ABSTRACTS
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PLASTINATION - A TEACHING AND RESEARCH TOOL

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Plastination is a unique technique of tissue preservation developed by Dr. Gunther von Hagens in Heidelberg, Germany in 1978. In this process, water and lipids in biological tissues are replaced by curable polymers (silicone, epoxy, polyester) which are subsequently hardened, resulting in dry, odorless and durable specimens. Silicone is used for whole specimens and thick body and organ slices to obtain a natural look. Epoxy resins are used for thin, transparent body and organ slices. Polyester is used for brain slices to gain an excellent distinction of gray and white matter.

The technique consists of four main steps: 1) Fixation, 2) Dehydration, 3) Forced Impregnation, and 4) Hardening. Fixation can be done by almost all conventional fixatives. Dehydration is achieved mainly by acetone because acetone also serves as the intermediary solvent during impregnation. Forced impregnation is the central step in plastination: vacuum forces the acetone out of and the polymer into the specimen. Finally the impregnated specimen is hardened by exposing it to a gaseous hardener (silicone), or by UVA-light and/or heat (polyester, epoxy).

Plastinated specimens are perfect for teaching. Silicone plastinated organs and body parts are excellent teaching tools because they can be grasped literally, they are dry and do not smell and they are almost everlasting. Sheet plastination provides an excellent tool for teaching sectional anatomy.

Particularly the plastination techniques for brain (polyester) and body slices (epoxy) are also used in research, particularly in comparison to CT- and MR-images.

STEP BY STEP INTRODUCTION TO THE BIODUR S10 STANDARD TECHNIQUE OF PLASTINATION

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The Biodur S10 standard technique of plastination is useful to preserve all types of teaching specimens in the medical field. It produces specimens that are odorless, dry, durable and lifelike by replacing the water content with silicone polymer. The method is carried out in 4 major steps: Fixation, Dehydration, Forced impregnation and Curing. Fixation with formaldehyde solution deactivates enzymes, halts autolysis, prevents putrefactive odor, and preserves the shape of the specimens. The preferred method of dehydration is freeze substitution with acetone at -19°C. The low temperature fixes the shape of the specimens and minimizes shrinkage. Usually, four bathes of acetone are required to complete dehydration. A hydrometer is used to monitor the acetone concentration. For most specimens an acetone bath at room temperature is recommended for degreasing. Alternately, a series of ethanol bathes allows dehydration at room temperature. Ethanol must be replaced by acetone or methylene chloride prior to the step of forced impregnation. In this step the volatile medium is removed with the aid of vacuum and replaced by a Silicone reaction mixture consisting of Biodur S10 and 1% Biodur Hardener S3. The speed of exchange is controlled by either an inline valve or a bypass valve. The vacuum is adjusted to a slow rising of bubbles in the silicone. This step is usually carried out at -19°C in a freezer in order to keep the reaction mixture reusable. It is considered complete when the manometer reading is 5 mm Hg or less and bubbling has stopped or nearly stopped. The specimens are returned to atmospheric pressure, removed from the silicone bath and warmed to room temperature. They are wiped down and exposed to Biodur Gas Cure S6 inside an airtight container. An apparatus consisting of an aquarium air pump, hose and bottle with Gas Cure S6 speeds up the process by saturating and agitating the atmosphere in the enclosure. Daily wipe downs are required to avoid pooling of oozing silicone. Calcium chloride is used to control moisture. Curing takes from 1 week to 2 months depending on the thickness and type of specimens.

SUBMACROSCOPIC INTERPRETATION OF HUMAN SECTIONAL ANATOMY USING PLASTINATED E12 SECTIONS

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The E12 epoxy method of sheet plastination for preparing thin, transparent and serially sectioned cadaveric teaching specimens has for the most part seen the finished sections utilized in the correlation of MRI and CT radiographic images. The unique properties of the E12 process offer an exceptionally vivid survey of the human body in any given plane resulting in precise delineation of the structural layout *in situ.* Sections were prepared in sagittal, horizontal and coronal planes from different regions of the body including head and neck, trunk, inguinal region, limbs and joints. The macroscopic structures within these sections correspond

precisely with images of the same structures obtained radiologically.

By introducing E12 sectional anatomy specimens to the anatomy teaching laboratory, the transition between gross anatomy and histology has been made possible by studying the one specimen. When utilized in our combined topographic anatomy and histology teaching laboratories, anatomical structures of thin and transparent slices can be magnified considerably. Standard histological slides providing detail of a specific structure within predetermined parameters, are often dictated by the physical limitations of the microscope slide itself. E12 sections provide a high degree of detail whilst retaining *in situ* structural integrity of the entire region in a complete and uninterrupted state.

Students are provided with significant detail of all components to the submacroscopic level from any one specimen thus linking the three disciplines, namely cross-sectional anatomy, radiology and histology using a single El2 slice. E12 plastinated sections have been recognized as an ideal teaching aid in conjunction with radiological correlation, but it is in the microscopy laboratory that a valuable new dimension of this multi-disciplinary plastination technique has recently been realized.

PRESCRIBED SEQUENCE LABELING METHOD: A STRATEGY FOR MASTERY OF SECTIONAL ANATOMY USING PLASTINATED SPECIMENS

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Previous studies (Lane 1998) have demonstrated that a prescribed sequence of labeling method (PSLM) increases the learning rate and comprehension of relationship of structures/features of anatomical photographs acquired from The Visible Human Project. This project was sponsored by National Library of Medicine.

This present study using photographs of plastinated anatomical brain sections correlates and parallels previous studies.

