalities or disease processes were detected.

Feature 6. (D2, D3-110cm).

This feature consists of a few bones of one adult with a second adult indicated

by two left scapulae, two first and two second cervical vertebrae. Other bones present include a left and right humerus, a left and right clavicle, left and right temporal, left and right maxilla, left and right mandible, left innominate, 9 additional cervical vertebrae, two lumbar vertebrae, and several rib fragments.

Small mastoid processes on the temporals, and general gracility of the skeleton suggest female sex for one individual.

Marked osteophytosis in the cervical vertebrae and extensive dental attrition suggest an age at death of between 40 and 45 years.

Maximum length of the left humerus of 297 suggests a living stature of about 156 cm (5 feet 1 inch).

No evidence of disease is present.

Twenty-six teeth are present showing no carious lesions and only slight dental calculus. Alveolar abscesses occur at the sites of the maxillary left second molar, and mandibular right first and second molars and the mandibular left first molar.

One partial skull is present, with the following measurements and observations: auricular height, 108; porion-bregma, 102; cranial length, 162; cranial breadth, 138; minimum frontal breadth, 92; upper facial height, 69; nasal height, 48; nasal breadth, 24; orbital height, 33; orbital breadth, 43; maxillary alveolar length, 50; maxillary alveolar breadth, 58; bigonial breadth, 101; height of ascending ramus, 54; minimum breadth of ascending ramus, 29; height of mandibular symphysis, 29; corpal length, 79. The following features were absent: mylohyoid bridge, accessory mental foramen, supraorbital foramen, auditory exostoses, pharyngeal fossa, and tympanic dehiscence. Marginal foramen of the tympanic plate was absent on the left but present on the right.

A small circular button osteoma approximately 18 mm in diameter is present on the left parietal.

Feature 7.

Only a calvarium and few other bones represent this feature. Specific bones present include the right humerus, left radius, left femur, right fibula, both temporals, left maxilla, right mandible, left patella, second cervical vertebra, one lumbar vertebra, the sacrum, one proximal hand phalanx, the right second and third cuneiforms, the right first, second, fourth, and fifth metatarsals, and one first proximal foot phalanx.

Size of the skull and long bones suggests female sex.

Lack of union of the cranial sutures, lack of osteophyte formation on the vertebrae, and the extent of dental attrition suggest an age at death of between 28 and 33 years.

No evidence of disease is present.

Fourteen teeth are present and none are missing antemortem. The teeth are caries free with calculus deposits ranging from small to medium.

The following measurements were recorded: auricular height, 115; porion-bregma, 112; cranial length, 177; cranial breadth, 147; minimum frontal breadth, 94. The following traits were absent: accessory mental foramen, squamoparietal synostosis, auditory exostosis, marginal foramen of tympanic plate. The following were present: frontal grooves, supraorbital foramen, and wormian bones. Tympanic dehiscence is absent on the left and present on the right. The skull shows a large inca bone approximately 40 mm in length.

Feature 8.

This feature consists of one adult skeleton with some infant remains also present. The adult bones are as follows: right humerus, both radii, right ulna, both femora, left tibia, right scapula, the mandible, left innominate, right patella, the first, second and four other cervical vertebrae, eight thoracic vertebrae,

five lumbar vertebrae, one right greater multangular, and various rib fragments.

Morphology of the innominate and other bones suggests female sex.

An age at death of between 45 and 50 years is suggested by extensive dental attrition and extensive osteophytosis and porosity of the cranial vault.

An estimated length of the right femur of 380 suggests a living stature of about 148 cm or 4 feet 10 inches.

Well remodeled periosteal apposition occurs on one ulna midshaft. In addition, both mandibular condyles are flattened with considerable pitting, indicating problems of the temporo-mandibular joint.

Fifteen teeth are present with only two missing antemortem. No dental caries were observed. An alveolar abscess occurs at the site of the mandibular right second molar. Calculus deposits range from small to large.

Measurements of the mandible are as follows: bicondylar breadth 118, bigonial breadth 94, height of ascending ramus 51, minimum breadth of ascending ramus 28, height of mandibular symphysis 35. Mylohyoid bridge was lacking on both sides while an accessory mental foramen was absent on the left but present on the right.

Subadult remains from this feature consist only of cranial fragments and one right mandible. Three deciduous teeth and one permanent tooth are present. The deciduous mandibular first molar has a complete crown with the root 25% formed. The deciduous mandibular second molar and canine have a complete crown with no root formation. This stage of dental formation suggests an age at death of about 10 months.

Feature 9.

This feature consists of most major bones of an adult male with an additional right femur of an adult. Specific bones present are as follows: right humerus, left and right radius, left and right ulna, one left and two right femora, one left and one right tibia, one left and one right

fibula, one right clavicle, one right scapula, one left temporal, one left and one right maxilla, one right side of a mandible, one sternum, one left and one right innominate, all vertebrae, the sacrum, one left hand navicular, one left lunate, one left capitate, one left hamate, one left first, second, fourth, and fifth metacarpal, one right fifth metacarpal, six proximal hand phalanges, six middle hand phalanges, three distal hand phalanges, one left and one right calcaneus, one left and one right talus, the left cuboid, one left and one right foot navicular, one left first cuneiform, one right fifth metatarsal and various rib fragments.

Male sex is suggested by a narrow pubis, large mastoid processes, and other morphological features.

An age of about 20 years is suggested by incomplete closure of the third molar root tips, extent of dental attrition, and general lack of degenerative change in the skeleton.

Measurements of both femora and the left tibia suggest a living stature of 155 cm (5 feet 1 inch).

Of the 27 teeth present, none show carious lesions and calculus deposits vary from absence to moderate. No teeth were observed to be missing antemortem and no alveolar abscesses were detected.

The skull was fragmentary but undeformed. Maxillary-alveolar breadth was 62 and the minimum breadth of the ascending ramus of the mandible was 32. The following traits were absent: mylohyoid bridge, accessory mental foramen, supraorbital foramen, squamoparietal synostosis, auditory exostoses, marginal foramen of the tympanic plate, and tympanic dehiscence. Wormian bones were present bilaterally.

Number of Individuals.

Assuming that individuals are not represented in more than one of the identified features, the data suggest that at least

22 individuals are represented by major bones in the complete Tolita sample. Note this figure does not consider that the extra premolar in Tola del Pajarito represents a separate individual. Ten of the 22 date from La Tolita Clasico and 12 from La Tolita Tardio. Twenty of the 22 individuals are adult, the only immature skeletons being the 4.5 to 5.0 year old child from feature 1 of Tola del Pajarito and the 10 month old infant from feature 8 of Mango Montano. This unusual age distribution strongly suggests that some factor of cultural selection or preservation has strongly biased the sample. In the large skeletal sample recovered at Ayalan, Ubelaker² reported that nearly half of the sample was below the age of 20 years.

Assuming a random sample drawn from a normal distribution of deaths in the population, one would expect an approximately equal distribution of males and females within the adult sample. In the Tolita sample examined here, only 4 of the 20 adults present are male while 13 are female and three are of undetermined sex. This irregularity is especially noteworthy from the La Tolita Tardio Period, where only one of 8 adults of determined sex is male. This would suggest an extremely high female death rate for the period represented by the sample or more likely some sexual discrimination in placement within the cemetery areas sampled.

Age Distribution

Ages estimated for the individual skeletons range from about 10 months to about 47 years. The average adult age at death for the entire sample is 34 years with a range from 20 to 47 years. Within the La Tolita Clasico Period, the mean age at death is 32 with a range from 20 to 47 years, while within the La Tolita Tardio Period, the mean is 36 years with a range from 27 to 47 years. The data also show little variation in the mean age at death

broken down by sex. Overall, the Tolita sample shows a mean age at death for adult males of 30.5 and for females of 35.3. Within the La Tolita Clasico sample, the male mean is 27 years and that for females 34. Within the La Tolita Tardio sample, the male mean is 34 years and that for females 37. Thus while the overall sample is heavily skewed toward females over males and adults over immature individuals, it shows a more normal age distribution within the adult categories, with the mean for females slightly greater than for males in both periods.

Living Stature

Estimates of living stature drawn from the entire sample range from 148 cm to 167 cm and average 164 (5 feet 4 inches) for males and 158 (5 feet 2 inches) for females. Stature was the same for females in both periods (158 cm), but males were taller in the La Tolita Tardio Period (166 cm vs. 161 cm). These values are considerably higher than average values reported from other prehistoric sites in Ecuador.⁵ Mean male values previously reported ranged from 159 at Cotocollao and the Ayalán sample to 161 at Sta. Elena and OGSE-MA-172. Female stature values ranged from 148 at Cotocollao to 152 at OGSE-MA-172.

Trauma

Three individuals show evidence of traumatic injury. These examples involving 7 bones consist of the cervical trauma in feature 2a and the depressed skull fracture in feature 3a of area Tola del Pajarito and the Colles fracture of feature 3, Mango Montano. One measure of the frequency and severity of trauma in the population is the ratio of the number of bones effected to the number of individuals in the sample. This ratio for the Tolita sample is .32, one of the highest values yet

reported for prehistoric Ecuador. Figures for other sites are .33 for OGSE-MA-172, .18 for Ayalán non-urn sample, .13 for Ayalán urn sample, .09 for Sta. Elena, and .03 for Cotocollao⁵. The trauma in features 2a and 3a obviously results from blows to the neck and head. The Colles fracture of feature 3 was produced by a fall and is similar to several found at Ayalán. Note that six of the seven effected bones date from La Tolita Clasico, a ratio of .60. The remaining example from La Tolita Tardio suggests a ratio of only .11 for that period.

Infectious Disease

Eight bones from four features show evidence of infectious disease. In all cases, these take the form of well remodeled periosteal lesions and involve apposition of bone rather than bony destruction. All of the skeletons are those of females and involve the tibia (2), fibula (3), femur (1), ulna (1), and parietal (1). The ratio of adult bones showing evidence of infectious disease to the number of adults in the sample is .47. Once again, this is the highest value yet reported for Ecuador with those previously reported⁵ ranging from .44 at OGSE-MA-172 to .04 at Cotocollao and Ayalán non-urn sample. Six of the eight examples date from La Tolita Clasico, a very high ratio of .80. The remaining two date from La Tolita Tardio and suggest a ratio of .22.

Porotic Hyperostosis

No examples of porotic hyperostosis or the related cribra orbitalia were detected in the Tolita sample. This may suggest that anemia was not the problem at Tolita that it may have been at the sites of Ayalán² and OGSE-MA-172⁶ where examples were found.

Dental Hypoplasia

Only one individual in the sample showed evidence of dental hypoplasia, the infant of feature 1a, area La Tola del Pajarito. Some hypoplastic defects were detected in the deciduous maxillary canine crowns. The complete lack of hypoplasia in the permanent teeth is unique in Ecuador since it has been reported from all other Ecuadorean samples with frequencies ranging from 0.3% at Cotocollao to 5.8% in the Ayalán urn sample.⁵

Dental Caries

Dental carious lesions were relatively uncommon within the Tolita sample. Only four of the 246 permanent teeth examined showed carious lesions, a frequency of only 1.6%. This figure represents the lowest yet reported from Ecuador⁵ and falls even below that of the early site of Sta. Elena (3%). Frequencies as high as 11% were reported from Ayalán. This is somewhat surprising, since other investigations have shown that caries frequency increases with time throughout prehistory, especially with the acquisition of agriculture and consumption of foods laden with starch and simple sugars. In the Tolita sample, the few caries found were evenly distributed between males (1.6%) and females (1.4%). The lesions were both root and occlusal caries, three from third molars and one from a mandibular second premolar.

Alveolar Abscesses

Alveolar abscesses refer to bony changes in the alveolus of the maxilla or mandible which show evidence of infection. These are usually formed at the root tips of teeth whose pulp cavities have been exposed through attrition, trauma, or disease processes and subsequently become infected. Nearly all examples in the

Tolita sample appear to have resulted from exposure of the pulp cavity as a consequence of extensive and rapid attrition of the teeth. Twenty-three examples of alveolar abscess were noted in the Tolita sample. Six of these were from maxillary teeth, while 17 originated from mandibular teeth. Seventeen of the 23 examples involve molars while three are from incisors, 2 from canines and one from a premolar.

The ratio of the number of abscesses observed (23) to the number of observations (abscesses plus normal, 269) in the Tolita sample is .09. This represents the highest figure yet reported in the literature from Ecuador.⁵ Other values range from .01 at Sta. Elena to .08 at OGSE-MA-172. The high figure seems directly correlated with the very high rate of dental attrition. The figure also varies markedly between the sexes at .02 for males and .13 for females. Broken down by time period, the data suggest ratios of .06 for La Tolita Clasico and .10 for La Tolita Tardio.

Loss of Teeth

Data on the antemortem loss of teeth offers another opportunity to view the effects of dental problems in the Tolita population. Of 333 observations on the presence or absence of permanent teeth in the sample, 18 had been lost for a frequency of 5 percent (.04 La Tolita Clasico and .06 La Tolita Tardio). Two of the lost teeth were maxillary; the remaining 16 were mandibular. The missing teeth involved 9 molars, 2 premolars, 1 canine and 6 incisors. Only 3 percent of male teeth were lost, while 7 percent of female teeth were missing. This figure is low in comparison with other populations within Ecuador,⁵ suggesting that while dental attrition and alveolar abscess were largely responsible for tooth loss in the Tolita sample, other factors may also have contributed to tooth loss in the other samples.

The comparative figures range from 6 percent at Sta. Elena to 40 percent at OGSE-MA-172.

Cranial Deformation

Observations on cranial deformation were possible on only nine of the crania. Two of these (11 percent) show some evidence of deformation. The child of feature 1a, La Tola del Pajarito shows slight occipital flattening, which may represent intentional deformation or perhaps just a cradle board effect. The male of feature 2, El Mango Montano displays flattening on the frontal which appears to represent intentional deformation.

Metatarsophalangeal Alterations

Observations on metatarsophalangeal alterations were possible only on 12 female tarsal bones and 19 male bones. Alterations were observed only in the third metatarsal of the male from feature 2, suggesting that he may have had activity or habitual rest posture that produced kneeling with hyperdorsiflexion of the right toes. The trait is best known in Ecuador from the site of Ayalán, where it occurred in much higher frequencies, but apparently only in females.

Vertebral Osteophytosis

Observations on vertebral arthritic change are available from six females and 4 males. As in most other populations, the lumbar vertebrae show more advanced osteophytosis than do the thoracic or cervical vertebrae. Females show slightly more arthritic involvement than do males.

Evidence of arthritic change elsewhere in the skeleton was minimal and evenly distributed between males and females.

Summary

The thirteen burial features analyzed here contained the remains of at least 22 individuals. The variability of completeness of the individuals reflects cultural factors more than preservation. Form of burial varied from primary interment with some later disturbance to secondary interment of incomplete skeletons. The 22 recovered individuals do not appear to adequately represent total deaths in the population. The entire sample is strongly biased against infants and children and the sample dating from La Tolita Tardio Period appears strongly biased against males. The age distribution of the adults appears to be similar between the two areas, with the average age of adults at about 34 years.

Analysis of the skeletal remains revealed the highest mean values for stature yet reported for Ecuador for both males and females. High values were also revealed for frequencies of trauma, infectious disease, and alveolar abscesses. In contrast, frequencies for dental caries and loss of teeth are among the lowest reported for prehistoric Ecuador. The dental data suggest that very high rates of dental attrition in the Tolita population resulted in the high rate of alveolar abscess. However, the comparatively low rate of dental caries did not lead to dental loss as it apparently did in other Ecuadorean samples. Thus the frequency of dental loss remained low, in spite of the high rate of abscess.

The Tolita sample also appears to be unique in producing record high frequencies of trauma and infectious disease yet low values for dental caries and complete lack of porotic hyperostosis. In other Ecuadorean sites, especially the Guangala site of OGSE-MA-172 infectious disease, caries, and porotic hyperostosis occurred together in high frequencies in what appeared to be a combined response to problems of nutrition and sanitation related to the shift with agriculture to

more settled, denser population centers and to a less varied diet. These interpretations apparently do not apply to La Tolita and further suggest that the interrelationship of these variables is much more complex than initially thought.

Division of the sample into the La Tolita Clasico and the slightly later La Tolita Tardio Periods enables a preliminary look at intra-site temporal trends. The data suggest that female stature remained constant, while male stature, antemortem loss of teeth and metatarsophalangeal alterations produced by kneeling increased through time. The mean age at death, and frequencies of trauma, infection, caries, and alveolar abscesses decreased through time at La Tolita.

Clearly, La Tolita samples are much too small to substantiate these trends and interpretations, but they document the need for continued controlled excavation at this important site to produce an augmented sample of human remains and a more complete picture of human biological history in northwestern Ecuador.

