

Academy of Surgical Research

Certification Study Guide

First Edition: Matthew Flegal, SRS and the ASR Certification Committee

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Part 1: Introduction

The purpose of this study guide is to provide an overview of some of the information contained in the Academy of Surgical Research's (ASR) "Recommended References" as posted on the ASR website for the SRS, SRT and SRA certification exams administered by the Academy. The intent and use of this study guide comes with the understanding that the ultimate source of exam questions originates from content contained within the ASR Recommended References and not solely from this study guide and thus topics covered in the references may appear on an exam without coverage in this study guide. Thus, do not use this guide as the sole study source in preparation for the certification exams. The outline format of the study guide design is to allow applicants to use it as a note-taking framework when reading the ASR Recommended References.

In any work of this size and scope, errors may have crept into the text. It is with hope that the users of the study guide will make the Academy aware of any inconsistencies in facilitation of correction for accuracy. In addition, because the purpose of the guide is to assist applicants in studying for their exam, suggestions and requests are welcome in order to make this study guide the most useful reference possible for applicants.



Part 2: Regulatory & Accreditation Overview

Section 2.1: Agencies

Section 2.1.1: United States Department of Agriculture (USDA)

- **Animal Welfare Act (AWA) and Animal Welfare Regulations November 2013:**
 - Originally passed by Congress in 1966,
 - Administered by the USDA Animal and Plant Health Inspection Service (APHIS),
 - Known as the Animal Welfare Regulations,
 - Published in Title 9 of the Code of Federal Regulations,
 - Information applicable to research facilities is contained in Subpart C of the Animal Welfare Act

Section 2.1.2: National Research Council (NRC)

- **Guide for the Care and Use of Laboratory Animals:**
 - Less specific than the Animal Welfare Act, “written in general terms so that its recommendations can be applied in diverse institutions and settings that produce or use animals for research, teaching, and testing.”
 - IACUCs have a key role in interpretation, implementation, oversight, and evaluation of institutional animal care and use programs.
 - APPENDIX B includes U.S. Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training.
 - “The use of laboratory animals for biomedical research, testing and education is guided by the principles of the 3 R's: replacement of animals where acceptable non-animal models exist, reduction in the number of animals to the fewest needed to obtain statistically significant data and refinement of animal care and use to minimize pain and distress to enhance animal wellbeing.”
 - The ‘Guide’ provides specific information regarding the following in reference to Surgery:
 - Training
 - Pre-surgical Planning
 - Surgical Facilities
 - Surgical Procedures
 - Aseptic Technique
 - Intraoperative Monitoring
 - Postoperative Care

Section 2.1.3: Office of Laboratory Animal Welfare (OLAW)

- Implements the Public Health Service (PHS) Policy on Humane Care and Use of Laboratory Animals (reprinted in 2015) mandated by the Health Research Extension Act of 1985 and the U.S. Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training.

OLAW also provides specific guidance, instruction, and materials to institutions and individuals that must comply with the Policy as recipients of National Institute of Health (NIH) grants.

Section 2.1.4: Food and Drug Administration (FDA)

- **Good Laboratory Practices (GLPs):**
 - GLP regulations apply to animal and non-animal studies funded by FDA as well as EPA and have specific mandates for personnel training, record keeping and quality assurance along with mandated development and adherence to SOPs describing all scientific and husbandry procedures performed in a facility including everything from cleaning procedures to surgical preparation of animals and patients. “If it isn’t recorded, it didn’t happen.”

Section 2.1.5: Environmental Protection Agency (EPA)

- EPA has similar regulations to the FDA regarding research studies wherein a surgical procedures, device, and/or compound administration are a study component in addition to waste management.
- These regulations vastly increase the required amount SOP compliancy and record keeping.

Section 2.1.6: Association for the Assessment and Accreditation of Laboratory Animal Care (AAALAC International)

- Formed in 1965
- Offers an accreditation program for qualified institutions
- Accreditation is not a requirement for facility operation
- Standards must be maintained and verified by periodic inspections or accreditation is lost
- Uses the 8th Edition of the *Guide for the Care and Use of Laboratory Animals (Guide)*, NRC 2011; the *Guide for the Care and Use of Agricultural Animals in Research and Teaching (Ag Guide)*, FASS 2010; and the *European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes*, Council of Europe (ETS 123) as its three primary standards for program evaluation.

Section 2.1.7: American Veterinary Medical Association (AVMA)

- Guidelines for Animal Surgery in Research and Teaching (GASRT):
 - Stalled at the issue of non-veterinarians performing surgery.
 - The AVMA board approved the original report up to the section on personnel and sent the remainder of the report to the American Society of Laboratory Animal Practitioners (ASLAP), which reviewed and published these guidelines in the September 1993 American Journal of Veterinary Research.
 - These guidelines emphasize the importance of veterinary participation and oversight in animal research while allowing surgical procedures to be performed by qualified non-veterinary surgeons.