Thirty-two (32) college students enrolled in sectional anatomy participated in this present research. They were randomly separated into two groups 1 and 2. All students were given the same pretest, followed by a study period, and then were issued posttests. The study material for group 1 consisted of an axial brain section, labeled in accordance with the PSLM protocol. Group 2 was issued the identical photograph, labeled randomly. Both groups were instructed to "list and recognize the parts/layers of a transverse brain section, form superficial to deep" by writing their answers in spaces provided as one of two posttests. The second posttest (multiple choice) stressed the adjacent relationship of those same structures. Group 2 was then issued the identical study guide distributed to group 1 initially, and thereafter, a set of posttests. These studies have shown that the PSLM significantly increased a given student's rate of learning and comprehensive of adjacent structures.

Statistical analysis shows a significant difference in group 1 and group 2 on both the written identification of structures and similar questions in a Multiple Choice format.

PSLM in both photographs from The Visible Human project and the photographs from plastinated sections appear to equally accomplish the following

- Learning rate increases
- Relationship of features are comprehended more rapidly and completely
- Well-organized student study system is advanced

For Further Information
Visit the web sites at:

http://www.triton.cc.il.us/inst.depts/biology/NLM
or
www.nlm.nih.gov

PLASTINATION TECHNOLOGY FOR BIOMEDICAL RESEARCH AND STUDIES IN KENYA

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In Kenya, preservation of biological tissues is done by embalming and perfusion with formaldehyde and gluteraldehyde. Plastination method was described in 1978, for preservation of tissues in a life-like state. It involves impregnation of biological tissues with a polymer which replaces water and lipids. The information on plastination in the literature is scanty and the method has been used recently in America and Europe.

From a pilot survey, it was found out that awareness of plastination method was very low amongst the Kenyan scientists. Incidentally, some international scientists were also not familiar with it. Compared with conventional methods, where fixation may be inadequate and long term preservation is poor, plastination maintains original morphological and histological integrity of tissues allowing them to be used for research as well as preservation of specimens for long term use. Fumes from acetone and fixatives pose a hazard in conventional and plastination methods. Special equipment is needed for plastination method.

In Kenya we have available human and animal cadavers which are preserved using conventional methods but are replaced when necessary. However, there is need for the knowledge on alternative methods with wide application in biomedical studies such as plastination. This method may also be used for long-term preservation of rare tissues and morphometric studies.

The advocacy of this method of plastination has been gradual in developed countries. The extent to which it may make an impact in biomedical field in developing countries will depend on cost effectiveness and feasibility of implementation as well as provision for training of personnel.

EFFECT OF LEAD ON THE PRENATAL DEVELOPMENT OF THE SPINAL CORD OF RABBIT (LUMBOSACRAL REGION)

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The histopathological investigations of lead on the developing central nervous system including the spinal cord are scanty. Moreover, investigations about the effect of lead on the prenatal development of CNS in mammals are still deficient.

The aim of this study is to throw light on the normal prenatal development of the spinal cord in Boscat rabbit and to investigate the effects of lead on it.

For this work one hundred sixty rabbits (160) were taken at 12, 14, 16, 18, 20, 24, 26 and 28 days of gestation and newborn rabbits. They were divided into control groups and experimental groups. The samples were prepared for both light and microscopic examinations.

The control groups showed that the development of the spinal cord passes into the following stages.

1. Stage of differentiation of cells of the ventral horn from the germinal epithelium.
2. Stage of appearance of cell columns.
3. Stage of spliting of cell columns into subsidiary columns.
4. Stage of appearance of Nissil granules.

The experimental group showed that the manifestations on the spinal cord development were delayed development, distortion of arrangement of cells, and pericapillary oedema. Experimental group also showed that lead has an effect on cell organelles and nuclei of motor cells, astroglial cells and endothelial cells of blood capillaries.

PLASTINATION AS A CLINICALLY BASED TEACHING AID AT THE UNIVERSITY OF AUCKLAND

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As a concerted move toward closer integration of the clinical and pre-clinical aspects of the undergraduate medical curriculum at the University of Auckland, the Department of Anatomy has established a formal link with the Department of Radiology resulting in a structured program of clinically based teaching of gross anatomy to second and third year medical students and several post graduate specialist training programs.

As sophisticated diagnostic techniques and methods of treatment have now become common place, our teaching program has been tailored to accommodate a greater degree of case based learning within the undergraduate course.

Dissecting room demonstration is provided by Radiology, Pathology, Ophthalmology and Surgical registrars, with a number of clinical procedures, pathological observations and diagnostic methods employed during the routine dissection of the cadaver.

The learning process is enhanced and aided on a number of levels through careful integration of several key plastination techniques, yielding a high level of anatomical detail and clinically relevant information in a readily accessible form.

While S10 silicone, P.E.M. polymerised emulsion and E20 injection casting all provide an excellent three dimensional concept of the human body, it is the El2 epoxy method of producing serial sectioned anatomy that has offered significant educational and research opportunities. The E12 epoxy technique has allowed an accurate and highly detailed orientation of the planes of the body, providing the student with a clearer understanding of anatomical structures and pathological anomalies as seen with modern imaging techniques.