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Angiostrongyliasis Cantonensis (Eosinophilic Meningitis): Historical Events in its Recognition as a New Parasitic Disease of Man

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ABSTRACT

In April 1961 the rat lungworm, *Angiostrongylus cantonensis* was the principal suspect as the etiological agent of the eosinophilic meningitis epidemics of 1948-1957 in the Pacific.^{2,4-6} This was affirmed by: (a) presence of rat infection in all areas where the disease occurred;^{4,7,8} (b) human infection resulting from ingesting raw slugs^{4,29} and freshwater prawns;¹² (c) experimental infection of simian primates;^{4,14} and (d) recovery of the parasite in human cases.^{32,39,45,47,51} These epidemics appear related to the spread of the giant African snail, *Achatina fulica*, believed responsible for introducing the parasite to the Pacific area.¹⁰

Introduction

In the background leading to the recognition of angiostrongyliasis cantonensis as a new parasitic disease of man, was the occurrence of three epidemics of eosinophilic meningitis of unknown etiology in Micronesia, New Caledonia and Tahiti from about 1948 to 1957. Rosen and associates in searching for the etiological agent, theorized that the disease was caused by a worm parasite in the skipjack

tuna or related fish eaten raw.⁴⁴ On the other hand, Alicata in April, 1961,^{2,4-6} strongly suspected that the rat lungworm, *Angiostrongylus cantonensis* (Fig. 1), served as the etiological agent. This new theory was soon confirmed by the independent observations of previous and subsequent investigators reported herein. Their findings led to recognition of a new parasitic disease of man, referred to as angiostrongyliasis cantonensis²⁷ and Alicata's Disease.³¹

The purpose of this paper is to summarize the more important events that led to the identification of the cause and means of transmission of this new disease,

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Fig. 1. *Angiostrongylus cantonensis*: adult male and female. $\times 1.3$ (Alicata and Jindrak, 1970)

and to reflect as to why, previously unknown in the Pacific, its appearance occurred in this area about the middle of this century.

Important Historical Dates and Events

1933

Chen in 1933 observed lungworm nematodes among rats in Canton, China,²⁴ and in 1935 described them under the name of *Pulmonema cantonensis*.²⁵ Matsumoto in 1937 found similar parasites in Taiwan;³⁷ in the same year, Yokogawa described them as *Haemostrongylus ratti*.⁵² Later the parasite was established taxonomically by Dougherty in 1946 as *Angiostrongylus cantonensis*.²⁶

1945

Nomura and Lin, 1945, were first to observe the presence of young adult nematodes *A. cantonensis* (but referred to as *H. ratti*) in the cerebrospinal fluid that they had casually recovered from a patient with symptoms of meningitis.³⁹ Although they did not definitely associate

this parasite with the disease, nor make further investigations, they suspected that food eaten raw by the patient before the illness might have been contaminated by rats. The report of these authors was published in Japanese in a local medical journal but failed to appear in abstracting journals. The reference was later cited in English by Hsieh in 1959,³⁰ though this also remained unknown generally until 1964, when most of the original report by Nomura and Lin was translated into English.¹⁹ This translation, however, appeared after Alicata had already incriminated *A. cantonensis* as the cause of the eosinophilic meningitis epidemic in Tahiti.^{2,6}

1948

In 1948, Bailey and two other officers of the Naval Medical Institute, Bethesda, Maryland, were assigned to investigate a supposed epidemic of encephalitis caused by a viral agent among natives of the island of Ponape, Micronesia.¹⁸ In their original serological investigation of the disease all findings proved negative for virus, bacteria, rickettsia, leptospira, and certain protozoa and helminths. Clinically, however, they recognized that some of the patients exhibited stiffness of the neck without true rigidity, presence of skin hyperesthesia, and pleocytosis with a high percentage of eosinophils in the cerebrospinal fluid in about half of the patients examined. These findings were finally designated by them as cases of eosinophilic meningitis of a character not previously reported in the literature and of unknown etiology.

1951

Trubert in 1956 reported an epidemic in New Caledonia of a benign form of eosinophilic meningitis in more than 930 persons. This was first observed in 1951, and was of unknown etiology.⁴⁸ Clinically, it was similar to that reported earlier in Ponape.¹⁸

1957-1960

Franco et al. in 1960 reported cases of eosinophilic meningitis in Tahiti of unknown etiology, which they had observed since 1957.²⁸

Rosen et al. similarly reported cases in Tahiti during 1958-1960.⁴⁴ In search of the etiological agent, and as result of extensive clinical and epidemiological observations, they theorized that the disease was caused by a helminth parasite of the skipjack tuna or other variety of pelagic fish commonly eaten raw in the area. Their speculation of a hypothetical parasite as the etiological agent was based on the presence of an eosinophilic syndrome, a factor often associated with an invasion of the host by helminth parasites. As far as is known, the above theory has not been confirmed.^{36,50}

During 1960, Vaillant et al. from their clinical and laboratory observation of cases of fish poisoning (ciguatera) and eosinophilic meningitis in New Caledonia, postulated that a common thermostable toxin resulting from the eating of certain fish, might be involved in these maladies.⁴⁹ This theory, as yet unproved, failed to take into account the absence of eosinophilic meningitis in the Samoas and Fiji, where fish poisoning was known to occur.³⁴ The cases of eosinophilic meningitis that occurred in American Samoa in 1979 were believed to be caused by a recent introduction of the rat lungworm, most likely by the giant African snail, *Achatina fulica*.²⁰

1961-1967

In 1961 Alicata incriminated the rat lungworm, *Angiostrongylus cantonensis*, as the cause of the eosinophilic meningitis epidemic then occurring in Tahiti.² This new theory, first communicated to Dr. Leon Rosen of the U.S. Public Health Service in an official letter dated April 5, 1961, stated "It is my strong suspicion that the syndrome is produced by an invasion of nematode larvae, and more specifically

a species of *Angiostrongylus*," viz. *A. cantonensis*. (For full text of this letter, see Alicata and Jindrak 1970,¹³ p. 6.) This letter was submitted soon after Rosen and associates had sent a manuscript for publication in which they theorized that the disease in Tahiti was caused by a helminth parasite of the skipjack tuna or other pelagic fish eaten raw in the area.⁴⁴

The rat lungworm theory was based on a 1955 report by Mackerras and Sandars which revealed that the infective larvae of *A. cantonensis* normally and obligatorily migrated and partially developed in the brain of the rat host before migrating to the lungs, and producing an inflammatory reaction.³⁵ With the finding in 1960 of the rat lungworm in Hawaii¹⁶ Alicata suspected that it might have been introduced recently in Hawaii, because in 1938 the characteristic pulmonary lesions of angiostrongylosis were not observed among rats surveyed for trichinosis in the Hawaiian Islands.¹

Beginning in 1961, the following are the major chronological events in the search for the causative agent of eosinophilic meningitis in Tahiti, the then area of attention.

1. According to Massal³⁶ early in 1961, Rosen and B. J. Myers went to Tahiti to investigate a variety of marine fish ("ature", "orare", bonite et thons) in search of the hypothetical parasite suspected of being responsible for eosinophilic meningitis, but they were unsuccessful.
2. On April 5, 1961, Alicata notified Rosen of the new proposed rat lungworm theory and the need for its investigation.² In addition, on April 18, 1961, he made plans to travel to Tahiti that June to ascertain the presence of *A. cantonensis* in wild rats in the area.³
3. On May 2, 1961, Rosen⁴¹ with the assistance of associates in Hawaii, secured the entire preserved brain of a mental patient who had died in a local hospital for diverse pathology, in-

- cluding eosinophilic meningitis. A few nematodes were recovered from this brain and, on May 5, 1961, were identified by Mrs. M. B. Chitwood (personal communication) as those of *Angiostrongylus cantonensis*. It is of interest to note that even though this finding was a direct affirmation of the rat lungworm theory, Rosen doubted that *A. cantonensis* was responsible for the disease in Tahiti. As a result, he wrote an official letter dated May 18, 1961 to an associate (Dr. E. Masal) in Tahiti stating "One direct way of ruling this parasite out is to show that it does not occur in rats in Tahiti. If present however, this fact alone does not establish it as a causative agent".^{6,43}
4. In June 1961, wild rats in Tahiti were found to harbor lungworms, *A. cantonensis*.⁴
 5. Later in June 1961, an observation was made in Hawaii of a patient who developed achy feelings, skin hyperesthesia, and eosinophilia in the cerebrospinal fluid. This occurred ten days after the patient willfully ate two veronicellid slugs collected from an area where similar slugs were later found to be infected with third-stage larvae of *A. cantonensis*.^{4,29}
 6. In the autumn of 1961, late third-stage larvae of *A. cantonensis* were recovered from the brain of a young squirrel-monkey five days after experimental infection with homologous third-stage larvae.⁴
 7. In February 1962, freshwater prawns in Tahiti were found to serve as paratenic (carrier) host for infective *Angiostrongylus* larvae. It was further ascertained from questioning patients that consumption of raw prawns and "taioro"—the latter a coconut sauce prepared by adding prawn juice, either of which may harbor infective *Angiostrongylus* larvae—served as an important source of human infection.¹²
 8. In 1962, experiments showed that infective larvae of *A. cantonensis* produced eosinophilic meningitis in an adult monkey, *Macacus rhesus*.¹⁴
 9. Experimental data showed that murine angiostrongylosis was present in all areas where eosinophilic meningitis had been investigated, including Hawaii and Tahiti,⁴ New Caledonia,⁷ Rarotonga¹⁵ and Micronesia.⁸
 10. It was theorized that the giant African snail, *Achatina fulica*, was largely responsible for the spread of the rat lungworm infection in Asia and several islands of the North Pacific.¹⁰
- Conclusions from the above results of systematic field, laboratory, and clinical observations, plus animal experimentation, led Alicata and associates to prove the major aspects of the rat lungworm theory.² This theory was further substantiated by recovering at autopsy the rat lungworm from the brain of a patient who had died of eosinophilic meningitis,⁴⁵ plus similar autopsy reports from Vietnam,³² Thailand,⁴⁷ and Taiwan.⁵¹ As a result, all these findings assisted in confirming the etiological role of the rat lungworm, *A. cantonensis*, in cases of eosinophilic meningitis in the Pacific Basin.³¹

Discussion

One of the important features concerning eosinophilic meningitis in the Pacific was the casual concomitant finding of this disease in Taiwan with that of *A. cantonensis*,³⁹ a parasite which later was first theorized and subsequently proven to be the etiological agent of the disease.^{2,31}

Historically, before the above findings, eosinophilic meningitis was unknown in the Pacific. As theorized by Alicata,¹⁰ the parasite was introduced in recent times with the incoming and spread of the giant African snail, *Achatina fulica* (Fig. 2), in the southern and eastern borders of Asia and several of the northern Pacific islands (Fig. 3).

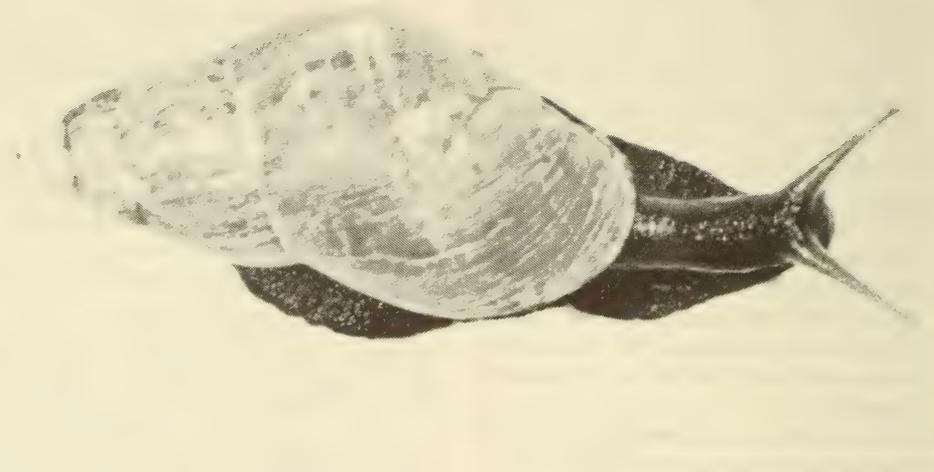


Fig. 2. The giant African snail, *Achatina fulica*. Natural size. (Alicata, 1966)

A. fulica is not only an ideal intermediate host for *A. cantonensis* but, as a scavenger, it is also able to travel extensively during wet conditions, feeding on all kinds of rotting vegetation, dead animals, and animal excreta. Mead³⁸ reports that man appears to have been directly or indirectly the chief dispersing agent. *A. fulica* was found in Madagascar before 1900, Ceylon in 1900, and Malaya in 1911. It was later found in eastern China about 1931, Taiwan in 1932, Okinawa in 1934, and thence was imported into Micronesia in 1938. It was found in Hawaii in 1936, and according to Beck et al.²⁰ in Samoa about 1975. The effects of this migration seem to demonstrate how a snail, with the help of man, enabled *A. cantonensis* to bring pestilence to a considerable portion of the North Pacific Basin.

In connection with the above distribution of the snail, angiostrongyliasis was reported in Taiwan, Guam, Hawaii, Ponape, Saipan, and Samoa 12, 25, 23, 8, 20, and 4 years, respectively after *A. fulica* was introduced to those islands. *A. can-*

tonensis was first observed in the rat population in China in 1933, Taiwan in 1937, Guam and Ponape in 1955, Saipan in 1963, and the Philippines in 1965.¹⁰

Although *A. fulica* is not known to occur in New Caledonia where angiostrongyliasis is endemic, it has been suggested that the parasite was transported there by infected mollusks or rats from Southeast Asia before World War II, possibly in connection with the importation of a large number of contract laborers for work in the nickel mines and plantations of New Caledonia.¹⁰ From there, it is likely that the parasite was introduced by way of oceanic trade routes to Tahiti and the Cook islands. In this connection, cases of eosinophilic meningitis occurred in New Caledonia in 1951, Tahiti in 1957, and Rarotonga in 1958. Moreover, evidence indicates that before 1957, the disease was unknown in Tahiti. Since the present human infection in this area is believed to be acquired largely by consuming freshwater prawns, and since the custom of eating these crustaceans goes back many



Fig. 3. *Solid lines*: routes and approximate dates of dispersal of *Achatina fulica* from East Africa to the Pacific Islands (adopted) with revision from Mead (1961) with permission of the University of Chicago Press). *Dashed lines*: theoretical method of dispersal of the rat lungworm, *Angiostrongylus cantonensis*, from South East Asia to the islands of South Pacific and Australia. *Plain stars* show where lungworms have been found in rats. *Circled stars* show where angiostrongyliasis *cantonensis* has been reported. (Alicata, 1966)

generations, it is apparent that the infection of prawns with *A. cantonensis* occurred in recent times. It appears therefore that the surge of epidemics of the disease in the Pacific occurred because the islanders were unaware that their food, commonly eaten raw, had recently become contaminated by an introduced parasite in their environment.

Angiostrongyliasis is known to be found in areas where murine angiostrongylosis is endemic. The sources of infection include a variety of mollusks and paratenic hosts^{9,11} that infect humans by being eaten raw or undercooked, being eaten accidentally with salad greens or ripe fruits, or eaten raw for supposed beneficial or curative qualities.

Some of the important varieties of hosts reported in the transmission of *A. cantonensis* to man include:

1. Mollusks: *Achatina fulica*, a land snail;^{23,33} *Pila ampullacea*, an amphibious snail;⁴¹ and *Cipangopaludina chinensis*, an aquatic snail.²¹ Included are the land slugs *Laevicaulus alte*²⁹ and *Vaginulus plebeius*.¹²
2. Paratenic hosts: *Macrobrachium* sp., a freshwater prawn;¹² species of land planarians as suspected in New Caledonia;^{7,17} species of frogs and toads, as reported in the Ryukyu;⁴⁰ and possibly certain species of amphibious⁴⁶ and land crabs.⁸

In addition to the above, the pelagic fish *Trachurops crumenophthalmus* (also referred to as "ature" and "akule") was found experimentally in 1967 to serve as carrier host for third-stage larvae of *A. cantonensis*.⁵⁰ In these experiments, even though the number of larvae recovered

from the fish was found greatly reduced within a few weeks after infection, some remained alive and infective for 29 days—the longest period tested. It was reported then that to incriminate this fish as a possible source of human infection, it is necessary to show the presence of the larval parasites in the fish in nature. This has not been confirmed to date. There is no record that marine fish in the Pacific are a source of angiostrongyliasis. In Hawaii raw fish (“sashimi”), derived from at least six types of marine fish including “akule”, is eaten by many islanders, especially those of oriental ancestry. According to the Communicable Disease Division of the Hawaii State Department of Health, no case of eosinophilic meningitis (angiostrongyliasis) has yet been reported in Hawaii as transmitted by the eating of raw fish “sashimi” (personal communication, November 6, 1986). Although cases of angiostrongyliasis have been reported in Hawaii since 1961,^{29,46} the source when known has been traced to the consumption of either raw snails⁴⁶ or slugs.²⁹ In one case, the mother of a 13-month-old-boy found a small snail in the child’s mouth before the onset of the illness.²²

Conclusion

Evidence indicates that eosinophilic meningitis first occurred in the Pacific Islands in the middle of this century, following the incoming of the giant African snail, *Achatina fulica*, believed responsible for the introduction of the rat lungworm, *Angiostrongylus cantonensis* in the area.