Section 2.1.8: American College of Veterinary Anesthesiologists (ACVA)

- Released “Suggestions for Monitoring Anesthetized Patients” in 1994.
- Originally published in the Journal of the American Veterinary Medical Association (JAVMA, 1995; 206, (7): 936-937) and updated 2009.
- Covers circulation, oxygenation, ventilation, temperature, neuromuscular blockade, record keeping, recovery period, personnel, and sedation.
- Originally for clinical veterinarians; however, often adopted to cover research animal anesthesia as well.
- A position paper on the treatment of pain in animals was released and modified 3/17/2006.

Section 2.1.9: Academy of Surgical Research (ASR)

- Peer Reviewed ASR Published Guidelines and Citation:
 - Guidelines for Training in Surgical Research with Animals. JIS, 1989;2(2):263-268.
 - Guidelines for Training in Surgical Research with Animals. JIS, 2009;22:218-225.
 - Guidelines for Rodent Survival Surgery. JIS, 2009;22:445–451.
 - ASR Citation: *The Guide*.

Section 2.2: Specific Regulations Relating to Surgery

Section 2.2.1: Major Procedures

- AWA and the Guide state that any surgical intervention that penetrates and exposes a body cavity or produces substantial impairment of physical or physiologic functions.
- The Guide gives examples such as laparotomies, thoracotomies, craniotomies, joint replacements, and limb amputations.

Section 2.2.2: Multiple Major Survival Surgery

- AWA allows only if it is justified for scientific reasons by the principal investigator in writing, is required as a routine veterinary procedure or to protect the health or wellbeing of the animal as determined by an attending veterinarian, or a USDA administrator determines that it fulfills appropriate special circumstances.
- The Guide discourages multiple major surgeries but permits it when scientifically justified and approved by the IACUC if:
 - Multiple surgeries are related components of a research project or,
 - Will conserve animal resources or,
 - Needed for clinical reasons.
 - Cost savings alone is NOT an adequate reason.
 - Requires that the IACUC should pay particular attention to the animal’s wellbeing through continuing evaluation of outcomes.

- PHS policy is similar in tone.
- AAALAC strongly discourages it but permits it if scientifically justified and approved by the IACUC if they are related components of a research project and deemed essential.

Section 2.2.3: Minor Procedures

- The Guide states that a procedure that does not expose a body cavity and causes little or no physical impairment (such as wound suturing; peripheral vessel cannulation; such routine farm animal procedures as castration, dehorning, and repair of prolapses; and most procedures routinely done on an "outpatient" basis in veterinary clinical practice).
- AWA does not define.

Section 2.2.4: Pain & Distress

- AWA states that any procedure that could be reasonably expected to cause more than slight or momentary pain or distress in a human is to be considered painful.
 - Defined as in excess of that caused by minor procedures such as injections.
 - Requires that the IACUC committee ensure that distress and pain will be avoided or minimized.
 - Requires veterinary consultation or guidance concerning pain-relieving drugs.
 - Requires that any procedure that violates the above should be performed with appropriate analgesics, anesthetics, or tranquilizers.
- PHS's "U.S. Government Principals for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training" echoes the AWA on the use of analgesics.
- The Guide is less specific than the AWA.
 - References *Recognition and Alleviation of Pain and Distress in Laboratory Animals* (1992) by the Institute for Laboratory Animal Research.
 - States that different species express pain and suffering in different ways so personnel must be familiar with species specific and individual expressions of pain.
 - Specifies that sedatives, anxiolytics, and neuromuscular blocking agents are not analgesics and should not be used as such.

Section 2.2.5: Euthanasia

- AWA and PHS require that animals that suffer chronic or severe pain or distress should be humanely euthanized at the conclusion of the procedure or, if applicable, during the procedure.

Section 2.2.6: Pre- & Post-Operative Care

- AWA states that pre- and post-operative care will be provided in accordance with established veterinary and nursing procedures.
- The Guide recommends the "team-concept" as often increasing the likelihood of a successful surgical outcome and that a continuing and thorough assessment of surgical outcomes should be performed.

- Modification of standard techniques is allowable as long as it does not compromise the well-being of the animals.
- Pre-surgery planning should include input from all members of the surgical team.
 - Identify responsible personnel.
 - Identify roles and needs.
 - Identify required equipment and supplies.
 - Identify the facilities involved.
 - Discuss preoperative animal health assessment and postoperative care.
 - Investigator and veterinarian share responsibility for postoperative care.
- While recovering from anesthesia, animal should be kept in a clean, dry area and observed often by trained personnel.
- During recovery, attention should be paid to body temperature, cardiovascular and respiratory function, and signs of pain and distress.
- Post-operatively animals should be observed for intake and elimination, signs of postoperative pain, infection, and the appearance of the incision(s).
- Mandates good care and timely removal of staples, sutures, clips, and bandages.