VENTRICLE CASTS IN S10 PLASTINATED HUMAN BRAINS

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The aim of this study was to provide students with plastinated specimens showing the three dimensional features and content of the rhombencephalon, mesencephalon and prosencephalon ventricles. The brains were removed from fixed bodies used in dissection course, and stored in 10% formalin at +4°C. To perform the filling of the ependymal cavities with gelatin and silicone, 6 cannulas were carefully introduced through the cortex into the anterior, inferior and posterior cornu of the lateral ventricles. One more cannula was introduced into the fourth ventricle between the posterior aspect of the medulla oblongata and the cerebellum. Injection of water via the cannulas allowed to ascertain that they were in good position. Filling of the cavities was performed either with 10% gelatin mixed with acrylic staining, or with a mixture of S10/S3/S6/S2 died with Biodur colorpaste. Injection was performed via both occipital cannulas until the filling material overflowed via the other five cannulas. The cannulas were then clamped, and the brains stored in cold water (+4°C) for 72 hours before being dissected. For the duration of the dissection, the brains were kept in 10% formalin. The lateral portion of the cerebral hemispheres was

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partly removed to expose both lateral ventricles and their choroid plexuses. The floor of the third ventricle and one cerebellar hemisphere were also removed to expose both third and fourth ventricles, respectively. The specimens were finally dehydrated by freeze substitution and plastinated according to the standard S10 technique.

OLD ANATOMICAL EMBALMING & PREPARATION METHODS

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This presentation will focus on historical embalming and specimen preparation methods used to prepare and preserve medical teaching specimens. At the turn of the past century, every school had its preparators, who developed various formulas and methods to accomplish the teaching needs. I will describe various solutions and formulas used and methods used to enhance the student's study of gross anatomy. Some of the methods and material are still found in use today, while others have been avoided as health risks. New methods have been developed, such as polymer impregnation of specimens, i.e. Plastination, that have greatly improved the specimen quality.

PLASTINATION OF HUMAN CADAVER LIMB SPECIMENS USED FOR VALIDATION OF MAGNETIC RESONANCE IMAGERY (MRI) AND COMPUTERIZED TOMOGRAPHY (CT) MEASUREMENT OF HUMAN SKELETAL MUSCLE

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The primary objective of this study was to plastinate cadaver limb sections used for the validation of magnetic resonance imaging (MRI) and computerized tomography (CT) measurement of skeletal muscle. Two limbs (one arm and one leg) were removed from embalmed cadavers, stabilized and fitted with internal orientation markers in preparation for imaging. Contiguous MRI and CT images were obtained every 1 cm over the entire length of each limb. These specimens were subsequently frozen in liquid nitrogen and sectioned at levels corresponding to each of the scans (119 sections). Following sectioning the specimens were carefully cleaned and photographed. Most of the sections were then plastinated using the S10 Biodur polymer method. The plastinated specimens retained excellent detail and provided reference necessary when confirming the identification of various tissues represented in the photographs of the unplastinated specimens. In addition to their utility for reference purposes, the plastinated cross-sections have been used with great success as teaching aids for gross anatomy courses in the Department of Anatomy and Cell Biology.

PLASTINATION OF HUMAN TISSUES FOR USE IN MEDICAL TEACHING

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The use of silicone has proven a valuable tool to preserve prosected and sliced tissue preparations for demonstrations, dissection courses and for a presentation in lectures. Human corpses were fixed by 17L of a perfusion solution (2% formaldehyde, 2.5% phenol, 5% glycerol, 22% alcohol) at room temperature. Body parts were prosected or frozen at -20°C and sectioned with an electrical band saw into slices of l-2cm thickness. These preparations were siliconized by the S10 silicone procedure described by G. von Hagens (Plastination Folder, Anatomisches Institut, Heidelberg, 1985). The samples were dehydrated at room temperature by increasing alcohol concentrations, and kept for 24 hours in acetone at 4°C. Tissues were completely dehydrated by several incubations in acetone at -20°C. Samples were kept for 24 hours in silicone at -20°C, and subsequently acetone was substituted by silicone using vacuum penetration. The pressure was lowered to 0.002 bar by maintaining a constant and light bubble formation. Specimens were polymerized with a volatile hardener S6 at room temperature. Human brain tissue, prior to plastination was colored by a Prussian blue reaction as described by Le Masurier (Arch Neurol Psychiat 34: 1065, 1935) where gray matter is colored in a Prussian blue tone. The use of plastinated tissue has already proven a valuable tool to be added to the dissection courses and demonstrations, given those specimens can be used over years without any tissue detriment. The dry state of specimens allows their introduction in lectures without having to take too many precautions. A video set-up in the lecture hall allows on-line presentation of specimens. Another advantage is that students and faculty can borrow plastinated tissues for individual learning and studies outside the dissection facilities. From the best samples digitized pictures are currently introduced on the server of our institute (Intranet) which is accessible to faculty and students providing another tool for an individual preparation of courses and exams. However, by making human tissue preparation accessible to a broader audience via Internet some ethical considerations are necessary, such as what and how to present samples, and how to prepare potential viewers to what they will see.

Nevertheless, the Internet allows also to exchange material with other institutions developing similar tools for gross anatomy teaching.

DEVELOPMENT OF TEACHING MODULES FOR HUMAN ANATOMY

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Self-directed learning has been frequently used as a mode of teaching anatomical subjects in the medical and undergraduate curriculum in many medical schools in Canada. In order to aid the students in learning and reviewing their course materials at their own pace without increasing time commitment of instructors or tutors, we have developed a number of modules for Gross Anatomy teaching. Well dissected wet and plastinated human specimens were used to produce teaching modules. Images showing various aspects and angles of the specimens were captured with a digital camera (Agfa; model e-photo 1680). For wet specimens it was necessary to remove all storage fluid in the specimens prior to photography. Images were stored as "TIF" files, and they were organized and labeled by Power Point software with a Pentium personal computer. Simple animation is possible with this program. We have produced teaching modules for teaching the heart, hand and urinary system and found that this is a very cost-effective way of producing custom-made teaching modules for various courses at many levels of education, i.e. high school, undergraduate and graduate studies. Provided there are enough manpower and infrastructure support in the institute, these teaching modules can be produced with very little cost (approximately $10-15,000). It is also possible to include a number of other media for presentation, e.g. charts, x-ray films and histology slides if a scanner is available. Images of the teaching modules can be printed out as projection slides, overhead transparencies or handouts. Examination questions can be made from these images as well. In conclusion, teaching modules are an efficient and effective way to educate students in programs using self-directed learning as a mode of delivery.