The first evidence of the relationship of the rat lungworm with eosinophilic meningitis was the concomitant finding of young adult *A. cantonensis* in the cerebrospinal fluid of a patient suffering with symptoms of meningitis in 1945.

In the wake of three epidemics of eosinophilic meningitis in the Pacific be-

tween 1948 to 1957, the rat lungworm was first theorized and later proven to be the etiological agent of eosinophilic meningitis, and this became recognized as a new parasitic disease of man referred to as “angiostrongyliasis cantonensis”.

The source of human infection lies in the consumption of raw mollusks (snails and slugs), which serve as intermediate hosts of the parasite, or the consumption of raw paratenic (carrier) hosts harboring the infective third-stage larvae derived from feeding on infected mollusks. Such carrier or transport hosts thus far reported include naturally infected freshwater prawns, land planarians, species of frogs and toads, and possibly crabs.

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The Portuguese Voyages of Discovery and the Emergence of Modern Science

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ABSTRACT

The successes of the Portuguese voyages of discovery depended upon the continuous application of scientific theory and technology to navigational problems. In establishing its colonial empire, the royal house of Portugal encouraged wide-ranging scientific researches to ensure Portuguese naval supremacy and to enhance trade advantages. Among the leaders in the Portuguese scientific ventures were scholars of Jewish origin—Yehuda ibn Verga, Joseph Vizinho, Abraham Zacuto, Garcia da Orta, Pedro Nunes, and others. Their work, emulated and expanded by scientists in the other maritime nations of Western Europe, was a major factor in the emergence of modern science.

Introduction

Before the mid-fifteenth century, scientific attainments were seemingly as far advanced in China, India, Southwestern Asia and the Levant as in Western Europe. But the next hundred years witnessed a radical change. Investigations in several domains of science suddenly proliferated in Western Europe. Researches abounded in astronomy and mathematics, in geography and chemistry, in medicine and physics. During the following centuries, modern science burgeoned in Western Europe with an ever-accelerating rate of growth.

Historians have offered a variety of answers to the basic question: Why did early modern science emerge in Western Europe when it did, and then develop there

almost exclusively? The various causes adduced have included: the invention of printing in Western Europe around 1453; the Turkish dismemberment of the Byzantine Empire and the release of Greek scientific treatises into Western Europe, especially after the capture of Constantinople in 1453; the recovery of scientific documents from monastery libraries; the inspirational example of Renaissance humanists; the rise of the independent, critical spirit that culminated in the Reformation; and the seminal antecedent labors of medieval scholars in the universities of Paris and Oxford, in Northern Italy, and elsewhere in Western Europe.

Although closer scrutiny has shown that some of these alleged causative factors derived from mythology rather than verifiable historiography, some of them

proved authentic. The mainstream of evolving science is fed by many rivulets and by mighty major tributaries. Among the tributaries insufficiently explored heretofore have been the scientific circumstances attending the voyages of discovery in the century and a half between 1400 and 1550. The results of documentary researches are cited here to demonstrate that the Portuguese voyages of discovery operated as a major contributory factor in the emergence of early modern science.

1. Prince Henry the Navigator and the Catalan Connection

Prince Henry the Navigator provided the resources and the driving force for an ambitious project to discover an all-water route from Portugal around southern Africa to the lands of the Orient. In 1418, he forsook the court of his father, King John I, and set up his permanent operations headquarters in Sagres at the southwesternmost tip of Europe. He then proceeded in a manner that has become characteristic of executives responsible for administering vast experimental programs in science and technology. He assembled the qualified personnel available in Portugal and, finding them inadequately trained for his purposes, he actively recruited experienced scientists and technicians from foreign sources. He hired sailors and shipbuilders from Italy and Scandinavia and Morocco to instruct his Portuguese crews on the intricacies of building rugged vessels and on the knack of sailing long distances over uncharted waters. In 1419, his mariners sighted and took possession of Madeira, about 600 miles southwest of Sagres and about 450 miles west of the Moroccan coast. Soon afterwards, Prince Henry invited an outstanding Catalan scientist to serve as his chief cosmographer, cartographer, and instrument-maker; to supervise and coordinate the activities of his growing

scientific staff; and to indoctrinate his technicians in their professional duties. John de Barros, writing more than a century afterwards, has provided the classical account of these events. In need of guidance for the exploitation of the recent discoveries, Prince Henry "summoned Mestre Jacome, of the isle of Mallorca, a man who was much learned in the art of navigation and in making charts and instruments; it was at great expense, but he brought forth in this Realm, by his indoctrination of scientific knowledge, a proficiency in that craft among the Portuguese." [Barros, 1539].

The identity of Mestre Jacome has been the subject of intense research. Jaime Cortesão [1980] recently declared that this identity dispute has been definitively resolved: Mestre Jacome has been unequivocally identified as Jaime de Mallorca, well known as Jafuda son of Abraham Cresques the cartographer of Mallorca and author of the celebrated Catalan Atlas or Mappamundi of 1375. (It should be noted for the record, however, that lingering doubts about this "unequivocally definitive" identification remain unappeased in some skeptical quarters. See, for example, Vernet [1978] and Grosjean [1978]).

The accumulated knowledge exhibited in Abraham Cresques' Mappamundi of 1375, and in the Mallorcan portolanos that preceded it, was a tribute to the veracity of the wide-ranging Catalan and Italian explorers. The accuracy of these charts was particularly impressive when they were compared to maps of the thirteenth century. Regarding these earlier maps, J. K. Wright [1965] wryly observed: "What strikes us first is their extraordinary inaccuracy." But, "when, during the latter years of the thirteenth century, the sailors of the Mediterranean, driven by the necessity of securing reliable aids to navigation, began piece by piece to construct marine charts upon which the contours of the coasts were shown with an approach to modern correctness, we have indeed a revolution in cartographic

art and geographical science." [Wright, 1965].

By the middle of the fourteenth century, Mallorca had become the chief center for portalano construction, and map-making later became a specialty of Jewish scientists. The kings of Aragon, eager to stimulate commerce, encouraged Mallorcan research in the navigational sciences, in mathematics and astronomy, and in the manufacture of magnetic compasses, astrolabes, clockworks, and other scientific instruments. The royal archives of Aragon in the fourteenth century contained frequent references to Jewish scientists engaged in these pursuits. According to Grosjean [1978], Abraham Cresques was mentioned at least twenty-one times. He was honored as a "Companion of the King" and as a "Master of Mappamundis and Compasses." Upon Abraham's death in 1387, his son and associate Jafuda Cresques was accorded similar encouragements, honors, and titles.

However, after 1391, Mallorcan scientific pursuits and commercial activities virtually ceased. The cataclysmic pogroms that swept Spain in 1391 wiped out the Jewish community of Mallorca. Many Jews were killed. Some escaped and found havens in Genoa and Algiers; they, like Portugal and England, had been former trading partners of Mallorca. Some Jews, among them Jafuda Cresques, submitted to forced conversion. Jafuda was baptized under the name of Jaime Ribes. He migrated to Barcelona, the mainland capital, around 1400. But the new king showed little interest in the sciences or in nautical ventures. The ensuing decline in the maritime activities of Catalonia and all of Aragon may have been one of the considerations that induced Master Jacome of Mallorca to accept Prince Henry's invitation to Sagres. Whether Henry's imported expert was indeed Jafuda Cresques alias Jaime de Mallorca, or some other Mallorcan scientist who specialized in cartography and instruments, he brought credentials assuring that his Portuguese clients would receive the full ben-

efit of the most recent Catalan advances in geography and the nautical sciences.

Cresques' Atlas of 1375, based chiefly upon the observational data of Catalan and Genoese explorers and Muslim and Jewish travelers, showed several groups of islands off the western coast of Africa, approximately where Madeira, the Azores, and the Canaries are actually located. Furthermore, the northwest coast of Africa was depicted in detail to a point south of Cape Bojador beyond the River of Gold; and Guinea, Mali, and Timbuktu were indicated in their proper situation. The 1413 planisphere of Mecia de Viladestes, identified as a Catalan Jew related to the Cresques family, reconfirmed these features and added further intriguing details. The Atlantic islands west of Africa and Cape Bojador on the coast became the immediate objectives of Prince Henry's expeditions under the guidance of his new chief scientist, Jacome of Mallorca. After years of hesitant probings, unproductive reconnaissances, and grumbling in high places about ruinous wastes of resources by quixotic scientists, the Portuguese expeditions reached both Cape Bojador and the Azores in 1434. Soon thereafter, shiploads of African gold, ivory, and slaves came into harbor at Lisbon and Oporto, rejoicing Prince Henry's more materialistic relatives as well.

The terminal date of Mestre Jacome's career in Portugal has not been established. Some time before 1439, he had been succeeded as chief cartographer by the Catalan Jew Gabriel de Valseca, thought to have been a relative of the Mallorcan Cresques family. Valseca's map of 1439 displayed the Azores archipelago with exact accuracy, and declared that the islands had been discovered recently by the King of Portugal's brave mariners.

When Prince Henry died at Sagres in 1460, his navigators had pushed southward to the Cape Verde Islands off the coast of Senegal and his pioneers had reached Sierra Leone on the African coast, 8° north of the equator. Thereafter,

southward progress slackened. One of the difficulties besetting the enterprise, even in Henry's time, was the problem of determining ship's latitude accurately. The navigator of a ship north of the equator can estimate its latitude simply as long as the north star (the "pole star") is visible. It is necessary only to measure the altitude of the north star by means of a sighting instrument such as a quadrant or an astrolabe. At first approximation, the latitude of the ship is the same as the observed altitude of the north star. But as the Portuguese explorers approached the equator, the north star disappeared from view. It became necessary to develop a new method for determining latitudes.

A solution to the problem was undertaken by Yehuda ibn Verga [1457], a Jewish scientist working at Lisbon, presumably in collaboration with Prince Henry's staff. Several of ibn Verga's Hebrew manuscripts on scientific subjects are among the holdings of the Bibliothèque Nationale in Paris. They include: *Kitzur ha-Mispar* ("An Abridged Arithmetic"); *Keli ha-Ofek*, ("Instrument of the Horizon"); *L'dat Middoth Kol D'var* ("Method for the Measurement of All Objects"); *B'ohr l'Luhot sh'Ahsa ha-Melekh Don Alfonso* ("Explication of the Alfonsine Tables") and *Pirush Alfargani* ("Commentary on al-Fargani's Astronomy"). The contents of these treatises are highly suggestive. They include edifying information on the daily positions of the sun at mid-day, instrumental methods for measuring these positions accurately, and rudimentary discussions of astronomy and arithmetical calculations. These components were identical with the basic elements of the successful procedure elaborated after 1482 by Abraham Zacuto, Joseph Vizinho, Master Rodrigo, and their colleagues, under the sponsorship of King John II of Portugal.

2. Abraham Zacuto, Joseph Vizinho and the *Almanach Perpetuum*

In 1482, King John II energetically resumed the unfinished project of his great-

uncle Prince Henry the Navigator. He appointed a three-membered junta, a board of scientific advisors, under the leadership of his Jewish physicians Joseph Vizinho and Master Rodrigo, with the charge of solving the latitude problem. Vizinho consulted his teacher Abraham Zacuto of Salamanca, distinguished Professor of Astronomy at the University of Saragossa. Zacuto had earlier completed his Hebrew astronomical treatise *Ha-Hibbur ha-Godol* ("The Great Codex") incorporating the scientific findings of Yehuda ibn Verga and many other eminent predecessors. In particular, Zacuto's treatise contained elaborately detailed tables on the position of the sun at mid-day for every day of the year, as well as: the positions and visibility of the moon, the planets and the fixed stars; data for the prediction of eclipses; and calendrical and other astronomical information. Using Yehuda ibn Verga's approach, Zacuto, Vizinho, and Rodrigo worked up a theoretical method for calculating latitude at sea by comparing the observed altitude of the sun at mid-day on shipboard with the altitude given in Zacuto's table of solar declinations for his latitude in northern Spain.

But many a searching field test was required before the validity of the theoretical method could be established. According to Barros [1539], Columbus later reported that Vizinho sailed with Bartholomeu Dias to the Gulf of Guinea south of the equator around 1485. There they conducted experiments on shipboard sightings of the sun by means of astrolabes and quadrants, with repeated calculations of the estimated latitude. They then "ran down the latitude" eastward to land on the African coast, where more accurate measurements were obtainable, and they verified the validity of their estimates. Their procedures prospered so well that within two years, Bartholomeu Dias brought the grand experimental project to its successful culmination when his vessels rounded the Cape of Good Hope and confidently proceeded northward along the east coast of Africa. The last leg of

the sea route from Portugal to India was now firmly within the realm of the feasible. Arabic and Jewish merchants had routinely sailed between the eastern shore of Africa and harbors in India for many centuries before 1487.

Vizinho [1496] translated Zacuto's treatise into Latin and prepared tables of the most pertinent information for the use of the Portuguese navigators. Vizinho and Rodrigo had earlier combined the data on solar declinations with a Portuguese extract of al-Fargani's "Rudiments of Astronomy" and an exposition on latitude calculations employing accurate instruments. The result of their work, corrected by Zacuto, was the *Regimento do Astrolabio e do Quadrante*. This compilation, a fundamental textbook on scientific instrument-aided navigation remained in use for more than a century, and influenced succeeding treatises for many a century thereafter.

In 1492, when Ferdinand and Isabella expelled the Jews from Spain, Zacuto migrated to Portugal at the invitation of King John II. He was appointed Astronomer Royal, an appointment that was renewed by King Manoel when he succeeded to the throne in 1495.

The duties of Abraham Zacuto as Portuguese Royal Astronomer included tutoring pilots and navigators on the mathematical and astronomical aspects of their nautical operations; constructing special astrolabes and quadrants for use on land or on shipboard; and providing written documents for the instruction of officers on the use of the instruments and observations involving data derived from the *Almanach Perpetuum*. The Portuguese historians and chroniclers have noted that he fulfilled all of his duties most nobly when Vasco da Gama, his officers, and his crew were briefed before their departure on the historic voyage of 1497 from Lisbon to India. It was Zacuto's last recorded service to Portuguese science and scientific technology. In that year, he parted from Vizinho and quitted Iberia for exile in Muslim lands, when

King Manoel decreed the forced conversion of all Jews in Portugal to Christianity.

In the same upheaval that resulted in Zacuto's departure from Portugal, Joseph Vizinho submitted to conversion. His subsequent career was far less eventful than his earlier years when he was chief scientist and confidential advisor to Portuguese kings. In that dual capacity, Vizinho had dealt in the 1480s with Christopher Columbus and his proposal that the King of Portugal finance an expedition to reach Cathay by sailing directly westward from the Azores. After much discussion in many a conference, Vizinho recommended to King John II that the proposal be rejected, for several cogent reasons.

Vizinho held, correctly, that Columbus grossly underestimated the distance between Portugal and China. Even with the most inspired instrument-aided navigation, and with the largest and soundest of vessels, no provisioning or crew could survive a contemplated voyage of such duration. Besides, the royal exchequer was already strained because of the continuing sixty-year investment in the probes down the African coast—a protracted set of experiments that now, finally, seemed just at the verge of a successful consummation. Reason and the scientific facts were with Vizinho, but destiny was with Columbus.

It is noteworthy that Christopher Columbus, who achieved his greatest fame in his voyages under Spanish sponsorship, had previously served for many years in the Portuguese fleets. He received pilot training under Portuguese officers; he commanded Portuguese vessels; and he learned the mathematical and astronomical basis of instrument-aided navigation by studying the methods of Vizinho and Zacuto. One of the extant copies of Zacuto's and Vizinho's Latin version of the *Almanach Perpetuum*, now in Seville, probably belonged to Columbus. It bears marginal notes said to be in Columbus' handwriting. It was also said to have saved the lives of Columbus and his crew

during one of his later voyages, when he overawed and overcame violently hostile Indians by using Zacuto's tables to predict the onset and duration of a complete solar eclipse, thus showing his magical mastery of the heavens.

Bartholomeu Dias worked with Vizinho and Zacuto to verify the practical applicability of their theoretical method for determining the latitude of a ship at sea. Vasco da Gama, Cabral (who discovered Brazil) and Ferdinand Magellan were natives of Portugal who were trained in the Portuguese maritime service from the days of their youth. Thus, all of the five most famous sea captains in the great age of exploration were indoctrinated in the scientific schools of Zacuto and Vizinho.

For these and other reasons, Portuguese and Spanish historians have acknowledged that Jewish scholars were preeminently influential in Iberian scientific enterprises before and during the great age of exploration. In his biography entitled *Christopher Columbus*, Salvador de Madariaga [1949] declared: "Cosmography, map-drawing, astronomy were then, we know, if not exclusively, predominantly Jewish occupations . . . [There was a] . . . strong proportion of Jewish master-cosmographers amongst the men of science whom Prince Henry had of old gathered at Sagres. At the time of Colon's arrival in Lisbon, the leader of these learned Jews was Mestre Joseph Vizinho, the King's physician, a pupil of the celebrated Spanish-Jewish astronomer Abraham Zacuto."