Section 2.2.7: Aseptic Technique

- AWA states that all survival surgery will be performed using aseptic procedures including:
 - Surgical Gloves.
 - Masks.
 - Sterile Instruments.
- The Guide states that all major survival surgery will be performed using aseptic procedures including:
 - Clipping of hair at and disinfection of the surgical site.
 - Preparation of the surgeon.
 - Decontaminated surgical attire.
 - Surgical scrub.
 - Sterile surgical gloves.
 - Sterile instruments, supplies, and implants.
 - All major survival surgery will be performed using good surgical technique including general asepsis, gentle tissue handling, minimal dissection of tissue, appropriate use of instruments, accomplishment so hemostasis, and correct use of suture materials and patterns.
 - Minor procedures and those involving rodents may use less stringent measures but still require aseptic procedures and instruments.

Section 2.2.8: Facilities

- AWA states that major non-rodent procedures must be conducted only in facilities intended for the purpose and maintained under aseptic conditions and that minor and rodent procedures do not require a dedicated facility but must be performed using aseptic procedures.
- The Guide states:

- Unless an exception is specifically justified as an essential component of the research protocol and approved by the IACUC, aseptic surgery should be conducted in dedicated facilities or spaces.
- Generally, agricultural animals maintained for biomedical research should undergo surgery with techniques and in facilities compatible with these guidelines.
- For most survival surgery on rodents, aquatics and birds, an animal procedure laboratory dedicated to surgery and related activities when used for this purpose and managed to minimize contamination from other activities is recommended.
- Designated Areas:
 - Clean: Operating room (OR), scrub room, sterile supply rooms.
 - Mixed (clean/dirty): Hallways between OR, prep rooms, recovery room, storage rooms, etc.
 - Contaminated (dirty): Prep rooms, dressing rooms, offices, housing rooms.
 - Areas are commonly separated by physical barriers but may be achieved with distance or timing of appropriate cleaning and disinfection between activities.
 - Reduce traffic and personnel.
 - Rooms should be designed for ease of cleaning and disinfection and appropriate ventilation.
 - Only required equipment and supplies should be kept in the operating room and storage minimized.

Section 2.2.9: Surgical Records

- The AWA includes requirements for recordkeeping for completion of the annual report and IACUC functions.
- OLAW also has annual reporting and recordkeeping requirements.
- The Guide discusses recordkeeping with regard to colony management, quality control, controlled substances, and medical records, and recommends maintaining the history of surgical procedures and postoperative care, especially for dogs, cats, nonhuman primates, and farm animals.
 - Good record keeping is useful for the continuing assessment of surgical outcomes.
- GLP regulations require that for surgical protocols performed under GLP regulations, documentation must exist that show that all parts of the protocol were followed in compliancy.
 - If it is not documented it did not happen!

Part 3: Sterilants, Disinfectants & Antiseptics

Section 3.1: Sanitization & Disinfection

- The surgical environment (rooms, structures, equipment, lights, etc.) should be appropriately sanitized/disinfected according to daily, weekly, and monthly cleaning protocols.

Section 3.1.1: Definitions

- **Sanitization:** Is the process of removal of organic/inorganic material and infectious debris to reduce the number of pathogens.
- **Disinfection:** The inactivation of most pathogenic organisms except for some highly resistant forms (spores) on inanimate objects and surfaces and implies the destruction of the vegetative forms of bacteria but not spores. Is antimicrobial and/or bacteriostatic.

Section 3.1.2: Methods

- Applies to inanimate objects and uses chemicals.
- Intermediate and some low-level disinfectants should be used for cleaning surfaces in surgery.
- Disinfectants are rated as high, intermediate, or low based on efficacy against microorganisms.
- **High-level Disinfectants:**
 - Used for instrument disinfection between procedures, for delicate endoscopic equipment that cannot be steam sterilized, and for critical surface cleaning.
- **Aqueous Iodine**
 - Contains high levels of free iodine.
 - Cytotoxic.
 - Stains surfaces.
 - 30 minutes of exposure for disinfection.
- **Aldehydes**
 - 30-45 minutes of exposure for disinfection.
- **Sodium hypochlorite (bleach).**
 - Toxic.
 - Corrosive.
 - 3,000 ppm for 45-60 minutes for disinfection.
- **Phenol compounds** (carbolic acid)
 - No longer commonly used due to possible toxicity
 - 30 minutes for disinfection.