PLASTINATED WHOLE ORGAN SECTIONS AND BONE DENSITY MEASUREMENTS OF THE MIDDLE FACE

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Introduction: Modern imaging techniques and the rapid development of cranial endoscopic surgery techniques increase the demand for accurate knowledge of the human skullbase and paranasal sinuses anatomy.

Serial sectioning after embedding with epoxy resins allow for artefact-free sectioning of tissues with marked differences in hardness, as found in the skull-base region. Subsequent to processing, quantitative and qualitative evaluations are delivered via imaging analysis systems.

Materials and Methods: Thirty cadaver heads were used for this study. The fixed specimens were watered, shockfrozen and subsequently dehydrated in cold (-30°C) acetone. The dehydrated specimens were embedded in a mixture of Biodur E12 and El. The resulting blocks were cut into 1 mm thick plane-parallel sections using a diamond wire saw (Firm Well, Mannheim, Germany). By adjusting direction, it is possible to cut the blocks into frontal, axial and sagittal planes. Material loss was not more than 0.3 mm per section. Radiograms of the sections were scanned into a computerized image analyzing system. Finally, data were calibrated against an aluminum wedge reference and then photographed from the monitor. The bone density decreases were colour-coded on a constant scale of red, yellow, green and blue. Another part of the sections were coloured with a special bone colour mixture for later histologic studies.

Results: The architecture of the orbit is shown under qualitative and quantitative aspects. Weak points of the osseous structure are revealed. Bone densities were highest in the region of the supra and infraorbital margins. Additionally, bone density was higher in the lateral wall than in the medial counterpart. Minimum bone densities were located in the cellulae ethmoidales, the orbital floor and in the infraorbital channel. The region of the lamina papyracea is an additional point of weakness and frequently involved in fractures. The dorsal wall of the orbit cannot be assigned to either group.

Summary and discussion: Bone density as well as morphology of fronto-basal and ethmoidal areas are clearly depicted on plastinated specimens. Weak points of the bony structure of the orbita are shown in detailed densitograms. The results provide a detailed and thorough impression of the human skull anatomy. Knowledge of these structures is very important for an early and exact evaluation of traumatic lesions of the midface and for precise planning of endoscopic minimal invasive surgery via transnasal approach.

PLASTINATION IN NEUROANATOMY

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Brain slices may be produced by both the S10 standard plastination technique and the P35 or P40 techniques.

The S10-standard technique is mainly used to plastinate whole brains and brain prosections. The plastinated brains can be sliced after final curing by means of a meat sheer or band saw. This results in smooth surfaces of the slices and thus slices are exactly adjacent to each other. Moreover, these

slices show good differentiation between gray and white matter, due to freezing and thawing during the S10 standard procedure. This technique allows to produce brain slices from 0.5 mm up to several centimeters. Therefore slicing S10 plastinated brains is much better than plastinating pre-sliced brain slices.

For the S10 technique I recommend to add the following steps to the standard procedure: Before starting the forced impregnation start with an immersion period. During this immersion-step the brains are immersed in the S10/S3 mixture for several days at -20°C. The longer the immersion time, the shorter the needed impregnation time will be. Moreover, this will also minimize the shrinkage of the brains. After curing is completed the brains are cut into slices of the desired thickness.

Polyester (P35 or P40) plastinated brain slices provide an excellent tool for teaching and research, because the differentiation between cortex, nuclei and fiber tracts is superior to all other techniques. The thickness of the slices can vary between 4 and 8 mm.

The polyester-procedure consists of the following steps: Fixation - Slicing - Flushing - Dehydration - Immersion - Forced Impregnation - Casting - Curing. P40 impregnated brain slices are cured by UVA-light only. For curing of P35 brain slices a well ventilated heat cabinet is needed. After a short light curing period P35 slices are finally cured at 40 - 50°C.

SILICONE CASTING OF THE AIRWAYS OF THE LUNGS

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The study of normal anatomy of the lungs is enhanced by viewing tracheobronchial casts. To aid understanding of the branching of the tracheobronchial tree, silicone casts of the lung airways were made from intact lung specimens harvested fresh from various cadavers. Excess tissue was removed and the trachea was cannulated. Lungs were flushed via the trachea with tap water to remove mucous and blood from the airways. Excess water was allowed to drip from the lungs and pressurized air was hooked to the tracheal cannula. Enough air flow and pressure were used to keep the lungs inflated to mimic normal inspiratory, anatomical position until the lungs were dry. Drying time was about 24 hours. After drying, Silastic E RTV polymer (Dow Corning, Midland, MI, 48640) or silicone P45 RTV polymer (Silicone, Inc., High Point, NC, 27261) was mixed with its hardener (10:1 ratio). The reaction mixture was syringed into the airways via the tracheal cannula. Filling was judged complete when the silicone could be seen through the lung parenchyma filling the small airways. The silicone was allowed to harden overnight. After hardening of the silicone, lung tissue was first macerated using boiling water and then completed in 5% hydrogen peroxide. Durable, anatomical duplicates of the conduction system of the lungs were produced.

MEDICAL MUMMIES: THE BURN'S MUSEUM COLLECTION

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At the University of Maryland's School of Medicine, there is a unique collection of human anatomical teaching specimens. Prepared by the eminent Scottish anatomist Burns in the late 1700's, today they exist as medical mummies and specimens, delicately detailing structures. Some of the specimens were prosected with special vascular casts and other unknown methods were used to create and preserve teaching specimens in the early era of medical education. A discussion of the collection's origin, history, and preparation methods will be discussed and a pictorial review of the collection will be presented.