Columbus himself went even further. As de Madariaga reported on page 93 of his biography, Columbus had written in the margin of a book discussing the proficiency of Jewish astronomers: "All peoples received their astronomy from the Jews." De Madariaga's more cautious formulation almost coincided with the assessment that Albuquerque [1962] ascribed to Bensaude: ". . . *os astrologos judeus desempenhado um papel preponderante em tal dominio.*" "The Jewish as-

tronomers played a predominant role in that domain." Albuquerque's own conclusions were stated on page 275 of his treatise: "The texts that were used to produce the guidebooks and manuals for our pilots reflect the Jewish astronomical tradition. It was fortunate that Abraham Zacuto was professor of astronomy at Salamanca while his disciple Joseph Vizinho was advisor to the King of Portugal . . . Another favorable circumstance was the fact that Yehuda Aben Verga, whose tables Zacuto utilized in composing his *Almanach Perpetuum* resided in Lisbon . . . Starting in the eleventh and twelfth centuries, Jews in successive generations continually improved the tables of ephemerides, up to the tabulations of Jacob Poel, Ismael Bonfils, Aben Verga . . . and finally Abraham Zacuto's, the basis of the nautical tables used by Portuguese mariners in the Age of Discoveries. . . . [Portugal] . . . was indebted to the rich exotic learning of the Hebrew community."

Abraham Zacuto's indirect testimony supported Albuquerque's conclusions. Judging from the *Almanach Perpetuum*, Zacuto [1496] was an exemplary scientist with scrupulous regard for accuracy, as well as scrupulous care in acknowledging the sources of his information. He named eighteen scientists as his precursors in astronomical work. Of those who had lived within two centuries of the publication date of the *Almanach*, all were Jews whose treatises were originally written in Hebrew (Jacob ben Makhir, Levi ben Gershon, Jacob Poel, Isaac Alhadib and Yehuda ibn Verga). Furthermore, of the many scientific sourcebooks that Zacuto cited, all were available to him in Hebrew or Aramaic, including Hebrew translations of works originally written in Arabic or Latin or Greek. Among these latter works were the *Alfonsine Tables* (Latin) credited to King Alfonso X and Isaac ibn Sa'id; the Arabic astronomical treatises of Moses Maimonides and the Muslim scientists al-Zarqali and Aben Ragel; and two of the ancient Greek classics, namely

Ptolemy's *Almagest* and Menelaos' text on spherical trigonometry. Zacuto also approvingly quoted the Hebrew mathematical and astronomical writings of the medieval savant Abraham ibn Ezra, as well as scientific statements of the ancient Talmudic sage Mar Samuel. Thus, the testimony of Abraham Zacuto points to an uninterrupted chain of influential works by Jewish scientists that extended from Hellenistic times through the middle ages and into early modern times.

The evidence cited here thus far has demonstrated that the success of the Portuguese voyages of discovery depended upon the insightful utilization of scientific technology and theoretical science. The following sections consider the impact of Portuguese enterprise on the emergence of early modern science in the sixteenth century.

3. The Objectives of Portuguese Science in the Sixteenth Century

In 1400, before the great age of exploration, Portugal was considered a minor isolated kingdom, even among the realms of the Iberian peninsula. Lisbon and Oporto were merely convenient way stations for the Genoese and Catalan merchant ships plying between the Mediterranean Sea and ports in Flanders and England. By 1550, Portugal had become a world power whose armed fleets operated along the well-mapped coasts of Japan, China, India and the East Indies; along the eastern and northern coasts of South America; along the western and eastern coasts of Africa; and in the Atlantic waters of Europe. Lisbon became an opulent commercial and financial center handling vast and complicated transactions. Lisbon was also the focal point of the scientific research needed to enhance instrument-aided navigation and to improve Portugal's trading advantages. These advantages depended, among other factors, upon gunnery and firepower

overwhelmingly superior to the weaponry available to native Asian, African and Brazilian forces and upon the health and proficiency of the Portuguese expeditionary forces.

Portuguese researches concerned with, or in support of commercial, naval, and military projects included far-reaching investigations on mathematics, drugs, the practice of medicine, the chemistry of metals, the physical theory of light, analyses of ships' motions and the trajectories of projectiles, as well as improvements in cartography and in nautical instruments. Early in the sixteenth century, for example, the *balestilha* or cross-staff, invented by Levi ben Gershon around 1340 (also called the "Jacob's staff" or "astronomer's staff") replaced the astrolabe and the quadrant as the Portuguese navigators' most trusty instrument for measuring solar altitudes and determining ships' latitudes. Spain and France soon followed Portugal's lead, adopting the cross-staff as standard equipment for their navies, also, just as they imitated Portugal's activities in science.

The scope of Portugal's scientific research programs in the sixteenth century may be illustrated by brief references to the accomplishments of several Portuguese scientists.

Francesco Faleiro (1480–1540) combined an early career at sea with a later career in his maturer years as a theoretical scientist and a scientific administrator. His elder brother Ruy, a trained astronomer, was Ferdinand Magellan's boon companion. When Magellan quitted the Portuguese court and offered his services to the Spanish crown, the brothers Faleiro went with him. Francesco Faleiro accompanied Magellan in the Spanish expedition that completed the first circumnavigation of the globe (1519–1522). Magellan died en route; Francesco returned safely. Shortly afterwards, he was appointed Director of the Royal Nautical School at Seville. There he wrote "the first true textbook on navigation" [Gomes Teixeira, 1925]. It relied heavily

upon the methods of Zacuto, Vizinho and their Portuguese successors. On the basis of experimental work that the Faleiros conducted jointly, Francesco "proposed the first published method for determining the magnetic declination" [Gomes, 1925]. His suggested procedure for measuring ships' longitudes by calculations based on observed magnetic declinations proved untenable.

Francesco and Ruy Faleiro were Portuguese Jews who probably had become converts to Christianity before they transferred their allegiance from Portugal to Spain. Their scientific careers, like the nautical careers of Columbus and Magellan, showed how richly Spain reaped where Portugal had sown.

In the case of Dr. Garcia da Orta (1498–1568), Portugal reaped rich benefits by utilizing Spain's cast-offs. Da Orta's parents were Jews who, like Abraham Zacuto, had crossed the border from Spain into Portugal during the expulsion of 1492. Five years later, when King Manoel initiated his conversion program, the da Orta family accepted Christianity. Garcia was born shortly thereafter.

Having completed his medical training, Dr. da Orta enlisted for overseas duty as fleet physician to an expedition sailing for Goa. He settled there permanently. In his extensive medical practice he had ample opportunity to study tropical diseases previously unknown to Western Europeans. He also carefully examined medicinal and edible plants of the Orient and experimented with many of them for possible cultivation in Europe. His book *Coloquios dos simples e drogas he cousas medicinals da India* has been acclaimed as a scientific and literary monument of Portuguese culture in the sixteenth century. It was translated into Latin in 1567, and soon became a seminal text in the evolving modern sciences of pharmaceutical botany, pharmacognosy, and epidemiology.

Another Portuguese New Christian who contributed significantly to the de-

velopment of the medical and pharmaceutical sciences was Amatus Lusitanus (1511–1568). He practiced medicine and engaged in medical research in the Low Countries and in northern Italy contemporaneously with Vesalius. Amatus' anatomical researches in collaboration with Giovanni Canano disclosed the existence of valves in the azygous veins, an important clue in the chain of evidence that permitted William Harvey to formulate his theories on the circulation of the blood. Amatus invented a method of enema-feeding for patients with esophageal obstructions and he devised instruments for treating inflammations in mammary tissues.

Among Amatus' major contributions to the medical sciences were his seven volumes entitled *Curationum medicinalium centuriae* and his commentaries on Dioscorides' *materia medica*. Each of the *Centuriae* described one hundred edifying case histories of patients whom Amatus had treated. They were obviously popular, for they were re-issued in many editions at many centers of learning in Western Europe. The eminent historian of science George Sarton [1955] concluded that "Amatus was at one and the same time one of the leaders of clinical medicine and one of the foremost exponents of Dioscorides."

Another notable New Christian physician, Pedro Nunes (1502–1578) devoted his attention to nautical affairs and related pursuits in scientific research. He was Portugal's Chief Royal Cosmotographer for several decades. In that post, he indoctrinated naval officers (including two future kings of Portugal) on the cartographic, mathematical and astronomical aspects of instrument-aided navigation. He was well-qualified to fulfill these duties, for he was an accomplished cartographer, mathematician and astronomer, as well as a prolific inventor of ingenious nautical instruments. The catalogue of Nunes' successful researches for the enhancement of Portuguese naval supremacy and the advancement of science

attested to his versatility and his brilliance.

Nunes discovered the relationship between rhumb line sailing and great circle sailing. He invented navigation charts with curved rhumb lines some years before Mercator constructed loxodromic terrestrial globes. He studied the mathematical properties of the loxodromic curve and characterized it as a distinctively generated spiral. He invented an improved technique for determining latitudes accurately that depended upon two measurements of the solar altitude and the azimuth. He studied the trigonometric properties of spherical triangles and the transformation of astronomical coordinates. His work on the projection of a sphere onto a plane led eventually to Mercator's famous cartographic projections. He formulated interesting models for the apparent motions of the sun, the moon and other celestial bodies. He wrote a commentary on the planetary theories of George Peurbach, the associate of Regiomontanus who had been an immediate forerunner of Copernicus. Nunes investigated the duration of day and night at various latitudes, and he satisfactorily explained the phenomenon of "second twilight" or afterglow.

In the domain of mathematical physics, Nunes applied algebraic and geometric analyses to Aristotle's problem regarding the precise relationship between boat positions and oar movements in rowing. He also studied the motion of bodies in air as well as in water.

Nunes announced some of his findings in Portuguese, but he published most usually in Latin for wider distribution of his views among scholars in Western Europe. In addition to his publications on original scientific research, he wrote valuable historical sketches and a textbook on arithmetic, algebra, and geometry. He was a poet whose sonnets in Portuguese have been admired by knowledgeable literary critics. He was an outstanding teacher. At the University of Coimbra, where Nunes served as Professor of Mathematics,

Christopher Clavius was his pupil. Clavius later gained renown as "the Jesuit Euclid"; he instructed, befriended, and sponsored Galileo in his younger days. Nunes was also generous in transmitting current scientific knowledge to his many foreign admirers, such as Gemma Frisius and Gerard Mercator of the Low Countries, and Dr. John Dee of England, with whom he corresponded frequently.

Pedro Nunes, like Garcia da Orta and Amatus Lusitanus, acted both as a role model and as a conduit of new scientific information to colleagues elsewhere in Western Europe. The efforts of Portuguese scholars in the sixteenth century signalled the emergence of early modern science. Their influence catalyzed the rapid evolution of modern science in the seventeenth century. The course of these events may be examined profitably by considering the emergence of modern science in Elizabethan England.

4. The Objectives of Science in Elizabethan England

The fame of the Portuguese attainments in commerce, in navigation, and in science excited the admiration and emulation of neighboring states in Western Europe. Spain, France, the Netherlands, England and other European nations avidly modelled their efforts in maritime commerce and in scientific research after the Portuguese pattern. The attitudes of English scientists in the Elizabethan Age were typical of the general European milieu.

Francis Bacon (1562–1626) has been recognized as one of the eminent philosophical founding fathers of modern science. His selections among the greatest achievements of science up to his time are enumerated in his utopian book *The New Atlantis*. The inhabitants of this imaginary principality prospered mightily because they had adopted the methods of science and scientific management that Bacon

sketched in his *Great Instauration*, his *Advancement of Learning* and his *Novum Organum*. On that island the Europeans who were accorded the highest honors for their benefactions were: first, "Columbus, that discovered the West Indies; also the inventor of ships; your monk that was the inventor of ordnance and of gunpowder; the inventor of music; the inventor of letters; the inventor of printing; the inventor of observations of astronomy; the inventor of works in metal; the inventor of glass; the inventor of silk of the worm; the inventor of wine; the inventor of corn and bread; the inventor of sugars. . . ." [Bacon, 1858]. In his essay *On the True Greatness of Kingdoms and Estates*, Francis Bacon noted that "The vantage of strength at sea (which is one of the principal dowries of this Kingdom of Great Britain) is great . . . because . . . the wealth of both Indies seems in great part but an accessory to the command of the seas." [Bacon, 1858]. His advocacy of naval power was echoed by many bold spirits, among whom Walter Raleigh was prominent.

In 1585, Walter Raleigh had dispatched Thomas Hariot (1560–1621), a promising young cartographer, to explore the Virginia territories with a view to the future settlement of English colonies. Armed with various instruments, including the cross-staff and ephemeris for determining latitudes, Hariot and his companion John White efficiently completed their survey. Soon after, Hariot published a favorable bulletin entitled *A briefe and true report of the new found land of Virginia*. He assured his readers that, in addition to an abundance of edible plants and animals, the new territories were blessed with "grass silk and worm silk;" iron, copper, and silver; pearls; sugar; dyestuffs; and valuable drugs, including sassafras (considered better than guaiacum as a medicine) and the incomparable "tobacco smoke," a sovereign remedy for many ailments. [Hariot, 1588].

Hariot became an associate of Raleigh, Robert Hues, and Henry Percy, the

"Wizard" Earl of Northumberland. His subsequent career seemed a continuation of Nunes' activities. Hariot instructed Raleigh's mariners on the mathematical and astronomical aspects of navigation. He prepared accurate maps and charts. He studied the paths of projectiles and meteorological phenomena. He invented a valuable modification of the cross-staff.

In cartography, Hariot extended Nunes' and Mercator's work on stereographic projections and the loxodromic curve. He developed a formula for calculating the area of spherical triangles. In algebra, his simplified notation facilitated the expression of relationships in equations; he developed a formula for determining the roots of equations by factoring; and he anticipated Newton's work on binomial coefficients. In physics, he discovered that the path of a projectile is a parabola with a tilted axis, and he investigated free fall acceleration and the motion of moving balls before and after collision, independently of Galileo's work on mechanics. He also anticipated Galileo's work with the telescope around 1610, studying the satellites of Jupiter and mapping craters on the moon. In optics, he solved Alhazen's mirror problem half a century before Barrow announced his solution; he discovered the sine law of refraction now known as Snell's Law; he determined refractive indices of colors separated by prisms, as well as the refractive angles and specific weights of various substances. He transmitted his findings on refraction to Kepler, with whom he corresponded on problems in physics and astronomy. Aside from his brief report on Virginia, only one volume of his work issued under his name, *Artis analyticae praxis* on algebraic equations, published posthumously in 1631. So Hariot perished, virtually unpublished and almost unknown by name to posterity. But his discoveries and his disciples enriched many a field cultivated in early modern science.

The scientific fortunes of Hariot's older

compatriot William Gilbert (c. 1540–1603) were entirely different. Dr. William Gilbert was a successful medical practitioner. He was appointed royal physician by Queen Elizabeth and he held that position until her death. Although reappointed to the post by her successor, he did not enjoy the honors long, for he, himself, died in the same year.

Gilbert's obligations as a physician did not preclude his attention to natural philosophy and experimentation. His one major scientific interest was magnetism and his one significant publication was his treatise on that subject, *De Magnete*. The force of his experimental findings and the originality of his work led to their immediate approbation, and he gained fame throughout Western Europe in his own lifetime.

Edgar Zilsel's critique [1957] of *De Magnete* showed how Gilbert's outlook and scientific activities were molded by England's driving interest in navigation. Zilsel's introductory remarks and further analysis noted that:

“William Gilbert's *De Magnete* appeared in 1600, six years before Galileo's first publication, five years before Bacon's *Advancement of Learning*; it is the first printed book, written by an academically trained scholar and dealing with a topic of natural science, which is based almost entirely on actual observation and experiment. An analysis of the origins of its scientific method, therefore, is not only interesting in itself, but is likely to throw some light on the origins of modern natural science in general. . . .

It is significant with respect to Gilbert's interest in scientific accuracy that all of his physical instruments are actually nautical instruments . . . He performs measurements practically only when he deals with quantities which are important in navigation, such as magnetic declination and inclination, altitudes of stars, and geographical latitudes. . . .”

Zilsel emphasized Gilbert's interest in the world distribution of iron, his famil-

ilarity with the processes of forging, his knowledge of operations in English gun foundries, iron mines, and metallurgical laboratories. The critique then reverted to nautical affairs:

“Navigation and nautical instruments play an even greater part in *De Magnete* than mining and metallurgy. In his survey Gilbert . . . mentions men who have observed the magnetic declination on long voyages: Thomas Hariot, Robert Hues, Edward Wright, Abraham Kendall. . . . Gilbert knows that the declination differs at different places dispersed over all oceans and continents. The remarkably wide range of his statements proves his familiarity with the reports of the English, Spanish, Portuguese and Dutch navigators and the books of learned cosmographers . . . He knows that the Portuguese royal cosmographer Pedro Nunes disregards declination entirely . . . Since determination of geographical longitude was a difficult and, consequently, an often discussed problem at that period, he tries to solve it by means of the declination of the magnetic needle . . . In the end he quotes the correct solution of Simon Stevin, the eminent Dutch expert in military engineering, navigation and book-keeping.”