- **Intermediate-level Disinfectants**

- Used for cleaning surfaces.
 - **Iodophors** (Povidone iodine)
 - Iodine complexed with surfactants or polymers for slower release of free iodine.
 - Dilution lowers cytotoxicity and increases bactericidal activity.
 - Rapidly deactivated in the presence of organic matter.
 - Residual activity for 46 hours.
 - May be mildly irritating.
 - Also used as an antiseptic
 - **Chlorhexidine**
 - Rapid onset and long residual activity (8-12 hours).
 - Not deactivated by organic matter.
 - Non-irritating.
 - Considered superior to iodophors due to residual action even when dried
 - Also used as an antiseptic.

- **Low-level Disinfectants**

- Used for instrument disinfection between rodent procedures and for critical surface cleaning
 - **Alcohol** (Isopropyl)
 - Bactericidal.
 - Ineffective against most spores and fungi.
 - Minimal residual effects and inhibited by organic debris.
 - Cytotoxic.
 - Degreaser.
 - 30 minutes exposure for surface decontamination
 - Used as part of an aseptic surgical preparation of patient's skin prior to surgery
 - **Quaternary Ammonium** (Quat, Zephiran)
 - Bactericidal.
 - Works by dissolving outer coatings on some pathogens.
 - Some bacteria, including *Staphylococcus aureus* and *Pseudomonas*, have common resistant strains.
 - Ineffective against spores and some viruses.
 - May support growth of some types of bacteria.
 - Per CDC, is not an appropriate sterilant.
 - Low toxicity in stable solutions.
 - 10-30 minutes for surface decontamination.

Section 3.2: Tissue Antiseptics

- Commonly used for surgical site preparation on the patient and for surgeons to scrub hands and forearms prior to gowning and gloving.
- Intermediate level disinfectants are often acceptable antiseptics.
- **Antiseptic:** A substance that inhibits or destroys microorganisms on or in living tissue. Is antimicrobial and/or bacteriostatic.
- **Asepsis:** A state of freedom from disease-causing contaminants.
- **Aseptic technique:** The steps required to prevent contamination of the surgical site with infectious agents.

- **Common Antiseptics:**

- **Iodophors**

- Available as tinctures, solutions, and detergents.
 - Work by contact time similar to chlorhexidine.
 - Principal antiseptic.

- **Chlorhexidine**

- Considered more effective than the iodophors due to residual activity.
 - Available as tinctures, solutions, and detergents.
 - Antiseptic activity based on contact time - requires sufficient skin contact duration for effect.
 - Can be irritating to mucosal surfaces and may induce allergic responses.

- **Alcohol**

- Useful for low-level antiseptics.
 - Has a minimal residual effect.
 - Evaporates rapidly and leaves no residue.
 - Inhibited by organic debris.
 - Not sufficient as the primary antiseptic per standard human and veterinary surgical texts.
 - Useful in conjunction with iodophors or Chlorhexidine
 - Breaks up surface oils and surface tension



Section 3.3: Methods of Sterilization

- **Sterilization:** The physical or chemical destruction of all microbial life including transmissible agents.

Section 3.3.1: Filtration

- May be used for gasses or liquids.
- Involves the separation of particulate matter of known sizes using a membrane.
- Commonly used for pharmaceutical liquids.
- Useful for heat sensitive media, offers high throughput, and provides absolute sterilization.
- Unable to differentiate between similarly sized particles.

Section 3.3.2: Radiation

- Usually gamma radiation from Cobalt 60.
- Provides penetration through relatively impervious materials (i.e., metal and plastic).
- Leaves no chemical residue.
- Can start a structural change in materials, especially some polymers, which may continue to develop over months.
- Usually used by manufacturers due to the cost of the process.

Section 3.3.3: Thermal

- Moist heat in the form of saturated steam under pressure is the most widely used and the most dependable sterilization process (autoclave steam sterilization).
- High heat temperature used to denature bacterial proteins.
- Sterilization is a function of time and temperature.
- **Two Types Or Thermal Sterilization Methods:**
 - **Dry Heat** (i.e. hot bead sterilizer, oven) used on moisture sensitive materials such as oils, powders, and petroleum products.
 - Useful for sterilizing surgical instruments during multiple rodent surgeries.
 - **Wet Heat** (boiling water and autoclave) kills bacteria via the coagulation of critical proteins.
 - **Boiling water**
 - A poor sterilant at ambient pressure.
 - Has a relatively low temperature.
 - May be enhanced by the addition of sodium hydroxide or sodium carbonate.
 - Destructive to instruments, especially glassware and rubber.
 - **Autoclave (Steam)**
 - Involves superheated steam under pressure to allow higher temperatures than normal steam can provide.
 - Requires materials and wrapping that are not damaged by heat, moisture, and pressure but are permeable to the steam.
 - Requires complete saturation of the surgical pack for effective sterilization (i.e., 121C° for 13-15 minutes, 5-10 minutes plus 3-8 minutes as a safety margin).
 - Larger or denser packs require more time for adequate steam saturation.
 - Time for the autoclave to reach temperature and saturate the pack is the heat-up time achieved by pre-vacuum autoclaves in 12 minutes.
 - ♦ Can be used for emergency “flash” autoclaving.
 - ♦ Also reach higher temperatures and so require shorter exposure times (131C° for 3 minutes).
 - Loads should be vented for ~10 minutes following a cycle to prevent condensation.