SILICONE CASTING OF THE AIRWAYS OF THE LUNGS AND THE PULMONARY VESSELS

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The study of lung vasculature and its relationship to the airways of the lungs is important. To aid understanding of the pulmonary vasculature and its relationship to the bronchial tree, silicone casts of the lung vasculature and airways were made from fresh en bloc heart and lung specimens from various cadavers. The caudal (inferior) vena cava, the left auricle and trachea were cannulated for flushing the heart and lungs and for later injection of the silicone. Excess water was allowed to drip from the specimen and the aorta and remaining transected vessels of the heart were ligated. Silastic E RTV silicone polymer (Dow Corning, Midland, MI, 48640) or silicone P45 RTV polymer (Silicone, Inc., High Point, NC, 27261) was mixed with its hardener (10:1 ratio) and colored using either blue or red color paste. The colored mix was injected into the cardiac chambers and hence into the pulmonary vessels via the cannulated vena cava and left auricle. Filling was judged complete when the silicone could be seen beneath the surface of the lung filling the small

vessels. To assure that the silicone injected vessels hardened in proper anatomical position, pressurized air was introduced via the tracheal cannula. Enough pressure and air flow was used to keep the lungs inflated in normal inspiratory anatomical position until the lungs were dry and the silicone had hardened (24 hours). The airways were then filled with white or clear silicone mix via the tracheal cannula. Filling was judged complete when the silicone could be seen through the lung parencyhma filling the small airways. After the airway silicone had hardened, tissues was macerated first in boiling water and then complete in 5% hydrogen peroxide. Durable, anatomical duplicates of pulmonary vasculature, airways, cardiac chambers and great vessels were produced. These served as an anatomical tool for understanding the relationship between the pulmonary vasculature and the airways.

ANATOMICAL BASIS FOR THE ENDONASAL APPROACH TO THE NASOLACRIMAL DUCT

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The main parts of the tear conducting system are the lacrimal sac and the nasolacrimal duct. The membranous duct extends from the lower part of the lacrimal sac to the anterior part of the inferior meatus of the nose. The duct is contained in an osseous canal, formed by the maxilla, the lacrimal bone and the inferior concha. The direction of the lacrimal canal is described by a line drawn from the medial corner of the eye to the second upper molar. It is directed downwards, backwards and laterally or straight downwards.

Stenosis of the lacrimal drainage system leads to epiphora. To improve lacrimal drainage in such cases of dacryostenosis the lacrimal drainage system can be connected to the nasal cavity by a stoma. This procedure, called dacryocystorhinostomy, is usually performed via a skin incision on the lateral aspect of the nose. An endonasal procedure, however, would help to avoid scars. For an endonasal dacryocystorhinostomy the thickness of the surrounding bones is of importance. In order to determine the easiest approach to the nasolacrimal duct we measured the thickness of bone in both plastinated horizontal slices and CT-scans of the nose.

We subdivide the lacrimal drainage system into three parts: 1) the lacrimal sac, 2) the upper part of the nasolacrimal duct lateral to the middle nasal meatus - the meatal part - and 3) the lower part lateral to the attachment of the inferior concha - conchal part.

We found that the surrounding bony structures are of different thickness. The thinnest part of the osseous canal is in its posteromedial quarter and in its lateral aspect adjacent to the maxillary sinus. For endonasal approach only the posteromedial quarter of the meatal part is of relevance. In this part the bony wall of the nasolacrimal canal measures 1 mm and less in thickness. In the meatal part of the right nasolacrimal canal the thinnest wall is in between 5 and 9 o'clock. Further down in the conchal part the thinnest part of the wall wanders a little bit forward, so that it is between 7 and 10 o'clock in the lower third of the nasolacrimal canal.

INJECTING URETERS AND RENAL VESSELS WITH RTV SILICONE FOR PLASTINATION OF THE KIDNEY

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The study of normal anatomy of the kidney is enhanced by silicone injection of the vasculature and the ureter. Bovine kidneys were obtained from the slaughter house. The perirenal fat was carefully removed and the renal vessels and ureter were isolated and cannulated. Cannula size was selected so that a catheter-tip syringe would fit snuggly into the cannula. Regular syringes for injection have a much smaller outlet which makes it difficult for the silicone mix to be pushed out of the syringe into the kidney. Silastic E RTV polymer (Dow Corning, Midland, MI 48640) was mixed with its hardener (10:1 ratio). The mixture for the vessels was colored using either a red or blue color paste. The colored silicone mix was injected into the renal vessels and the non-colored mix into the ureter. Filling was judged complete when silicone could be seen through the parenchyma, when back pressure on the syringe increased markedly or when silicone ruptured to the surface. After injection, the specimen was submerged in cold 5% formalin solution and the silicone allowed to harden overnight. Later the kidney was prosected to show desired internal anatomy. Freeze substitution was used to dehydrate the specimen and impregnation was via the standard S10 procedure.