Thus, it is clear that Gilbert's celebrated treatise on the magnet, like the more diversified efforts of Hariot and Bacon, reflected upon many of the mainstream concerns that exercised scientists in Western Europe during the formative years of early modern science. It is also clear that direct links connected the scientific investigations of Western European scholars in the sixteenth century with antecedent labors of the Portuguese scientists. Further, the subsequent achievements of Kepler and Galileo, Descartes and Pascal, Huygens and Newton in astronomy, mathematics, and physics may be viewed as a continuation of the grand progression initiated by the Portuguese scientists in the great age of exploration.

Summary and Conclusions

Historical evidence supports a novel set of conclusions regarding the influence of the Portuguese voyages of discovery on the emergence of modern science in Western Europe:

1. Instrument-aided navigation and improved cartography, developed through the continual application of scientific theory and technology to nautical problems, were indispensable to the success of the Portuguese voyages of discovery.
2. To enhance its navigational procedures, and to protect its newly acquired territories and trade routes, the sources of enormous wealth, the Portuguese crown encouraged wide-ranging researches in many scientific domains, particularly astronomy, mathematics, and physics.
3. The contributions of scientists of Jewish origin—Yehuda ibn Verga, Abraham Zacuto, Joseph Vizinho, Garcia da Orta, Pedro Nunes, and others—were crucial to the emergence of modern science in Portugal during the fifteenth and sixteenth centuries. Hence, these Jewish scientists may be reckoned among the true progenitors of modern science.
4. The maritime nations of Western Europe, eager to emulate Portugal in the acquisition of overseas colonies and in the accumulation of wealth, imitated the Portuguese style in nautical innovation, in commerce, and in scientific research. The impact of the Portuguese inspiration may be traced readily in the accelerated development of science in Elizabethan times, and in subsequent scientific activities. Thus, the Portuguese example acted both as a catalyst inducing the emergence of modern science in Western Europe and as a prototype for the early modern scientists of the sixteenth and seventeenth centuries.

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The Development of the State Mental Hospital System in the United States: 1840-1980

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ABSTRACT

Using data from the National Institute of Mental Health and the Census Bureau, the authors examine summary trends in the utilization of State and county mental hospitals by mentally ill populations for the period 1840-1980. Attention is given to trends in admissions, inpatient residency, growth trends in numbers of hospitals, and annual expenditures.

For more than twenty-five years, deinstitutionalization of mental hospital patients and provision of alternate service for them have been popular topics in both the general and mental health literature. Negative aspects of institutionalization have been publicized, and the implication has often emerged that the mental hospital as traditionally envisioned would

soon be only a memory. But, as Goldman et al., and others point out, some 100,000 seriously ill long term patients are still being served by the State hospital system, and about 400,000 additions occur annually in the same system (1). Some writers suggest that problems of crisis proportion face states and communities as they consider an appropriate mixed type delivery system adequate for the decades ahead (2,3,4). Given this situation, it is important to examine long term trends in institutionalization of the mentally ill in the State and county hospital system to aid in future planning of resource use.

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While care of the seriously mentally ill has been considered to be primarily a State function, for almost one hundred-fifty years, the Federal Government has been concerned with the collection and distribution of data on this category of disabled citizens. The earliest attempt to draw a full enumeration was made in the 1840 decennial census, although, at the time, the mentally ill and retarded were not distinguished in the census summary reports (5). The agency originally assigned the enumeration task was the U.S. Bureau of the Census, and it continued this function with reasonable consistency until the end of World War II. While initial attempts at data collection were of a modest nature, and the results the same, they represented a beginning. They are of historical interest, and they provide a baseline for the study of trends in the future which are related strongly to policy issues.

As so-called "defective classes," the deaf, dumb, and blind, by "white" and "colored" designations, were counted in 1830. To the total category was added "insane and idiotic" in the 1840 census. The latter two types were lumped together and reported in one column in the summary census reports.

Starting in 1850, the insane (mentally ill) were delineated separately from the idiotic (mentally retarded). This practice was to continue throughout future governmental enumerations. Regular census counts of the mentally ill were undertaken in each decennial year until 1880, at which time a special census was drawn (6). Household enumeration, as such was discontinued in 1900. Special studies were undertaken in 1904 (7), 1910 (8), 1923 (9), and 1926 for residents in institutions for the mentally ill. In 1916, a limited administrative study was completed (10). From 1926 to 1946, annual censuses of institutional residents were conducted by the U.S. Bureau of the Census. The National Mental Health Act of 1946 assigned the responsibility for census enumeration of the mentally ill institutionalized pop-

ulation to the Public Health Service, which agency conducted the 1947 and 1948 surveys. The Biometry Branch of NIMH emerged in 1949 as the specific organizational unit responsible for this task. NIMH has carried out this activity between 1949 and 1984, with the Survey and Systems Research Branch serving as the organizational unit for data collection and analysis.

While some of the early enumeration approaches have been subject to criticism, the results form part of an historical record of service utilization (11). This paper will focus on summary trends in utilization of State and county mental hospitals by mentally ill populations over the past one hundred forty years, with attention being given to long term trends. A few States such as Wisconsin, have traditionally had county hospitals that carry out functions similar to facilities which are State sponsored in other States. We have included these in the analysis. Henceforth the term "State hospital" will be used to include State mental hospitals and county mental hospitals.

Data Source and Method

The Early Period: 1840-1900

As previously indicated, the "insane and idiotic" were counted by census enumerators starting in 1840, in one grouped category. From 1850 onward, the two sub-categories were distinguished and separated. In the early years, community and familial definitions of insanity were used as the basis of classifications. In using household schedules, field census representatives would routinely ask heads of households to designate which members were insane or idiotic. No attempt at medical or scientific definition was made. In fact, in 1870, individual schedules suggested that idiocy and insanity would "be better determined by the common consent of the neighborhood than by at-

tempting to supply any scientific measure of the weakness of the mind or will" (5).

By 1880, enthusiasm for the use of local and familial definitions had waned. It was estimated that this informal approach had produced a serious undercount. Based on legislation passed in 1879, a new special agent was chosen to head a specific section of the census. He was to make a special report on various sub-classes of "defectives" including both the institutionalized and non-institutionalized insane. Census field enumerators were given special schedules for the insane, and physicians in various sections of the country were furnished forms upon which to indicate insane (and idiotic) persons known to them. By this time, Kraepelian type diagnostic categories were emerging in psychiatry, and this development was reflected initially in the 1880 census. Seven forms of insanity were delineated, including mania, melancholia, monomania, pareses, dementia, dipsomania, and epilepsy. In practice, it was found that a subcategory could be reported for only about 80% of the cases (6).

The 1880 effort seemed to represent a peak of interest in an effort to carefully enumerate the insane. This effort represented a type of national prevalence study, and none of that magnitude has been attempted since 1880. The 1890 census was more "routine." In that year, regular field census enumeration procedures were followed, with no attempt being made to use physicians as special consultants. The summary report of 1890 was also not as inclusive as the preceding special one; it lacked the descriptive detail and attempt at causal analysis which distinguished the 1880 report.

The 1900 to 1946 Period

The turn of the century brought a change in orientation and procedure as far as the federal Government was concerned. There was a developing reluctance to use the local informal method of designating the mentally ill. Congress leg-

islated against the method in 1902 and proposed to substitute special studies of "defective" populations. From this thrust came federally sponsored surveys in 1904, 1910, 1916, and 1923, respectively. In practice, this meant that enumeration was not undertaken until the major censuses of manufacturing, agriculture and the general population had been completed. Primarily because the regular enumerators would no longer be employed, their use as in previous periods was not possible. Instead, schedules were sent to heads of mental institutions. No attempt was made to enumerate those mentally ill persons residing in almshouses, jails, or private homes.

In 1904 and 1910, general demographic descriptions were made of institutionalized patients, in some detail. In 1916, a special study, limited in scope, was undertaken with only summary totals on patient data being indicated. The focus was on administrative detail, by State. The 1923 survey was extensive, and it included first admissions, deaths and other patient movement, plus expenditure and maintenance provisions per patient. Special schedules were used to gather information on finances, plant facilities, and personnel of State hospitals. From 1923 through 1946, annual enumerations of resident populations of the mentally ill were made, following the general patterns of reporting started in 1923, although the scope varied occasionally in given years.

The 1947 to 1980 Period

World War II brought new attention to mental health issues, with Congress responding by passing the National Mental Health act of 1946. This Act created the National Institute of Mental Health (NIMH). The newly created agency was given the responsibility for census enumeration of the mentally ill. From 1946 to 1949, the Public Health Service performed this task. Since 1949, the responsibility has been carried out by NIMH. Beginning in 1947, a major shift in data

collection technique developed. In previous modern censuses of institutionalized patients, line schedule data was available for all patients "in movement," i.e. release, transfer, etc. The 1947 change in procedure meant that reporting institutions submitted only consolidated reports reflecting aggregate counts by age, sex, diagnosis, etc. This approach was presumed to better maintain patient confidentiality and to be simpler and easier to prepare by the responding institutions. However, the new system did add new elements of rigidity into the data base. This meant that crosstabular type analyses would be severely limited in the future.

In this paper, no attempt will be made to trace patient trends by diagnostic subcategories. In 1923, Director of the Census Steuart warned against their use from any previous census. During the 1920's, a diagnostic classification system which had been jointly developed by the National Committee for Mental Hygiene and the American Psychiatric Association was adopted by most public mental hospitals. This system has been in use and modified slowly through the years to conform to Diagnostic and Statistical Manual (DSM) standards of reporting.

With DSM categories in mind, it is apparent that the combination of schizophrenic and affective types of patients have been predominant groups in State mental hospital populations. Organic syndromes, including senile dementia, have typically been referred to in hospital diagnostic categories. Until the last two decades, paresis was a common category, primarily of males. Alcoholic patients, predominantly males, are consistently included in the reports. Epileptic patients were included until the modern period, when alternate services were provided for them. A small proportion of mentally retarded persons have always been reported for mental hospital populations. And always, reference is made to those without psychoses or who cannot be classified, or both. Over the years, then, there has been

some reasonable consistency in sub-types of populations appearing in mental institutions, even though variations would at times occur.

There has been considerable consistency in terms of the operational definition of patienthood to be used here. For most of the years under study, the majority of clients were involuntary patients who had been declared legally insane. Behind this was involved a community sorting process based on lay conceptions of mental illness and insanity. Local stereotyped concepts and norms defined the boundaries of tolerated behavior. When an individual's behavior went beyond the boundaries with some consistency, action was finally taken. Typically, this meant certification by a local physician and legal decision by a judge, after formal charge by a local lay person. According to reports, neither the local physician nor the magistrate typically had any graduate psychiatric diagnostic training. Regardless of this, they officially engaged in processing of individuals. The main criterion for hospitalization over the years has been that of presumed insanity. This legal concept has not had precise DSM or other measurement type referents. The issue has been whether the individual in question was disturbed enough by local definition to be referred to the State hospital.

Inpatient hospital residency and admission patterns have always been affected by many variables, including public attitudes, availability of facilities, alternate psychiatric services and the interrelationships among them, socioeconomic and geographic factors, and administrative practices. Added to the above, sex and age factors are involved. In future papers, attempts will be made to trace patient loads over time by subcategories. In this initial paper, only totals will be reported.

Comparability issues regarding facility type can be raised. The focus in this paper is on State and county mental hospitals. In a few states, county or city sponsored hospitals have been used as functional

equivalents to State hospitals. The number of county mental hospitals has declined in the last two decades, and they presently total less than 20. In gathering statistics, we have separated State data from private hospital, Veterans Administration and other facility data, to the degree possible. Specific sources of data by year are cited in the footnote to Table 1. Since 1855 data have been included from St. Elizabeths Hospital of the District of Columbia. Also included since 1923 are a small number of State psychopathic hospitals. In 1923, there were 4 in existence, and, in recent decades, they number 10 in total.

Data Analysis

Fortunately, summary data for the institutionalized mentally ill from 1830 to 1880 was included in the 1880 census report (6). Table 1 indicates the growth trends for the State mental hospital system. While there were eight hospitals in existence by 1830, only four were public. Over the next five decades, the growth in number of State hospitals was very noticeable. This meant that by 1880 there were 65 State hospitals with some 36,000 resident patients. This represents a steady rate of growth in spite of the fact that the country was experiencing major social change and upheaval including civil war during the period.

It should be noted that Rothman (12) and Grob (13) have provided thorough accounts of the circumstances which led to the development of the first mental hospitals in the period preceding the Civil War. A later work by Grob (14) relates mental health institutions and practices to conditions existing between 1875 and 1940.

The post civil war period involved a steady stream of new immigration and increasing urbanization of the country. Between 1870 and 1890, the number of State and county hospitals was to double. By

1900, yearly admissions numbered about 40,000 and the resident patient population was slightly over 100,000.

The turn of the century ushered in an era of further expansion. The number of inpatient residents in the State hospital system increased as well. From a population just slightly in excess of 100,000, the population increased by a factor of five by 1950. Patient population counts must be balanced by reference to the national total population base as well. The crude rate per 100,000 civilians was 159 to 1900. It was to grow to 341 per 100,000 by 1950. This expansion pattern was a steady, upward one through the half century, seemingly not directly correlated with serious social upheavals, such as World War I or II (15).

The post 1950 period brought the expansionist phase for State mental hospitals to a dramatic peak. The actual high point occurred in 1955 with some 559,000 resident patients being enumerated for that year. An equally dramatic 75% drop in the total resident population occurred between 1955 and 1980. The causal processes at work which brought about the decline are as yet not completely understood, but references are consistently made to the use of psychoactive drugs, the adoption of deinstitutionalization practices, and the provision of various community-based, alternate-service programs (16). Opinions differ sharply as to whether the steep downward trend will continue, or whether a "leveling-off" phase is immediately ahead regarding inpatient residency patterns. A hard-core, chronic, long-term population continues to exist, according to many reports (17,18). A substantial proportion of such clients are relatively young.

Numbers of admissions for the same 150 year period indicate similar upward trends. Data for the first fifty years reveal an upward trend from about 400 annual admissions to State mental hospitals in the middle 1830's to 15,000 by 1880. The average for each hospital ranged from about 50 per year in the middle 1830's to almost

Table 1.—Number of residents, admissions, hospitals, and annual expenditures, for State and County mental hospitals, United States, 1831 to 1980.

Year	Resident patients	Rate per 100,000 total resident population	Admissions	State	Number of hospitals	Annual expenditures (in thousands)
					City, or county	
1831	150	1.0	200	4	0	30 ^a
1840	471	3.0	691	9	2	121
1850	3,275	14.1	2,266	16	2	360
1860	7,696	24.4	4,462	32	5	1,259
1870	14,605	36.6	8,609	42	6	3,200
1881	36,780	71.4	16,617	66	9	6,520
1890	69,445	110.1	25,645	111	114	10,596
1903	144,653	179.4	44,912	138	88	21,329
1910	180,242	195.1	53,452	143	106	30,070
1923	255,245	228.0	71,803	165	148	63,673
1931	318,821	257.0	82,334	174	37	85,683
1940	423,445	320.9	110,119	178	80	127,020
1950	512,501	338.9	146,568	211	111	396,721
1960	535,540	297.6	220,616	233	47	919,619
1970	337,619	165.7	384,511	275	40	1,734,276
1980	132,164	58.3	336,414 ^b	262	14	4,085,765

^a1831 is provisional based on reference 6; 1910 expenditures are provisional based on references 7 and 9.

^bAdmissions include admissions and readmissions; 1980 is a provisional estimate based on additions, which includes admissions, readmissions, and returns from long-term leave. Beginning in 1976, only information on number of additions is available.

Sources of data:

1. 1830–1880: Reference 6
2. 1881–1890: Reference 11
3. 1900–1903: Reference 7
4. 1910: Reference 8
5. 1923: Reference 9
6. 1931, 1940, 1950, 1960: NIMH, Patients in Mental Institutions
7. 1970: NIMH, Statistical Note 106
8. 1980: NIMH, Additions and Resident Patients at End of Year, State and County Mental Hospitals, by Age and Diagnosis, by State, United States, 1980.

125 annually by 1880. Admissions were to reach the 50,000 level in the early twentieth century, and the 150,000 level by the end of the World War II period. Table 1 also shows the steady rise in admissions during the post-war period. In the modern period, the peak of admission lagged behind the peak in residents by more than a decade, occurring in 1971, with 402,472 admissions being reported for that year.

After 1971, the admission rates started to drop, but at a modest pace. For example, in 1972, the total was 390,000, and by 1975 it was 376,000. The decline was slow in the next five years, reaching about 340,000 by 1980. The modern rates are

incongruent with projections made in the 1960's (19). During that period, deinstitutionalization was well underway and a new community-oriented philosophy was emerging. Alternate services and facilities have expanded considerably since 1960. Especially notable are expansions in psychiatric units in general hospitals, free-standing psychiatric outpatient clinics and community mental health centers (20). In spite of these developments and extension of community oriented services, admission rates have remained relatively high for the State hospitals.