Section 3.3.4: Liquid Chemical

- Important to differentiate between sterilants and disinfectants:
 - Sterilants are designed to kill all microorganisms, disinfectants are not.
 - Disinfectants are NOT adequate for instrument and implant/catheter sterilization.
- Chemical sterilants are regulated by the FDA and EPA as medical devices.
- Approved chemical sterilants will say on the bottle that they are sterilants.
- Non-sterilant chemicals will have disinfectant written on the bottle and should not be used for instrument or device sterilization.
- Cold sterilants work by contact, care should be taken that all surfaces are in contact with the solution
- Flush sterilant through catheters, open all latches, etc.
- Cold sterilants are tissue irritants and require complete rinsing (sterile water or saline) of sterilized objects to remove all chemicals prior to tissue contact.
- **Cold Sterilants:**
 - **Aldehydes (Glutaraldehyde)**
 - Requires >12 hours of full immersion for sterilization of resistant spores.
 - Noncorrosive.
 - Activated solutions have < 2 week shelf life.
 - Toxic to skin, eyes, and respiratory tract.
 - Glutaraldehyde solutions come in different strengths.
 - Only those classed as sterilants should be used for instrument or device sterilization.
 - **Formalin**
 - 37% aqueous formaldehyde.
 - Requires >24 hours of full immersion for sterilization of resistant spores.
 - Toxic to skin, eyes, and respiratory tract.
 - **Hydrogen Peroxide**
 - 6% aqueous solution with >30 minute exposure may kill some resistant spores in addition to less hardy microorganisms.
 - Potentially explosive at high concentrations.
 - Corrosive.
 - Irritant to skin and eyes.
 - **Peracetic Acid (35%)**
 - Registered by the EPA as an antimicrobial in 1985 for indoor use on hard surfaces

Section 3.3.5: Gas Sterilization (Chemical)

- **Requires An Enclosed Chamber Similar To An Autoclave**
 - **Ethylene Oxide (ETO)**
 - Colorless gas.
 - Flammable, explosive, toxic, and irritating to skin and mucus membranes.
 - Destroys metabolic pathways by alkylation.
 - Older manual systems require 12 hours of exposure.
 - Time is inversely proportional to pressure.
 - “Newer” automated systems (i.e. 3M system, for example), use heat and moisture to decrease both the exposure and aeration times.
 - **Hydrogen Peroxide**
 - Safer than ETO for the user.
 - Requires little ventilation and shorter exposure times.
 - Cannot be used with absorbent materials such as paper or cloth (cellulose-based materials).
 - Can condense into water and soak the packaging, preventing gas contact and allowing post sterilization “wicking” of microorganisms through the packaging.
 - STERIS stopped supporting use in a research environment ~2012.

Section 3.4: Sterilization of Surgical Supplies

- All instruments must be thoroughly cleaned prior to sterilization.
- Organic debris can dramatically extend the required time for sterilization.
 - Example:** Glutaraldehyde sterilization time increases from 12 hours to 48 hours in the presence of organic debris.
- For most forms of sterilization instruments should be dry.
- Not as important for steam autoclaving.
- Some residual moisture is important for ETO sterilization.
- Multiple layers of sterilization indicators should be used to verify proper sterilization of items.
- Sterilization sleeves have indicators on them.
- Packs should use indicators inside the inner wrap and under or inside any containers or large objects.
- Instruments should be in an open position when preparing wrap packs so that they are optimally accessible to steam or gas methods of sterilization allowing access to hinges and clasps.
- Items should be placed to prevent inadvertent puncture of the wraps or sleeves; protectors should be placed over sharp tips.
- Packs and sleeves should be dated the day that sterilization is performed.
- Paper/plastic wrapped items/packs are considered sterile for 12 months when stored in closed cabinets.
- Cloth wrapped items are considered sterile for six months when stored in closed cabinets.
- Packs and sleeves that get wet or are damaged (e.g., punctured) should be considered contaminated and thus non-sterile.
- If there is any doubt about sterility, consider it contaminated and thus non-sterile.