SHEET PLASTINATION OF BRAIN SLICES - P35 PROCEDURE

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The P35 procedure is used to produce semitransparent, thin (4 - 8 mm) brain slices. The brain is fixed thoroughly with formalin for several weeks and then sliced. The slices are rinsed of formalin and cooled to 5°C prior to submerging in cold acetone for dehydration by the freeze substitution method. After dehydration is complete, the brain sections

are immersed in two successive reaction mixture (P35/A9, 100/2) bathes. After the two immersions are complete, they are impregnated with the polyester reaction mixture. After impregnation is complete, the brain slices are placed in a flat chamber. The flat chamber is fashioned from four sheets of glass (two regular glass and two tempered glass), an appropriate diameter gasket (2mm thicker than slice) and clamps. The plastinated brain slice is placed on a double layer of glass. The gasket is placed on the glass, the second set of glass is placed on the gasket and finally clamps are placed around the perimeter of the apparatus. The flat chambers are set upright and filled with the polyester polymer mixture (P35/A9). Hence, the plastinated slices are incorporated into sheets of the plastination resin. The sheets containing the slices are cured initially using ultraviolet light from UVA lamps and finally in a 45°C oven. They are not merely embedded in the resin. The specimens show marked delineation of white and gray matter and are durable. Using this technique, brain slices show more detail, are more durable and easier to handle than those produced with other techniques.

EDUCATION OF A WIDER COMMUNITY WITH PLASTINATED SPECIMENS

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Anatomists led the way in using plastinated human tissues for teaching their students, followed by Pathologists and Veterinarians. We have reviewed how the scope of use of these specimens has developed over the last ten years.

With material from hospital autopsies in which permission to use organs for teaching was granted, we have built a teaching museum consisting of almost 900 specimens. The specimens consist of case groupings and individual organs of interest, as well as normals of each organ that are essential for comparison. The museum is indexed and cross reference by organ, disease and case type, both electronically and in hard copy. The museum is locked for security, and specimens have to be signed in and out.

In the first two years of operation, the specimens were used by pathology staff for teaching of undergraduate medical students in seminar settings. Due to the popularity of these demonstrations, each year has shown a wider audience starting with education of allied health professionals and the Hospital Board of Governors.

A meeting with the Heads of the local School Board Science Departments paved the way for use of non-human plastinated specimens in science classes, which was followed by the loan of human specimens. Other school events have included a medical student organized health outreach project, and an annual demonstration to high school law class. Other clients are the local Health Unit who use specimens on long term loan for smoking cessation classes and prison health educators who use the specimens in anti-drug and smoking education.

We continue to seek ways in which we can expand the use of plastinated specimens for education, reaching out into the community, from whence after all, the material originated.

SHEET PLASTINATION OF BRAIN SLICES - P40 PROCEDURE

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The P40 procedure is a newer version of the classic P35 technique. Both are used to produce semitransparent, thin (4-8 mm) brain slices. The brain is thoroughly fixed with formalin for an appropriate period and then sliced. Formalin is rinsed from the slices using running tap water. After rinsing, the slices are cooled to 5°C in preparation for dehydration by the freeze substitution method. The slices are submerged in cold acetone which is changed twice at two day intervals. After dehydration is complete, the brain sections are submerged in the polyester polymer for twenty four hours prior to plastination with the polyester reaction mixture (P40). The slices are impregnated either in the cold or at room temperature and in the dark. After impregnation is complete, the brain slices are placed in flat chambers. These flat chambers are fashioned from only two sheets of regular glass (2 mm), an appropriate diameter gasket (2mm thicker than slice) and clamps around the perimeter of the chamber. The flat chambers are set upright, a slice is inserted and the chamber filled with the polyester polymer (P40). Hence, the plastinated slice is incorporated in the plastination resin and is not just embedded in the resin. The sheets are cured using ultraviolet light from UVA lamps. The specimens show marked delineation of white and gray matter and are durable. Using this technique, is a less expensive. Since only one polymer immersion is used, less polymer is required. There are no additives to the P40 polymer and no tempered glass is needed.

MACROSCOPIC INTERPRETATION OF THE DISTAL PART OF THE EQUINE FORELIMB BY USING PLASTINATED SECTIONS (S10 AND COR-TECH PR-10)

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Six horse digits (distal part of the forelimb) were removed from fresh cadavers. All specimens were injected on both arterial and venous sides. The fetlock joint was

injected by its palmar pouch, and the pastern and coffin joints were injected by their dorsal pouches. The digital sheath was injected between the tendons of the deep digital flexor and the superficial digital flexor. The arteries (aa.), veins (vv.), and synovial formations were injected with red, blue and green colorated latex, respectively. The injection was done with normal manual pressure with a 10 to 20 ml syringe. Specimens were frozen and cross-sectionally sliced with a band saw (1 to 1,5 cm thickness), in a direction to the distal surface, lied from the carpal joint to the hoof. Twenty sections of each horse digits were plastinated according to the standard S10 and COR-TECH PR-10 techniques. Students are using them in the practical lectures with high didactic success. The quality of the material and differentiation of the anatomical structures are quite optimum. This fact let us give to undergraduate students and veterinary professionals a clear and accurate overview of the extension, limits and relationships of anatomical complex structures as the dorsal and palmar pouches of fetlock, pastern and coffin joints; the navicular bursa; the digital sheath; the interosseus "muscle"; the hoof cartilage; the digital cushion; the coronary and laminar dermis; palmar, metacarpal and digital aa. and vv.; lateral and medial palmar nerves, etc. These sections, highly appreciated by veterinary professional because their applicative use, can be correlated with other modern diagnostic imaging techniques such as radiology, CT and MRI.

POSTNATAL DEVELOPMENT OF THE HUMAN PARANASAL SINUSES

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The human paranasal sinuses are the maxillary sinus, the sphenoidal sinus, the frontal sinus, and the ethmoidal air cells. The development of these paranasal sinuses starts during the 10th and 12th fetal week building the ethmoidal air cells. Some ethmoidal cells expand beyond the margins of the ethmoid bone, thus, forming the other sinuses.

To determine which sinus are present at birth ten newborns' heads were plastinated with Biodur™ S10. After plastination five heads were sliced horizontally and five were sliced coronally.