In Table 1 the estimated expenditures for the total State hospital system are

listed by year, excluding capital improvements. The figures from 1830 to 1880 are based on estimates made by the 1880 census director for the fifty year period. As can be seen, the amounts were relatively low for the first one hundred years, if one considers population growth during the period. In the last fifty years, they have risen sharply in total dollar amounts, the sharpest increase in the trend line of costs coming in the last decade. The rise during the 1970's is due totally to inflation.

During the modern period, Federal funding for inpatients increased greatly because of changes in social security entitlement programs. Part of the expenditure increase in the early 1970's can be related to the attempts to improve hospital conditions which were mandated by legal provisions in some States and threatened in many others. Included would be changes in staff ratios, adjustments in employee wages and benefits, and provision of more definitive diagnostic and treatment services (21).

It is doubtful that the tendency for expenditures to remain relatively high can be explained fully by legal requirements. Included for consideration must be institutional inertia, staff and employee resistance to cutbacks or change, and local community interest in keeping hospital operations intact. Proposals to transfer funds and patients simultaneously from State hospitals to local facilities will need to take the above factors into account.

Growth of Facilities

The record of mental hospital development, as such, may be of interest. As has been well publicized, the first public mental hospital, known as the Eastern Lunatic Asylum, was established in 1773. During the middle 1830's, it was treating less than 100 patients annually. By 1880, the number of inpatient residents had risen to 323. A growth pattern similar to this was typical for many early hospitals. Morrissey et al. (22) provide an important case history of one of the oldest and most

influential mental institutions, Worcester State Hospital, and its organizational characteristics as they relate to changing conditions.

As indicated in Table 1, the number of State hospitals grew from 4 in 1830 to over 100 by the end of the century. Although county hospitals are included in this study, the great majority have been State sponsored and controlled. For example in 1923, 165 mental institutions were State sponsored. This number climbed slowly but steadily, so that by 1940 there were 178, and by 1950 there existed 211 State sponsored inpatient facilities, out of a total of 321. A decline in numbers has been evident since 1950, but it has been more moderate than the corresponding decline in resident inpatient population. In the 1970-1980 period, widespread publicity was given to hospital closures in California, Illinois, Massachusetts, New York, Ohio, Oklahoma, Washington and Wisconsin. This publicity masked the fact that in some States no hospitals were closed and, in a few, new mental hospitals were built. The latter included Delaware, Florida, Georgia, and Virginia (23). At any rate, the majority of State mental hospitals are still functioning, often with some modifications in what had been their traditional role.

Discussion

Attention has been given to enumeration of the institutionalized mentally ill since 1830. The source of the motivation for the original counting is not clear. The so-called "defective classes" evidently emerged as problems demanding attention. Apparently, local community pressures eventually were carried to the Congressional level which resulted in attempts at census taking to provide some indication of the scope of the problem. The 1830 to 1890 period brought the development of the State hospital system, with reformers such as Dorothea Dix fa-

cilitating the process. It would follow that minimal enumeration would be important to provide a data base for analysis and policy use. Irrespective of the reason, national record keeping attempts regarding the mentally ill have been conducted for about 150 years.

The data presented have demonstrated a relatively steady increase in the size of the mentally ill resident patient population until the middle 1950 period. There followed a period of decline in the numbers of mentally ill who were residing in hospitals. Admission rates followed a similar pattern of growth from the 1830's to the post World War II period, with a drop starting in 1971 and continuing in modest fashion through 1980. Annual expenditures climbed slowly over the years, with a sharp rise appearing for the 1970 to 1980 period in terms of actual dollars. Taking inflation into account, financial support actually decreased.

If figures for resident load, admissions, and expenditures are followed, it appears that all show parallel upward trends for the years 1830 through 1950. Incongruence between them appears in the post 1950 era. Numbers of inpatient residents are sharply down from what would have been projected in the pre-1950's; admissions are relatively high, as are expenditures. In effect, this means that relatively large amounts of money are being spent for a smaller patient load.

Results of this new combination of circumstances should mean, theoretically, a more positive total environment for patient care, and some reports indicate that such is emerging. A number of States report increases in staff-to-patients ratios. Higher wage scales for staff and employees have developed in some areas. More time and attention to admission, diagnosis, and screening is also reported (24). Whether or not the hospital atmosphere has significantly changed for patients is still being debated (25). There are available no accepted instruments at this time to measure total treatment milieu. Many mental health writers who have strongly

supported deinstitutionalization have done so because they believe the State hospital system exhibits inherent inadequacies (26). Others believe the State system can, with some upgrading, provide the best long term care facilities that can be realistically supported at this time (27).

It does appear that the deinstitutionalization process has been modified for the present. Additions (including admissions and returns from leave) dropped only from 423,000 to 377,000 in the period 1976 to 1980. During two of those years, 1978 and 1979, they remained essentially constant. The older, long term population will eventually be phased out. Contrary to most expectations and predictions, new eventually long-stay patient groups are appearing. Many planners and theorists have failed to take into account demographic risk factors associated with psychotic breakdown in the general population. Kramer in 1977 made projections for 1985 based on age categories (28). Taking into account the "baby boom" cohort, Kramer projected a 26 percent increase in the sub-category schizophrenia for the age-groups 15-24, 25-34, and 35-44, respectively for 1985 compared to 1970. Projections for other diagnostic subcategories were made as well. Reports from various States tend to confirm Kramer's projections. They suggest the emergence of a new, long-term, somewhat male dominant population exhibiting serious disorder (29,30). Some individuals of this type have had repeated contacts with State hospital admissions departments, and substantial proportions are becoming part of the inpatient State hospital residency load. Others are straining local facilities (31). The size of this type of potential patient group needing long term support and care is difficult to estimate. The group will, if the trend continues, keep a minimum State hospital population intact unless alternate community facilities are provided.

This appears to be a critical period for the mental health service delivery system. As we approach the end of the first

quarter century of the modern community orientation, many challenges to the assumptions of the ideology of the sixties are being raised. A pluralistic service system now exists, with developments in the private sector being especially noticeable. Contrary to many assumptions and projections, the State hospital is still relatively active.

Proposed changes in the role and function of the State hospital will ideally involve consideration of important policy and planning issues. Among variables to be taken into account are lay and professional attitudes toward the mentally ill, socioeconomic and political considerations, and the level of scientific knowledge about mental health.

One hundred fifty years is substantial in terms of North American institutional history. Major manifest and latent functions have been carried out by State hospitals. It would appear that we are approaching a critical juncture in American mental health history. Plans now being made will carry over to the twenty first century. What is the essential role of the State mental hospital system, if any? That is an important question for the mental health community in the immediate future.

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Report on the Scientific Symposium of the Consortium Research Fellows at the U.S. Army Research Institute

Edited by Robert S. Ruskin and Sherman Ross

PREFACE

We began this project in 1981 to develop a model relationship between the academic and governmental sectors. Certainly most of the pieces were there: an organization with proven leadership in the university community (the Consortium of Universities) and a research institute of proven strength in the scientific and governmental communities (the Army Research Institute). It was our desire to build a dynamic working alliance between the imagination, energy, and expertise of established scientists at ARI and the extraordinary graduate students attending Consortium universities. What was missing was a structure to bring together these two entities. Through the development of the Research Fellows Program, this structure was put in place.

The program has been in operation for six years, and we now have a flourishing, truly cooperative venture, as described by Drs. Johnson, Ruskin, and Ross in the next article. Everyone has benefitted so far, but these benefits are maintained only through careful and continued nurturance.

The following pages provide the reader with the unique perspectives of all parties involved in the project, from technical and project directors to the student fellows themselves.

Lieutenant General John S. Crosby
Deputy Commanding General for Training
United States Army Training and Doctrine Command

Colonel Wm. Darryl Henderson
Commander
United States Army Research Institute for the Social and Behavioral Sciences

Reverend John P. Whalen
President
Consortium of Universities of the Washington Metropolitan Area

Correspondence should be directed to Dr. Robert S. Ruskin, Director of Research and Program Development, Consortium of Universities of the Washington Metropolitan Area, 1717 Massachusetts Avenue, N.W., Suite 101, Washington, D.C. 20036.

Consortium Research Fellows at the Army Research Institute: Background and Update¹

Edgar M. Johnson,² Robert S. Ruskin,³ Sherman Ross^{4,5}

The 1980 Defense Appropriations Act allowed a closer relationship between defense laboratories and universities. This opportunity was seized by Father John P. Whalen, Executive Director of the Consortium of Universities of the Washington Metropolitan Area and Dr. Joseph Zeidner, then Technical Director, United States Army Research Institute for the Behavioral and Social Sciences (ARI) and Chief Psychologist, U.S. Army. Their initiative resulted in a contract, signed in 1981, between the Consortium and ARI which stipulated that the Consortium would provide technical and analytical support for the in-house research being conducted at ARI. This support has been provided by graduate students, known as Consortium Research Fellows (CRFs), from the institutions which are members of the Consortium. A previous article by Ross, Sasmor and Whalen⁶ (1983) described the basic agreement. This report provides an update and status report on the program.

Army Research Institute

ARI is the Army's primary people-oriented research laboratory. Its mission encompasses the full spectrum of behavioral and social sciences. The research programs are carried out by four elements organized around the following research product lines:

Manpower and Personnel Research Laboratory. Manpower requirements and resources, recruiting and retention, leadership, and personnel measurements.

Systems Research Laboratory. Human factors, command control communications and intelligence, manned

systems design, and system assessment.

Training Research Laboratory. Institutional and individual, unit training, devices and simulators, and advanced technologies.

Office of Basic Research. Design of intelligent interfaces, leadership and organizational effectiveness, problem solving/decision making, and skill building technologies.

ARI employs over 200 scientists, with about 125 located at ARI headquarters in Alexandria, Virginia, and the remaining at field sites in the United States and Europe. These scientists are highly qualified—over 65% hold Ph.D.s. For such scientists to apply their energy and skills most effectively, individuals with knowledge and experience beyond the bachelors degree were needed to assist them by undertaking tasks such as data collection, data analysis, literature review, and report writing. The main objective of the contract between ARI and the Consortium has been to provide qualified graduate students to perform such technical and analytical support services for research programs at ARI.

Consortium of Universities

The Consortium of Universities is a non-profit corporation chartered in 1964 to encourage and coordinate joint academic and resource planning and student exchange among the member institutions. The Consortium is uniquely qualified to establish and manage broad support programs, since policies are in place for cooperation among the member institutions. These institutions are: The American University, The Catholic University of America, Gallaudet University, George Mason University, The George Washington University, Georgetown University, Howard University, Marymount University, University of the District of Columbia, University of

Maryland, Mount Vernon College, and Trinity College.

Research Fellows

At ARI, the Director of Basic Research⁷ develops a list of scientists who require assistance in conducting their research programs. This list is provided to the Consortium. In order to facilitate the matching of interested graduate students to these scientists, the Consortium of Universities appointed a Steering Committee. The task of the Steering Committee was to solicit applications from graduate students, screen them, and match them to openings at ARI. The Steering Committee also set policies and procedures for the Consortium Research Fellows and appointed Project Directors.⁸

Once selected, the CRF is assigned to a scientist at ARI (the "Mentor"). Fellows may work up to 20 hours per week during the school year and full-time during the summer months, and the fellowship appointments are for three years, assuming that acceptable performance at ARI is maintained. The students cannot hold other fellowships while serving as Consortium Research Fellows and must maintain satisfactory progress toward their degree. The pay for these graduate students is based on the level of their most recent degree and the amount of experience they have had. Each Fellow is expected to turn in a short Status Report at the end of every month so that their progress may be monitored, and their Mentors at ARI are asked to evaluate their performance at the end of each year of service. The Project Director and the Director of Basic Research provide general oversight and work to resolve any problems.

Completion of thesis or dissertation research at ARI is encouraged as is the appointment of ARI Mentors to doctoral committees. Several graduate students are working on their theses or dissertations in ARI labs.

Results

Since the inception of this program in 1981, there have been 45 CRFs. While full or part-time regular employment at ARI is not a product of the fellowship, it has become a by-product of the program. Thirteen Fellows have received offers of jobs at ARI and nine are employed there.

As of February 1987, eighteen CRFs (16 women and two men) were employed at ARI. Two worked in the Office of Basic Research, seven in the Manpower and Personnel Research Lab, two in the Systems Research Lab, and seven in the Training Research Lab. There were three CRFs from American University, two from Catholic University, one from George Mason University, two from Georgetown University, six from George Washington University, three from Howard University, and one from the University of Maryland at College Park. CRFs were involved in research efforts ranging from "A cognitive model for simulator training," to "The rater factor in job performance ratings." They were collecting and analyzing data and completing literature reviews. Some advanced students were also doing dissertation research under the joint guidance of their major professor and the ARI Mentor.

To date, most of the Fellows have been from graduate departments of psychology. However, graduate students from any of the behavioral and social sciences are accepted, and the intent is to get students from other disciplines involved (e.g., computer science and engineering).

Summary

The arrangement between the Consortium and the Army Research Institute has proven to be mutually beneficial. ARI receives a great deal of necessary technical and analytical assistance and the graduate students receive financial support while they are acquiring excellent experience in research theory and skills. In fact, this program has been so successful that the

Consortium is now exploring ways to develop similar programs in other research settings around the Washington metropolitan area and to include other disciplines in such programs, and ARI has established similar arrangements with other universities in some of its field units.

Notes

1. The views, opinions, and findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.
2. Technical Director, Army Research Institute and Chief Psychologist, U.S. Army.
3. Director, Research and Program Development, Consortium of Universities
4. Assistant Project Director, Consortium of Universities, and Howard University.
5. Correspondence should be directed to Dr. Robert S. Ruskin, Director of Research and Program Development, Consortium of Universities of the Washington Metropolitan Area, 1717 Massachusetts Avenue, N.W., Suite 101, Washington, D.C. 20036.
6. **Ross, S., Sasmor, R. M. and Whalen, J. P.** 1983. Research Fellows of the Washington Consortium of Universities at the U.S. Army Research Institute. *J. Wash. Acad. Sci.*, **73**, 151-152.
7. At the time of the Symposium, the Director of Basic Research was Milton S. Katz, who replaced Robert M. Sasmor in 1985. The current Director is Michael Kaplan.
8. The current Project Director is **Robert S. Ruskin**. Former Project Directors have been: Sherman Ross, 1983-1984; C. E. Rice, 1982-1983; and Elliott M. McGinnies, 1981-1982.

Proceedings of the Symposium of the Consortium Research Fellows¹

Robert S. Ruskin, Edgar M. Johnson, Sherman Ross

The second scientific symposium of the CRFs was held on April 13, 1987, in the ARI Conference Room. The major purposes were (1) to provide an overview of the Consortium-ARI program, (2) to provide the CRFs an opportunity to describe their activities, and (3) to effect the sharing of this information among the CRFs,

the ARI scientists (Mentors), and the Consortium representatives.

A brief welcome was given by Edgar M. Johnson, Technical Director, Army Research Institute and Chief Psychologist, U.S. Army, and Robert S. Ruskin, Director of Research and Program Development, Consortium of Universities. Statements were provided by COL Wm. Darryl Henderson, USA, Commander, ARI, the Reverend John P. Whalen, then Executive Director, Consortium of Universities, and MAJ GEN John Crosby, USA, then Assistant Deputy Chief of Staff for Personnel.

The primary organization of the symposium was based on the unit of relevance with a brief presentation of the responsibilities and activities by the Director, and appropriate reports by the CRF. The section which follows is arranged to indicate the unit, its program, and is followed by an abstract of the report of the CRF with identification of the university and the ARI Mentor.

I. Office of Basic Research Milton S. Katz, Director

The Office of Basic Research plans and executes long-range research in the behavioral and social sciences. Specific research objectives are to advance concepts, theory, techniques and data in selected areas of the behavioral and social sciences, to contribute to the store of scientific and technical knowledge, and to lead the next generation of applied research in the behavioral sciences for the Army. The Office seeks to fill gaps in existing behavioral science methodology and develop a cumulative data base on which to build new technologies to improve Army effectiveness. If not addressed, such gaps would hamper ARI's ability to conduct applied research programs several years in the future.

The organization and development of the basic research program parallel the

applied research missions of ARI's three laboratories: manpower and personnel, education and training, and the human element in Army systems. Proposed projects are evaluated primarily in terms of their relevance in supporting future applied research, their scientific merit, potential payoff and their synergistic impact on other work being supported. Proposals are invited in such areas as: 1) Planning, Problem Solving, and Decision Making; 2) Manpower, Personnel, and Unit Performance; 3) Skill Building Technologies; and 4) Designing Systems for People.

The Office capitalizes on new research and emerging technologies by involving innovative civilian scientists in projects of potential use to the Army. At the present time the Office has contracts with over sixty universities, nonprofit organizations, and businesses. Special programs, such as the Consortium Research Fellows, bring university and high school faculty and students to ARI headquarters for research, and an in-house program supports ARI staff in the conduct of basic research. Other activities include management of Congressional, Department of Defense and Department of Army mandated programs such as Small Business Innovation Research, DoD University Roundtables, and University Research Instrumentation Program.