– **Preparation Of Double-Wrapped Packs:**

- Pack instruments in layers (or separated layers using drape material or gauze sponges) in sterilization tray or dish.
- Place a sterilization indicator under the instruments (most difficult area for sterilant to penetrate).
- Place two cloth or paper drapes on a flat, hard surface in a star pattern, arranged so that the corner of the first drape is closest to you and a long side of the top drape is closest to you.
- Place pack on top of the drapes.
- Fold the bottom edge over the pack, followed by each of the two sides; pull the sides tight; pull the top side down and tuck it under the sides.
- Place a sterilization indicator on top of the single wrapped pack.
- Fold the bottom corner up over the pack, followed by the sides.
- Pull the sides tight, then pull the top corner down and tuck it under the sides, ensuring that the wrap is tight.
- Tape the 2nd drape with indicator tape and label pack with contents and date of sterilization.



Part 4: Principles of Aseptic Surgery

► Surgical Asepsis

- Relies on engagement of a series of best practices involving use of aseptic techniques during surgery to prevent and/or minimize the contamination of the surgical site with infectious agents. The ultimate goal is to lower the concentration of microorganisms to below the level required for infection.

► General Attire For Operating Room Entry

- Cap
- Mask
- Clean scrubs
- Booties
- Gloves

Section 4.1: Antimicrobial Therapy & Wound Infection

– Major Bacteria Involved In Surgical Wound Infections Are:

- Staphylococcus aureus
- Streptococcus pneumoniae
- Pseudomonas multivorans (not a bacteria)
- Coagulase negative Staphylococci
- Enterococcus (spp)
- Escherichia coli



- In general, bacteria do not directly affect tissue cells.
- Bacterial waste products such as endotoxins and cytotoxins damage and kill cells.
- The body provides bacteria with food, shelter, humidity, and warmth.
- Generally, bacteria are localized until they gain entrance to the bloodstream, then they become systemic infections.
- The body fights extracellular bacteria and other organisms in an antibody-mediated immune response.
- Antibodies recognize foreign bodies and call in phagocytes.
 - Phagocytes engulf and consume foreign material, dying in the process.
- Immune response causes an increase in temperature, production of pus, and influx of serous fluid.
- Surgical infections result in prolonged wound healing due to:
 - Damage from toxins
 - Physical debris
 - Changes in local circulation
- **Antibacterial Therapy**
 - Species and target tissue specific.
 - Antibacterial Treatment:
 - Prophylactic (preventative strategy).
 - Therapeutic (healing strategy).

– **Antimicrobial Agents**

- Bactericidal - a substance that kills bacteria
- Bacteriostatic - a biological or chemical agent that stops bacteria from reproducing, while not necessarily killing
- Other Antimicrobial Agents
 - Antivirals
 - Antifungals
 - Antiprotozoals

Section 4.2: Aseptic Patient Preparation

Section 4.2.1: Cursory Animal Bathing

- Cursory cleansing of animals is typically done for larger animals (i.e., livestock) if needed
 - Example: Some animals, especially livestock, may have large amounts of contaminants (feces, dirt, and bedding material) on their fur/skin. These contaminants may be removed prior to surgery by cursory bathing or washing.
 - Be aware that getting the animal wet may reduce their temperature, especially if already anesthetized.

Section 4.2.2: Preliminary Surgical Site Preparation

- Remove excess hair.
 - Hair should be clipped close to the skin around any potential incision sites to create a working surgical field with wide margins. This is dependent on the surgical procedure to be performed and is species specific.
 - In rodents, this should be a minimum of ~ 2 cm from the incision site.
 - In larger animals, this should be a minimum of 4-6 cm from the incision site.
 - Shaving with a blade is not generally recommended as skin trauma may lead to increased bacterial counts.
 - Clipping hair the day before surgery is associated with higher bacterial counts due to skin trauma and thus this practice should be avoided.
 - All hair should be removed from the animal and prep site with a vacuum.
 - For rodents, sticky tape may be used to remove hair instead of using a vacuum by pressing the tape to the clipped hair.
- It is recommended that gloves be worn for the following steps to minimize contamination from the technician's hands.
 - Perform a preliminary scrub to reduce the contamination load prior to starting the formal aseptic prep.
 - Aseptic Surgical Preparation of the skin