The slices showed that the ethmoidal air cells were all present at birth, however, they were separated by relatively thick connective tissue. Also the maxillary sinus is present at birth. It has the size of a coffee bean with the sagittal expansion bigger than the transversal expansion. A frontal or sphenoidal sinus has not been found in any of the newborns.

Further investigations in 150 skulls of children from newborn to fifteen years showed that the frontal sinus starts to develop in the fourth postnatal year and the sphenoidal sinus starts in the sixth or seventh postnatal year.

The conclusions are:

1) An infant may suffer from maxillary and/or ethmoidal sinusitis; the latter may be dangerous for the eye.

2) The variability in the pneumatization of the sphenoid body and the frontal squama may be due to the late development of the respective sinuses.

PREPARATION AND PLASTINATION OF A SPECIMEN TO DEMONSTRATE THE COURSE OF THE HUMAN FACIAL NERVE

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The head of a 68 year old male was sectioned and injected via both common carotid arteries with 20 ml on each side with a mixture of S10 / S3 / S2 / S6 / AC50. It was kept at 4°C for 48 hours before being frozen at -25°C. The head was sagitally sectioned and stored in a modified Kayserling solution containing *5%* formalin. Dissection of the facial nerve was performed on the left side by a retrolabyrinthin approach and a squeletization of the facial canal. The superficial lobe of parotid gland was removed and the dissection of the facial branches was performed. The sternocleidomastoideus and the platysma were partially removed. The specimen was then dehydrated by freeze substitution and plastinated according to the standard S10 procedure. This plastinated specimen shows the course of the facial nerve from the geniculate ganglion to its ending.

A NEW PROCEDURE IN FINISHING MEDIUM THIN PLASTINATED TISSUE SLICES USING THE BIODUR S10 TECHNIQUE

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Medium thin tissue slices are of great value for teaching medical students sectional anatomy in combination with CT and MRI scans because they show depth and allow us to follow structures throughout the specimen. After getting experienced with the plastination of whole organs and larger parts of the human body using the Biodur S10 technique we wanted to produce medium thin slices (1 cm) of the human body using the S10 technique. Major difficulty using the S10 technique was the finishing of the surfaces of the fully cured slices.

Slices were made from the head of a cadaver, fixed and used for normal anatomical dissection courses. After freezing sections were made with a band saw. Dehydration with

acetone and impregnation was performed using the Standard technique described by von Hagens (1978). Impregnated slices were placed onto a glass plate covered with plastic foil. The edges of the foil were lifted, forming a box with the specimen in it. The box was filled with Biodur S1O/S3 mixture until the specimen was submerged and slow-curing was performed.

After curing a block of silicone was obtained, with one side of the slice at the outside of the block. This side was attached onto a flat surface, the other side of the slice (covered with silicone) was carefully milled, using a top-milling machine in a supporting frame to insure that the upper side of the block became exactly parallel with the underside of the block. In this way the silicone covering the slice was removed, hardly any tissue was removed of the slice. If necessary the procedure was repeated at the other side of the slice. Remaining silicone at the circumference was peeled of.

The slice was then attached onto a large wooden shelf, using several steel nails without head. A heavy belt sander was placed on the slice, supported by adjustable wheels wide away from the slice resting on the underlying shelf, insuring the belt sander stayed parallel with the shelf and the surface was polished. This procedure was repeated at the other side of the slice producing two very smooth and exactly parallel surfaces. Loss of tissue was less than 1 mm.

THE RESTORATION OF ANATOMICAL AND ARCHAEOLOGICAL SPECIMENS USING THE S10 PLASTINATION METHOD: WITH SPECIAL REFERENCE TO PRESERVING THE GOOD HEART OF A GOOD PRIEST

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Plastination is a process that permanently preserves biological materials using curable polymers that render the tissues and whole specimens dry, odourless and durable. The process involves fixation, dehydration, impregnation and curing. Plastinated specimens retain their original surface relief and cellular identity.

On January 29,1828 his Excellency, the Most Reverend Archbishop of Baltimore, Ambrose Marechal died of distressful asthma. In his will he bequeathed his heart to St. Mary's Seminary. Enshrined in a glass reliquary, it was preserved in whisky and rested in the seminary chapel until 1925. Recently rediscovered within the archives, the Baltimore Archdiocese released the heart (relic) specimen to the Anatomical Service Division of the University of Maryland School of Medicine for plastination. The 166 year old post-mortem heart specimen was received at the lab in June 1993. The specimen's appearance was dark; the tissue was hard, showed signs of shrinkage, and evidenced an odour of distilled alcohol (whisky).

The specimen's treatment began with immersion in a bath of 5% hydrogen peroxide for one week, resulting in a markedly lighter colour and hydration to a more normal appearance and shape. Plastination commenced with freeze substitution in 100% acetone followed by dehydration in three baths of 100% acetone over a 30 day period at -28 degrees Celsius. Forced impregnation in S10 silicone polymer followed. After 7 days the heart was removed from the silicone vacuum chamber, reoriented to its natural shape using polyethylene plastic film for packing the cavities and gum rubber bands to hold the shape, and placed in a curing chamber. Following the curing Archbishop Marechal's heart was now permanently preserved and was returned on October 5, 1993 to be reinstalled in a new reliquary at the St. Mary's Seminary.

The above account outlines one particular use of the S10 technique in restoring anatomical material that may or may not have been properly preserved at the onset of fixation. This technique not only lends itself to the restoration of anatomical materials, but may also play a significant part in preserving archaeological remains such as bone (animal or human), skins (leather) or wood.

This presentation will outline some of the uses and results obtained when applying the S10 plastination technique for these purposes.