**A. Steven Kronheim,
American University
Judith Orasanu, Mentor**

As a doctoral student in social psychology at American University and with broad research and teaching experience, a logical preference for my CRF experience was the Office of Basic Research. I perform duties necessary for meeting the Office's main mission of providing ARI with the appropriate scientific knowledge base designed to address key military problems. For instance, to help the office assess and complete the research projects it supports at universities, private labo-

raries, and other government agencies, I helped implement an efficient and rational contractor report routing system which guides staff in dealing with all Basic Research reports that are received. These must be coded, filed, and delivered to the appropriate agencies for documentation in the Department of Defense publication system. This task required creating an MIS database including brief summaries of each sponsored research project and earmarked for entry into the Defense Technical Information Center (DTIC).

My work has also been directed toward assembling the annual report of recently completed, ongoing and newly awarded contracts. This task involved the building of a database of research synopses and reviewing and editing them. At the present time, the 1986 Basic Research Annual Report is being drafted.

Expert staff psychologists monitor contracts organized under four major categories: unit performance, systems design, skill building and planning. I completed a literature review on unit performance. I drew some tentative conclusions which point to the need for further research on issues immediately relevant to the Army. These included leadership and women, stratified decision making, reward allocation, performance appraisal, training techniques and open systems theory. I addressed some of these concerns at a Basic Research In-Process Review (IPR) conference in March 1987 on Unit Performance and Organizational Effectiveness at the Center for Creative Leadership.

In addition, I read reports, summarize research destined for publication in the Army Research Institute's Research Bulletin, familiarize myself with some of the computer software systems available at ARI. The Office of Basic Research represents a scientific information and research warehouse. I am requisitioned, at times, to administer correspondence, organize conference information, or to gather materials.

I also act as a coordinator and intermediary among the Research Fellows, ARI, and the Consortium.

Finally, I was part of a research team headed by a Consortium Research Fellow, Cassi Fields, which produced a survey feedback intervention at ARI. Sponsored by ARI and the Federal Women's Program, we examined the needs and perceptions affecting female civilian workers here at ARI. Analysis of the data revealed some positive trends toward achieving equity between women and men on the workforce though more effort is needed in the area of recruitment and promotions at the higher pay grade levels of the organization.

**B. Carmen Moten,
Howard University
Judith Orasanu, Mentor**

As a newer Consortium Research Fellow, I am presently engaged in a literature search of intelligent tutoring systems. An intelligent tutoring system is a computer program that uses artificial intelligence techniques for representing knowledge and interacting with a student.

Computer systems for intelligent tutoring are being developed to provide the student with the same instructional advantage that a sophisticated human tutor can provide. A good private tutor understands the student and responds to the students' individual needs. Computers have a similar potential. Of particular importance is computer tutoring in the fields of mathematics and science that are prerequisites for entrance into the scientific community and the world of high technology.

There are now over 10,000 pieces of educational software available. Almost all of this software can be classified as computer-assisted instruction (CAI) in contrast to intelligent computer-assisted instruction (ICAI). A CAI system individualizes instruction, but can only cope with student responses which have been specified in advance by the author-programmer. Intelligent tutoring systems are

an improvement because they not only have explicit knowledge of the subject domain and the student's history, but also have the capability to use a specific teaching operation in immediate response to the types of errors that the student makes.

ICAI incorporates several procedures which include observing teachers as they give remedial instruction to students, analyzing these protocols, formulating the essence of these interactions as a series of rules, and implementing the system which integrates these procedures. There have been attempts to bring artificial intelligence techniques in the development of ICAI. Until recently this was viewed as impractical and largely remained a task for the research laboratory. One reason was the prohibitive cost of ICAI. It was common to require a million-dollar machine to interact with one student, and often the response time of the machine was slow. Another reason was the length of time associated with creating software. It can take 200 hours to produce one hour's worth of conventional CAI. ICAI requires even more time. Finally, there was no established paradigm for enabling students to acquire knowledge. Early ICAI efforts were often ill-focused attempts to interact intelligently with the student without any clear understanding of the impact of those interactions on learning.

These obstacles are now being overcome. Advances in artificial intelligence and cognitive psychology have significantly diminished the time it takes to create instructional lessons. It is no longer necessary to specify every interaction with the student, but only the general problem-solving principles from which these interactions are generated. Advances in cognitive science have also provided a theoretical basis for designing educational software that is effective. There are now models of how successful students perform various cognitive tasks. This enables one to be precise about instructional objectives for a particular course of study. Furthermore, current theories address

the issues of how the student acquires new cognitive skills. The learning principles derived from these theories provide the direction needed in the design of instructional software. Much work has been based on Adaptive Control of Thought (ACT) theory. Among the most well-known systems based on ACT theory are the Geometry Tutor for high school students and the LISP programming tutor.

Most importantly, students working with the tutoring systems learn the material more quickly and achieve a higher level of proficiency than students working with the same textbook and problems in the standard learning environment. Yet some students do not seem to benefit from the tutor's instruction, due to impediments of a fully effective intelligent tutoring system to successfully model the human teacher. The major goal of the current research on intelligent tutoring systems is to characterize the type of knowledge these students are lacking and the type of assistance these human tutors are able to provide, thereby developing complete and proficient tutoring systems.

II. Systems Research Laboratory **Robin Keesee, Director**

The Systems Research Laboratory (SRL) conducts research designed to assist the Army in achieving the full potential of new weapon systems entering into service. Applying concepts and empirical findings from the areas of human factors, cognitive and organizational psychology, SRL addresses soldier-system issues across a range of system levels and at each step in the weapon system acquisition process. Emerging products take the form of materiel acquisition guidance, advanced methods for assessing manpower, personnel and training requirements, prototype soldier-system interfaces, information processing and decision aids, training systems and system evaluation methods. SRL executes its research pro-

gram through subordinate units located in Alexandria, Virginia; Ft. Leavenworth, Kansas; Ft. Bliss, Texas; and Ft. Hood, Texas. Research projects under SRL's jurisdiction are also conducted within other ARI field units located across the continental United States.

A portion of the research being conducted with Alexandria, Virginia, focuses on the general issues of information processing and decision-making for the tactical battlefield. As emerging technology offers the potential for assembling, processing and distributing ever greater amounts of information on the battlefield, it is important that the design and introduction of this technology be consistent with the skills, capabilities and needs of the human decision-maker. In order to accomplish this, however, it is necessary to better understand the underlying cognitive skills and processes employed by the soldier on the Air/Land Battlefield.

Accordingly, SRL has devoted a major portion of its resources to the study of human decision-making and cognition, with specific applications in the areas of battle management and military intelligence. Examples of the research being conducted within this area include (1) the investigation of cognitive style and its relationship to decision-making performance, (2) the identification of cognitive skills required for the operation of future weapon systems, (3) the refinement of methods for codifying operational expertise, and (4) the development of objective measurement systems for assessing decision-making performance within real-world operational settings. It is within the general context of this research focus that Consortium Research Fellows have been employed.

A. Frances L. Carter **George Mason University** **Vanessa Irizarry, Mentor**

The Battlefield Intelligence Systems Technical Area is concerned with the

measurement and assessment of military intelligence personnel. The project on which I am working seeks to determine the most efficient and thorough rating scales to characterize the performance of Morse Code intercept operators.

Because the attrition rate of Morse Code intercept operators is quite high (25–40%), the development of a comprehensive psychological battery and profile may eventually be used to select individuals who are likely to succeed during initial training and in the field. My efforts have been focused on a review of the pertinent literature and selection process undertaken to develop the rating scales for this project.

Three major categories of rating scales are potentially appropriate for measuring Morse Code intercept performance. Research on the first two, behaviorally anchored rating scales (BARS) and behavioral observation scales (BOS), generally provides ambiguous results. Some studies find deficiencies with either one of the scales, and some indicate no differences between the two. Each has its respective deficits. BARS involves more complex and often unreliable judgments about performance, while BOS is also subject to biases about the frequency of observed behavior. Compared to the BOS and BARS, the graphic rating scale (GRS) is inexpensive, quick and easy to develop. It is also a standardized scale which makes it comparable across individuals. However, it is prone to a number of serious errors which add variability to the overall scoring system. Behavior scales remain superior.

Given the evidence in the literature and the time constraints of administering the various scales, a BOS was developed for use by Morse Code intercept instructors, and a BARS was developed for use by Morse Code intercept supervisors. For both scales, critical aspects of the job were identified and presented in such a way that the rater was to indicate the frequency with which each behavior was actually observed.

These rating scales turn judgments about operator performance into usable data. To this extent, the scales can be seen as examples of extensive job analyses because they clearly define the responsibilities and behaviors which constitute Morse Code intercept jobs. They can be used as general tools of performance appraisal and become essential elements of a total performance evaluation system.

**B. Virginia Rappold,
George Washington University
Vanessa Irizarry, Mentor**

My project at ARI is concerned with the measurement and evaluation of military intelligence personnel to improve training and systems design. Current attrition rates of 24% to 40% for Morse Code Intercept Operators (O5H) training suggest that some recruits may not be suitable for this type of advanced individual training. The U.S. Army Intelligence Center and School, Devens, Massachusetts, has proposed a two-part approach to reduce the high attrition rates. One involves a new computer-based training system, while the other involves a re-examination of current measures used to select incoming O5H students. For the latter, recent research shows that selection scores obtained from standard Army test batteries (e.g., AFQT) are only peripherally related to successful Morse decoding and transcribing.

Efforts to develop psychologically-based indicators which capture successful O5H performance have included preliminary interviews with key personnel at Devens. Relevant skills for Morse Code operators thus far identified include sense of rhythm, musical aptitude, concentration, short-term memory, attention, and a certain sense of optimism on the part of the individual.

Based on this, a battery of psychological tests has been utilized which includes:

- (1) digit symbol and digit span short-term memory measures from the Wechsler Adult Intelligence Scale (WAIS).
- (2) pitch, loudness, rhythm, time, tonal memory and timbre subscales from Seashore Measures of Musical Talent.
- (3) perceptual speed measure which distinguishes between same and different pairs of numbers.
- (4) personality dimensions of changeability/stability and intraversion/extraversion and episodes of concentration and attention from the Eysenck Personality Inventory and the Tellegen and Atkinson Personality Scale.

The O5H test battery is expected to provide a basis for development of a standard selection tool for use by the Army in obtaining a higher percentage of successful O5H personnel. In addition, the empirical data collected from this effort will provide a scientific basis for delineating those factors crucial to Morse Code Skills.

III. Training Research Laboratory **Jack Hiller, Director**

The mission of the Training Research Laboratory (TRL) is to perform research and development that will yield advances in techniques for the determination of training requirements, design of training and evaluation programs, and in training management to achieve cost-effective use of resources. These advances will ultimately contribute to the goal of better-trained and more capable soldiers and units. Research on training strategies and technologies, and research on the learning process will contribute to the goal of a better-trained Army. Research is currently underway on these topics in two Technical Areas of TRL, ably supported by several Research Fellows.

The CRFs assigned to the Training and Simulation Technical Area, which is

headed by Robert Seidel, provide research support to the Automation Development Research Team. Carol Pollack and Diane DeMarco collected, analyzed, and contributed to the interpretation of data in a study designed to investigate the effects of varying levels of fidelity on cognitive skill acquisition. Cheri Wiggs conducted an extensive review of the literature on various techniques used in knowledge elicitation for building expert systems.

Students who worked in the Instructional Technology Systems Technical Area, which is headed by Zita Simutis, focused their work on two processes: the changing nature of knowledge as one acquires expertise, and spatial skills training. Daria Sneed and Jocelyn Turner used a variety of techniques to analyze complex data on the knowledge states of individual students at different stages during their learning of Lotus 1-2-3. Cassi Fields conducted data analyses on research concerned with map interpretation and terrain association that resulted in the definition of a measure that quantifies an individual's spatial memory span. Patti Watson assisted in all phases of research concerned with identifying individuals who have skills that would be useful for operating remotely controlled devices.

A. Cheri L. Wiggs, **Georgetown University** **Ray S. Perez, Mentor**

Expert systems are a class of artificial intelligence computer programs intended to serve as consultants for decision making. They are called "experts" because they address problems in the same manner and with the same results as a human expert, i.e., someone with extensive knowledge within a narrow class of problems. One interesting branch of research within expert systems addresses how one extracts knowledge from an expert. This area is important not only to expert sys-

tem development but may also be applied as a basis for instructional development.

My current research reviews knowledge extraction methods and addresses the fruitfulness of combining knowledge acquisition techniques with traditional task analysis to enhance maintenance training. Maintenance training is particularly applicable in that the problem solving approaches required are well defined and use specific facts.

Methods used for knowledge acquisition include: (1) structured interviews with experts by knowledge engineers, (2) verbal protocols, (3) naturalistic observation of experts in simulated environments, and (4) having experts directly interact with knowledge-based systems.

Knowledge maps are then designed, modeling the expert's possession of facts, explicit rules, and heuristic reasoning. A comparison between expert and student knowledge maps may show precisely what gaps need to be filled during training.

Although expert systems have been successfully built and run, researchers agree that knowledge acquisition is a major bottleneck to further progress. Two consistent problems are time consumption and the complete "expression" of expert knowledge. Furthermore, with no structured method for analyzing the knowledge elements, knowledge maps may be incomplete. This is generally not a problem for expert systems, as the criteria for their success is that they simply "run." However, such "missing links" in knowledge maps may hinder the effectiveness of instruction and training.

Task analysis has been used in instruction to identify and arrange the series of actions that a learner must take when s/he successfully performs a task. Traditional task analysis approaches include behavioral, cognitive, gestalt, and most recently, information processing. My work suggests that task analysis be used to lend structure to analyzing knowledge acquisition.

B. Carol A. Pollack Nelson,
George Washington University
Ray S. Perez, Mentor

My research focus has been the application of computer-based simulators to training. This summer, we conducted an experiment at George Mason University which looked at the use of simulators for training a troubleshooting task. Troubleshooting involves the identification of a faulty component in a piece of equipment. Participants were asked to troubleshoot a fault in an electronic relay panel. Two of the dependent variables we were interested in were the amount of time it took them to troubleshoot faults during a transfer test and the number of erroneous fault identifications made. The independent variable which was manipulated was the level of simulator fidelity upon which the subjects were trained.

The term "fidelity" refers to the extent to which the simulator looks and functions like the equipment it is replicating. The concept of fidelity can be viewed as ranging from very low to very high levels. While some researchers feel that high fidelity simulation training is necessary to ensure that trainees are comfortable with both the task and the equipment that they will eventually be expected to operate, others have found success with low fidelity simulators. Advocates of the low fidelity approach feel that there are two important drawbacks to high fidelity devices since they replicate so many of the details found on the actual equipment. First, they are likely to overwhelm the trainee with details with which the novice is not yet able to cope and, therefore, negatively affect transfer. Second, they cost significantly more to develop and maintain than low fidelity devices.

The experimental design employed in this study consisted of four groups of participants. Each group received somewhat different troubleshooting training based on the fidelity of the simulator on which they were trained. One group was trained on a low fidelity device exclusively. A sec-

ond group was trained on a high fidelity device exclusively. Two additional groups were trained on both low and high fidelity devices (mixed-fidelity). Subjects in these groups began their training on the low fidelity simulator and at some later point, switched over to high fidelity simulation training. The difference between these two groups is the point at which they switched from the low to the high fidelity device.

We hypothesized that groups receiving mixed-fidelity simulation training would perform the best on the transfer task in terms of the number of erroneous fault identifications made and the time to troubleshoot the transfer problems. However, analyses showed no significant differences between the four groups in terms of the two dependent variables. For this reason, it may be financially more practical to employ low fidelity training devices which are easier to both develop and maintain than training devices of higher fidelity.

These non-significant findings should not, however, rule out the advantages of a combined training program utilizing both low and high fidelity devices. It is possible that the lack of significant findings in this particular study could have resulted from a "wash out" effect, brought on by allowing subjects too much of an opportunity to practice the task prior to transfer assessment. It is likely that a combination of fewer training problems and more challenging transfer problems will lead to significant results.

A subsequent analysis of covariance, which controlled for the subject's level of mechanical aptitude (measured by the Bennett Mechanical Aptitude Test) revealed highly significant differences between the four groups in terms of the number of erroneous fault identifications made. Subjects in the mixed fidelity conditions made significantly fewer errors during transfer than did the other two groups.

This finding in terms of the number of errors made also has implications for the

amount of time and money used by each group. In an actual troubleshooting situation, the troubleshooter would be required not only to identify the faulty component but to fix it also. In our study, subjects did not have to repair the equipment. Thus there was no time penalty associated with each erroneous fault identification. If there had been, it is likely that there would have been a significant difference between the four groups in terms of the time to troubleshoot during transfer. A paper discussing this study and its results was presented at the ADCIS convention in November 1986.