- A typical scrub consists of an application of chlorhexidine, povidone iodine scrub soaked gauze sponges followed with a wipe with 70% isopropyl alcohol, or sterile water soaked gauze sponges.
- With oily or dirty skin, an initial wipe with 70% isopropyl alcohol may be performed to remove oils and reduce surface tension.
- Remember that the evaporation of alcohol may cause a significant loss of body heat, particularly in rodents and neonates. This can be reduced by heating the containers of prep solution in a 100-105 F° hot water bath.
- Alcohol soaked gauze sponges should be damp but not dripping wet.
- Warm sterile water or saline may also be used instead of alcohol
- This scrub should be performed 3-5 times.
- Each scrub should begin over the incision site and follow a concentric circle away from the incision site. Never return to the incision site or previously cleaned area with the same gauze sponge once you reach the outermost area.
- When surgically preparing a limb, it may be useful to tape the foot to an IV stand and suspend it for prepping.
- When the final scrub has dried, apply povidone iodine or chlorhexidine solution to the surgical site.
- Normally a final surgical site preparation is performed after the animal is moved to the operating room and placed in proper recumbency.
- A povidone iodine or chlorhexidine film antiseptic system (i.e., 3M DuraPrep 0.7% iodine povacrylex and 74% isopropyl alcohol) or ChloraPrep (2% chlorhexidine gluconate in 70% isopropyl alcohol) may then also be applied to the skin.
- Allow an antiseptic solution to dry prior to sterile draping.

Section 4.3: Surgical Mindset

- If there is a question as to whether a step has been performed incorrectly, assume that it was and start over.
- If there is suspicion that a prepped surgical site may have become contaminated, re-do the entire prep.
- If there is suspicion that a drape in the operating field has become contaminated by contact with non-sterile material replace it or, if this is impractical, cover the suspected contaminated area with a new sterile drape.
- If there is suspicion that an instrument is contaminated remove it from further use and request a sterile replacement.
- If there, is suspicion, that a sterile glove has been perforated or contaminated, discard it and aseptically don a new sterile glove(s).

Section 4.4: Surgical Positioning

- The surgeon(s) should direct appropriate positioning of the animal on the table.
 - Surgeons often have specific animal positioning requirements that allow them to better visualize the surgical site. This will vary from surgeon to surgeon.
- Positioning is named by the part of the body in contact with the table:
 - Right lateral recumbency = animal laying on its right side.
 - Dorsal recumbency = animal lying on its back.
 - Sternal or ventral recumbency = animal lying on its sternum.

- The animal may be kept in place with the aid of sandbags, troughs, rolled towels, “beanbags”, limb ties, or incisor clips (for rodents).
- Care should be taken that limb ties do not occlude normal blood flow.
- For limb prepping and positioning:
 - Prior to prepping, the foot should be wrapped in VetWrap or similar.
 - When brought into the OR, the limb should be suspended from an IV pole and then prepared.
 - The suspending tape should be cut close to the limb and a sterile stockinette placed on the foot and unrolled towards the body.
 - The wrapped limb may be passed through a hole in the sterile drape.
- The limb can then be wrapped in SteriDrape™. Stereotaxic positioning:
 - For procedures where skull stability is important the animal may be placed in a stereotaxic frame device. **Note:** Care must be taken to ensure that nose clamp and ear/jaw bars are not too tight and cause nares occlusion/trauma or eardrum/jaw/skin trauma.
 - Difficult to maintain sterility as the horizontal slides must be accessible for movement of the manipulator arms yet must be used during positioning of the animal prior to creation of the sterile field. Wrapping the frame in stockinette prior to sterilizing helps. Holes are cut to allow insertion of the ear bars. Once the animal is positioned, the stockinette is cut off and the animal is draped.

Section 4.5: Aseptic Draping & Sterile Field Maintenance

- When the animal is properly positioned and aseptically prepped for surgery, a sterile field is created by strategic aseptic placement of sterile drapes to isolate the sterile "working" field.
- Generally, a sterile field should be large enough to prevent accidental contamination of the incision site(s), operating team, and sterile instruments and equipment.
- Sterile drapes can make it difficult to physically monitor respiratory and cardiovascular (CV) functions during surgery, which underscores the necessity of engaging electronic monitoring as a safety net whenever possible.

Note: In some cases, especially with larger animals, practical use of a Mayo stand or overhead table strategically positioned above the animal to isolate the head and neck regions can serve to benefit both surgeons and anesthetists in providing the necessary aseptic surgical isolation and tray utilization via sterile draping for surgeons while permitting visualization and good working room for head and neck access for the anesthetist, which in turn will not interfere with routine surgical asepsis.

- **Rodent:**
 - At a minimum, a sterile fenestrated drape whose opening reveals only the surgical site is recommended.
 - Commonly the drape covers the entire animal.
 - Clear plastic adhesive surgical drapes may also be used.
 - A table drape may also be placed prior to positioning the animal on the table to enlarge the field.