PLASTINATION OF THE AORTA FOR USE IN THE TRAINING OF PHYSICIANS IN THE TECHNIQUE OF VASCULAR CATHERIZATION

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The training of clinicians in the technique of vascular catherization has been greatly enhanced through the use of anatomically correct plastinated aortic specimens produced in our laboratory. These human teaching specimens have an advantage over other synthetic materials which have been designed to mimic the vascular system in that they are more representative of both the normal anatomical features of the aorta and its branches, as well as pathological changes that may be encountered in performing this technique on patients in the clinical setting.

The aortic specimens were processed using a modification of the procedure outlined by Corcoran Laboratories, Inc., Bay City, Michigan. Previously fixed cadaveric aortic specimens were carefully dissected ensuring that the branches of the aortic arch, as well as the renal and

iliac branches of the descending aorta, were preserved. The vessels were packed with gauze to aid in maintaining the correct anatomical alignment and to prevent their collapse. Specimens were then dehydrated in three changes of acetone at -25°C. They were then immersed in COR-TECH PR-10 preservation polymer containing 3% COR-TECH CR-22 crosslinker. To enhance impregnation, specimens were processed in a vacuum chamber for two days. Following impregnation, the gauze packing was removed from the vessels and the preservation process was completed using COR-TECH CT-32 catalyst.

These plastinated specimens are currently being used in vascular catherization training sessions as follows. The aortic specimens are filled with water and with the aid of a fluoroscope a catheter is guided through the vessel by the physician. An unexpected, yet welcomed, advantage to the use of this type of specimen is that the plastination polymer renders the vessels radio opaque. This allows the physician the advantage of actually being able to visualize the vessels he/she is directing the catheter through. This novel use of plastinated human vascular specimens is currently being perfected. Undoubtedly, it has potential to play a significant role in medical education. Hence, additional uses are currently being explored.

PLASTINATION AS A CONSOLIDATION TECHNIQUE FOR ARCHAEOLOGICAL BONE, WET LEATHER AND WATERLOGGED WOOD

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Natural and man-made environmental conditions may adversely affect archaeological materials causing them to become weak and fragile. This has been of concern when trying to preserve specimens such as archaeological bone, leather and waterlogged wood.

In order to restore their strength and lengthen their lifespan these objects have often been treated with synthetic adhesives and consolidants. After analysing the effects of these treatments, it was decided to research the possibility of using a method called plastination.

Specimens of bone, leather and wood were prepared using the standard S10 method of plastination (von Hagens, 1985). Control specimens were prepared involving: plastination without dehydration and defatting [bone only], bleaching before plastination [bone only], solvent cleaning before curing the S10 [bone, leather, wood], air-drying [wood and leather only], vacuum freeze-drying [wood and leather only] and vacuum freeze-drying followed by plastination [wood and leather only].

All specimens were evaluated for: weight change, dimensional stability, colour change, hardness [bone and wood], indentation resistance [wood only], flexibility [leather only], removability and clean-up of the polymer and light aging. A chemical analysis of the S10 polymer was also done.

After assessment and evaluation, the S10 was found to be a promising consolidant. Treated specimens were: well penetrated, showed little dimensional change and were aesthetically pleasing. Although the polymer was found to be irremovable, it was valuable for specific applications.

Until further studies are completed assessing its long term stability and effects on specimens, the plastination technique cannot be recommended for consolidation.

LOCAL FLAPS FOR FINGERTIP INJURIES - PLASTINATED HAND SPECIMENS IN SURGERY EDUCATION

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Normal, formalin-fixed anatomical specimens are of great use in studying anatomy. They are, however, not hygienic and smell, which greatly prevents their clinical use, although the exact knowledge of anatomical relations is essential in many disciplines, e.g. in surgery. Plastinated specimens in turn are dry, hygienic enough to be stored and used in clinics as well. By this method the discipline of anatomy gains new perspectives in medical education. The present study offers a help for surgeons, who apply local flaps for fingertip injuries.

Fingertip injuries often occur in the general surgical practice. The wide variety of these injuries and the great number of methods in treatment make the choice of the best therapy often difficult. The knowledge of the regional anatomy and blood supply is essential. Unfixed, human hand was used to demonstrate the anatomical basis, the harvesting technic, the three dimensional appearance and the indications of the numerous local flaps published in the literature. The Atasoy, Hueston, Moberg, O'Brien and the Venkatasvami-Subramanian methods were applied. The specimens were dehydrated in acetone at -25°C, and underwent forced impregnation with silicone at -25°C. These specimens can be used to study the anatomical relations in clinics right before operation.

THE MODULAR RESOURCE CENTER - LEARNING RESOURCES FOR THE STUDY OF VETERINARY MEDICINE

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The Veterinary College at Cornell has implemented a student-centered, tutorial-based curriculum in which learning issues in gross anatomy, histology, genetics and animal

development are brought to light through the use of clinical case scenarios. This curriculum creates an entirely new set of relations between the learner and resources. A key element of this program is the availability of visually oriented resources in "modules" where information has been organized into thematic, mixedmedia presentations for individual or small group study. These presentations are particularly well suited to disciplines in which gross, microscopic, and radiographic anatomy constitute core material.

Modules are self-contained study stations that contain a combination of plastinated and wet specimens, bone preparations, models, illustrations, radiographs, cross-sectional panels, microscope slides, computer-based images, and other materials. Plastinated specimens play a key role in many of these modules. Modules combine 2- and 3-dimensional materials to present a defined set of learning issues augmented by a brief text that helps the students more effectively interact with the specimens. The modules are clustered by body system, body region or by discipline and permanently housed in rooms that are available at all times to faculty, staff, residents, interns and veterinary students.