C. Jocelyn O. Turner,
Howard University
Sharon Mutter, Mentor

As a CRF, I have been assigned to the Smart Technology for Training team. During the past year, I have been involved in the data collection and analysis of a project designed (1) to study how novice knowledge representation of computer command language changes with increasing expertise, (2) to examine the relationship between knowledge representation pertaining to facts (declarative) and knowledge representation pertaining to skills (procedural), and (3) to enhance Army training through the application of cognitive science and artificial intelligence in order to develop intelligent tutoring systems. Because the Army employs various computer technologies, the study of computer command languages and knowledge representation is essential.

Subjects are tutored on the Lotus 1-2-3, a command language that allows one to store and organize information on a computer screen spreadsheet. Prior to and at three month intervals after training, subjects performed numerous cued and uncued trials of reconstructing and modifying spreadsheets. Subjects also

completed a background questionnaire designed in part to measure computer literacy and frequency of use of Lotus operations.

Together with another CRF, Daria Sneed, the procedural and declarative knowledge data are being analyzed. My task has been to analyze declarative knowledge data by using an algorithm that looks for consistencies of organizational orders. The assumption of this analysis is that items are organized into "chunks" which are further organized into units by the subject. The "chunks" and organized units of knowledge representation form a hierarchical tree-like structure which represents consistencies in the data. By comparing the structures obtained at different times during testing, it is possible to examine how knowledge representation changes as learning progresses.

Preliminary results indicate that (1) novice knowledge representation initially shows a non-Lotus organization, (2) frequent practice of Lotus changes this representation to one that is more meaningful in the Lotus context, (3) expert knowledge representation of Lotus concepts and commands is organized in a way that is meaningful in the Lotus context, and (4) novice knowledge after training and practice of Lotus is not identical but approximates expert knowledge representation.

D. Daria C. Sneed,
Howard University
Sharon Mutter, Mentor

As a CRF with the Smart Technology for Training section, I am primarily responsible for data analysis pertaining to procedural knowledge, defined as skills. Previous research suggests differences in knowledge representation between novices and experts. The present research investigates the transitional change in knowledge representation from novice to

expert. It is expected that as novices acquire knowledge, their organization structure will approximate that of an expert. In order to determine the transition from novice to expert, soldiers were tutored on a command computer program (Lotus 1-2-3). After training, subjects reconstructed a spreadsheet which required them to type and enter values, labels, and formulas (note: formulas are simple math operations). At a later date, subjects modified the reconstructed spreadsheet.

The data was analyzed using two techniques. The first method was the Command Language Grammar (CLG), which is a method for mapping out the correct procedures that must be used to complete a goal. A second method of data analysis was Keystroke Analysis which determines the amount of mental time needed to perform an operation. Use of these two methods allowed for a study of the transition from novice to expert. In addition to analyzing these data, I will be aiding in writing the methodology section of the technical report.

E. Cassi L. Fields,
George Washington University
Sharon Tkacz, Mentor

Research conducted with my Mentor showed that high spatial individuals will be more effective at locating their position on a topographic map. High spatial individuals also perform more effectively in a videogame called MAZE, which simulates positioning in the real world. Therefore, individual performance in MAZE was analyzed to detect the important spatial components of position-fixing in the real world.

MAZE requires that subjects escape from a 125 room cubic maze by typing directions (e.g., east) in order to move from one room to another. The goal of the game is to escape the maze as quickly as possible. Subjects played 16 games in which position and goal information were

available only upon request. Difficulty level was also increased by forcing the subject to change orientation every four games, first facing north, then east, then west, and finally south.

Five dependent measures were analyzed. These were:

- (1) a spatial test battery consisting of orientation, two and three dimensional object rotation, embedded figures, and a reasoning test.
- (2) a real world test consisting of the number of times subjects correctly locate their position within several hundred meters in the field.
- (3) the number of seconds required to escape the maze.
- (4) the average number of seconds elapsed between position and goal requests.
- (5) the average distance (in rooms) travelled between position and goal requests.

High spatial individuals (i.e., those who received higher scores on the spatial battery) escaped from the maze more quickly and were better at locating their position in the field. High spatial subjects also had larger spatial spans, which is a measure of the amount of distance travelled in the maze before requests for position coordinates. This suggests that individuals with a larger spatial span were able to maintain and update the representation of their position (e.g., orientation information) better than low spatial span subjects. With practice, subjects in general requested MAZE position coordinates more frequently.

In a continuing study, we plan to determine more precisely the capacity of this short term spatial span for both low and high spatial individuals. Further, we may want to determine how to improve subjects' ability to "chunk" and retain spatial information in short-term memory. This may permit the training of low and high spatial ability individuals to do a better job in recoding, maintaining, and updat-

ing spatial information when using it in the field.

**F. Patricia Watson,
Catholic University
Sharon Tkacz, Mentor**

Most of my work as a CRF deals with the Snakebyte, a project designed to identify the cognitive components that underlie remote operation skills. These principally involve the procedural spatial skills acquired through self-directed movement in the environment. Spatial skills are required for navigation, understanding graphic displays, and remote control of autonomous vehicles. Since actual travel may not always be feasible or practical in training remote operations skills, we are exploring ways to capitalize on the motivating aspects of videogames to provide effective simulated travel.

A number of different measures of spatial ability have been compared with skill acquisition scores on Snakebyte. Early results indicate that physics majors are better players initially, and acquire expertise much more rapidly than lower-level college majors. The cognitive measures that seem to mediate these group differences in game performance target the ability to process verbal descriptions of spatial relationships.

Current research is examining chemistry and engineering students. Closer scrutiny of cognitive skills in remote operations may become important for the selection and training of teleoperators. Initial analysis of these data shows significantly higher scores for the upper level engineering students on a number of cognitive tests and Snakebyte.

**IV. Manpower and Personnel Research
Laboratory
N. Kent Eaton, Director**

The Army operates one of the largest personnel systems in the United States,

including both military and civilians. The mission of the Manpower and Personnel Research Laboratory is to improve and enhance the readiness and effectiveness of this system through scientific research on manpower requirements and policies, econometric manpower models, recruitment, selection, classification, retention, personnel allocation, NCO and Officer leadership, unit cohesion, family, and civilian personnel management. This mission encompasses the active Army, Army Reserve, National Guard, and civilian components.

The research programs address the sequence of tasks which must be accomplished to man the force and develop effective leadership. These include: (1) projections of personnel requirements for the future Army, (2) personnel resources for meeting those requirements have to be identified and ensured through retention of highly qualified soldiers already in the Army or through recruitment, (3) recruited individuals must be selected and assigned to jobs or training tracks in a manner which will optimize the fit between job requirements, the criticality of the jobs, and the capabilities of the individual applications, (4) effective soldiers within the Army must be identified and retained in order to take maximum advantage of the investment in training and experience which these soldiers represent, (5) family factors affecting readiness and retention have to be identified and enhanced, and (6) leader and organizational development, from NCO and junior officers through General Officer level and Senior Executive Service on the civilian side, must be based on sound principles of optimizing individual leadership capability, improving leader performance assessment technology and civilian personnel management and performance assessment, leader doctrine development, development of organizational design theory and technology, and unit cohesion technology.

The ultimate goal of MPRL research is to ensure that the Army will have capable

soldiers and leaders to accomplish the missions entrusted to them.

A. Jeanne K. Mason,
George Washington University
Lawrence M. Hanser, Mentor

Because the Army is charged with the responsibility of protecting and defending the nation, it is essential that the performance of its workforce be assessed frequently so that proper steps can be taken to minimize deficiencies and to act appropriately when deficiencies do occur.

The most common strategy for evaluating employees in nonproduction jobs is for supervisors to rate subordinates on appropriate work dimensions. This rating process requires knowledge of the subordinate's job requirements and performance. This method, however, frequently falls short of providing reliable or valid ratings unless the correlations between rater traits and subordinates' performance ratings is taken into account.

One aspect of performance appraisal currently attracting attention is the role of self-relevant dimensions in evaluating others. Project A is, in part, an investigation of this issue with the goal of improving the selection, classification and utilization of Army enlisted personnel. Working with Jane Arabian, I examined the relationship between soldiers' scores on the Army's Skill Qualification Test (SQT) and three new performance measures of job knowledge and proficiency. Data analyses revealed strong correlations and suggested that the SQT remains a good measure of job performance and a good choice for making personnel management decisions.

The results of this study were presented at the Military Testing Association meeting held in November 1986. A working paper describes the project's rationale, data collection method, analyses and results. Present efforts involve examination of additional rater variables, including

temperament, that may influence performance ratings.

B. Cyril E. Kearl,
University of Maryland
David K. Horne, Mentor

I have applied my understanding of economic theory and application to the problem of recruitment in the Army. Specifically, the effort expended by individual recruiters is fundamental to the recruiting process. Difficult to observe or measure, recruiter effort is usually ignored. This is acceptable only if its effect is random or the same for each recruiter. Unfortunately, evidence suggests that recruiter effort depends on the probability of achieving the intended quota (mission) and the reward payment structure.

An alternative approach to setting missions is to choose a mission that maximizes enlistment contracts. However, setting a large mission has no greater explicit cost for the United States Army Recruiting Command (USAREC) than a small mission. It would follow, then, that if the recruiting mission has a positive effect on enlistments, it should be set as high as possible since there is no increased cost. This has the effect of doing away with any meaningful or attainable quotas and effectively eliminates mission as a policy tool. This contradictory policy implication (i.e., set the mission so high that there is no effective mission) highlights the fundamental shortcomings of implying a one-to-one correspondence between mission and effort.

The decision by the recruiter to work harder requires a balance between the costs of additional work and potential benefits of group recognition, improved working atmosphere, desirable future assignments and increased chances for promotions. When the recruiting mission is set at low levels, achieving it requires little effort and increases in the mission are obtainable with little additional cost. As the

recruiting mission increases, a recruiter must work harder to have the same chance of making the mission. As long as the additional costs do not exceed the marginal benefit of this effort, the recruiter will respond to increased mission with more effort and production. At one point, however, the recruiter will decide that the chances of making the increased mission are so small that there is no point in exerting any effort. Over this range, increases in the mission may actually decrease recruiter effort.

A mathematical model is used to estimate the nonlinear relationship between the recruiting mission and recruiter effort. The estimated parameters are then used to spread the mission among the various recruiting battalions to maximize recruiting. Preliminary data analysis suggests that this approach offers an alternative method of distributing recruiting quotas more soundly.

C. Christina M. Lynn,
George Washington University
Guy L. Siebold, Mentor

Values are important ideas that people share about what is good or bad, right or wrong. Vital to military performance, "Values" was chosen as the 1986 Army Theme. ARI was directed to conduct a survey examining the importance of values to Army personnel. A questionnaire was administered to over 7,000 soldiers and Army civilians in the United States and Germany in Spring 1987. Participants rated the personal importance of several core American and core soldier values on a 7-point scale. Core American values include those found in the U.S. Constitution and the Declaration of Independence, such as freedom and equality. Core soldier values include loyalty to the Army, teamwork and discipline.

To determine the validity of the questionnaire and to obtain more in-depth data, interviews were conducted with 73

soldiers, noncommissioned officers, and officers stationed in Germany. Participants were asked to indicate what each of the twelve soldier values listed on the questionnaire meant to them personally. Examples of these values included, "being disciplined and courageous in battle," "loyalty to the U.S. Army," and "commitment to working as a member of a team." A content analysis yielded three categories of responses: 1) redefinition of the value, 2) consequence of the value, 3) general comment on the value. For example, in response to the item, "being honest, open, and truthful," one soldier redefined the value as, "being honest to my leaders and other soldiers around me." A noncommissioned officer responded to the same value with the comment, "That's how you set an example". Overall, interviewees gave similar meanings to the twelve values, which confirmed the validity of the questionnaire.

Participants were also asked to state which five of the twelve values were most important to them, to explain why, and to provide an illustrative example. First, an analysis of responses revealed there was a fairly even distribution of values selected as important among the twelve. Second, interviewees had no difficulty applying these soldier values to everyday situations. For instance, a noncommissioned officer indicated that the value, "commitment to working as a member of the team" was important for accomplishing specific tasks. He noted that when he orders his subordinates to do a task, he also participates. In general, values were found to be important in facilitating the mission of the Army.

This research indicates how values function in the daily life of the soldier. Army personnel recognize and apply important core values in their work. These findings have important implications because soldiers with strong values tend to be more cohesive, are better able to withstand stress, and perform at a higher level within their units [as reported in: Siebold, G.L. (April 1987). Bonding in army com-

bat units. Paper presented at the Southern Sociological Society Annual Meeting, Atlanta, GA.].

D. Sharon D. Ardison,
Catholic University
D. Bruce Bell, Mentor

Because of its unique missions, concept of service, and lifestyle of its members, the Army seeks to assure adequate support to families in order to promote wellness, a sense of community, and the partnership that presently exists between the Army and Army families. The Personnel Utilization Technical Area (PUTA) has been involved in organizing a major research program focusing on these issues.

Historically, the relationship between the Army and Army families has evolved slowly. From 1860 until World War I enlistment was denied to married men. Despite lifting some restrictions by World War II and making minor improvements during the 1950s and early 1960s, it wasn't until the Viet Nam era that the Army recognized the adverse impact of chronic family problems at home on soldiers' performance overseas. In the early 1980s the Army Officers' Wives Clubs held Army-wide symposia examining family concerns which encouraged the decision to mandate research addressing family difficulties.

PUTA is examining five basic family research issues. These include: assessing the shifting demographic characteristics of its families in order to improve the programming of services, reordering the agencies so that they promote a sense of partnership and community, and determining which programs, policies, and practices best promote family wellness, soldier retention, and individual and unit performance.

My involvement can be divided into three phases. During the evaluation phase, requests for family research pro-

posals were announced. As responses came in, they were reviewed and summarized. My review of the relevant literature assisted research panel members' decisions. I helped construct an appropriate evaluation tool for the evaluation team.

In the contract management phase, panel members submitted their numerical ratings and computed averages for each proposal. I helped prepare the results of these evaluations for presentation to superiors. With the contract awarded, a one year projection of task (family wellness, soldier retention, readiness, and spousal employment) and option (community support, policy, and volunteer) activities has been developed and will be monitored on a monthly basis.

In the current research phase, efforts are underway to study the single parent soldier and the dual Army career couple. In addition, the family strength and community team is conducting a review of the literature and summary of research findings related to family adjustment in Europe. Topic areas include demography, incentives to extend enlistment, housing, family coping and stressors.

E. Connie J. Schroyer,
George Washington University
Lawrence M. Hanser, Mentor

For my initial work with the Leadership and Management Technical Area, I was involved in designing and implementing a survey dealing with job satisfaction and performance appraisal practices in the civilian workforce. The survey data were analyzed and presented to the Management-Employee Relations branch of the Civilian Personnel Office. The results were used in dealing more effectively with the civilians served.

I also had the opportunity to participate in meetings with civilian personnel psychologists as well as with military officers

and psychologists from the Navy Personnel Research Development Center.

My first project in the Selection and Classification Technical Area dealt with the issue of the effect of job experience on the validity of ability tests. The validity of cognitive ability tests has been well established. We do not know, however, if this validity remains constant or declines as experience on the job increases. This issue is important for several reasons. We need to know if ability tests given to applicants when they apply for a job are able to predict performance as well at five years on the job as they do at six months. In other words, can we predict long-term performance using ability tests?

I investigated the validity of an Army ability test (AFQT) in predicting job performance at different experience levels. The results show that as experience increased, the AFQT became slightly less effective in predicting performance in the Army. However, the validity of ability tests still remained fairly high even after eight years of experience.

I have also been involved in another project examining the causes and trends of attrition in the Army. My job here is to investigate the various codes of attrition contained in the data sets available, determine the best way to categorize these codes, and make this information available to ARI. My future work will involve research on the amount of faking that applicants engage in when they complete biographical inventories. I also plan to investigate whether or not this faking affects the validity of biographical inventories.

F. Debby Deme,
American University
N. Kent Eaton, Mentor

Since my recent appointment as a CRF, I have been working on the Preliminary Predictor Battery, which is part of Project A. The goal of my work is to determine

and report on the relationship between certain personality constructs and relevant indices of leadership, promotion rate, likelihood of completion of first term of enlistment, and re-enlistment.

The effort is divided into two stages. In the first stage, I will use the Preliminary Battery. The Preliminary Battery is a battery of off-the-shelf personality tests, such as internal-external locus of control, and scales from the California Psychological Inventory. The tests were administered to approximately 9,000 soldiers. I will evaluate ways in which the various instruments have been combined to yield the predictor scores.

The second stage will involve determining the relationships between these predictor constructs and measures of employee turnover as well as job perform-

ance (promotion rate, supervisor ratings of effectiveness, etc.). Turnover consists of three categories: a) attrition during first term, b) completion of term without re-enlisting, and c) reenlistment. Reenlistment, in turn, can be broken down into three subcategories: a) eligible and re-enlisted, b) eligible and not reenlisted, and c) not eligible and not reenlisted.

In this project we hope to demonstrate the relationships between characteristics of soldiers' personality and subsequent behavior on the job.

Notes

1. The views, opinions, and findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

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