- **Non-Rodent:**

- At a minimum, a sterile fenestrated drape sufficient to cover the animal and surgical field is recommended.
- Sterile cloth or paper drapes may be used and should cover all areas except those immediately adjacent to the incision site(s).
- Towel clamps or sterile surgical staples may be used to affix the drape(s) in place.
- A sterile plastic adhesive incise drape (e.g., 3M Steridrape) may be placed over the drape fenestration extending the field to the edge of the incision and limiting possible contamination.
- Sterile bandaging patches (e.g., Tegaderm) are more conveniently sized and may be used instead.
- Equipment such as drill cables, fluoroscopic C-Arms, and imaging equipment that cannot be sterilized and will be in the surgical field should be draped or covered with sterile sleeves.
- It is convenient to sterilize light handles or provide sterile covers so that sterile personnel can adjust operating lights during surgery.

Section 4.6: Surgical Personnel Attire & Preparation

Section 4.6.1: Attire & Operating Personnel Preparation

- Street clothes, especially shoes, are a major source of contaminants.
- Street clothing should be replaced with clean scrubs for all personnel working within the OR
- Recommended to tuck scrub tops into pants to reduce the dispersion of skin debris.
- During hair clipping and prep a clean lab coat or Tyvek coverall can be worn to protect the scrubs. This is especially important when working with rabbits. Alternatively, a link roller can be used to remove fur from scrubs prior to entering the OR.
- Street shoes should be replaced with sanitized OR-specific shoes or covered with shoe covers.
- Safety glasses are recommended and are mandatory for nonhuman primate surgery.
- Surgical caps/hair nets should be worn to prevent contamination from shedding hair. If hair is longer than shoulder length, it needs to be secured with hair pins/elastic so that it stays under the hair net.
- Facial hair should also be covered.
- Surgical masks should be worn to filter expired air.
 - Masks are short-term filters only and should be replaced between surgical procedures.
- Exam gloves are helpful to minimize skin contaminants.

Section 4.6.2: Surgeon Scrub

- **Scrub With An Antiseptic Soap** (e.g., Chlorhexidine, Povidone Iodine)
 - Removed all jewelry including wristwatches.
 - Fingernails should be clipped short to prevent tearing gloves and decrease bacterial load under nails.
 - Antiseptic solutions work by contact over time.
 - Scrub should take ~10 minutes (~5 minutes per cycle) to allow sufficient time for the antiseptic scrub to work.

- Hands should be kept higher than elbows during the entire process to maintain drainage from without trouble to elbows.
- Once the scrub is begun, hands and forearms should only touch sterile surfaces.
- If you have a hand or finger wound, aseptically scrub appropriately, aseptically dry and then cover to isolate wound with an appropriate sterile bandage.
- If there are any breaks in technique during the surgeon scrub process, start over.
- **Typical Scrub Protocol Examples:**
 - Wet hands and forearms.
 - Apply antiseptic scrub to both hands and forearms.
 - Use brush to scrub under nails, sponge to scrub skin
 - Scrub hands first, followed by forearms.
 - Perform one cycle at a time: scrub, rinse and repeat cycle for up to 10 minutes.
- **Anatomical (Column) Scrub:**
 - Scrub each skin surface (four sides of fingers, top of hand, etc.), ten to fifteen times.
- **Timed Scrub:**
 - Scrub each surface for a set amount of time (~5 minutes per cycle).
 - Some research suggests that a final covering with the antiseptic soap prior to toweling dry enhances antimicrobial activity during surgery
- **Aseptic Towel Drying Of Hands:**
 - Dry hands with a sterile towel.
 - Use opposite corners for each hand so that if one hand is unknowingly contaminated the contaminants are not transferred to the other hand.
 - Keep hands and forearms well away from scrubs and any non-sterile surfaces.
 - Hands are clean but not sterile and thus should be considered to contaminate any sterile objects that they touch.



Section 4.6.3: Aseptic Gowning

- Sterile gowns should only be handled by inside surfaces to not contaminate the outside of the gown.
- Gowns may be picked up by the collar or the inside shoulder seams.
- If required, gently shake the gown to allow it to unfold completely.
- Slip arms into sleeves.
- Do not allow hands to protrude from the cuffs.
- For batch surgeries of rodents - Consider wearing the same sterile gown for multiple surgeries or wearing sterile Tyvek sleeves with intermittent change out after each batch.
 - Requires greater attention to possible instrument or device contamination by touching non- sterile areas, skin or scrubs.

Section 4.6.4: Aseptic Gloving

- **Closed Gloving:**

- Recommended method as it minimizes chances for contamination
- Lay the glove on the cuff above the palm of the hand with the thumb side down and fingers towards the elbow.
- Grasp the palm side of the glove through the cuff.
- Grasp the top side of the glove with the other hand through the cuff.
- Pull the cuff of the glove over the cuff of the gown.
- Advance fingers past the cuff and into the glove.
- Pull the glove cuff as far down the sleeve as possible - If performed properly, the cuff of the gown should cover the back of the hand to the fingers under the glove.
- Repeat steps 1-4 with the other hand.

- **Open Gloving:**

- Open gloving is useful when performing multiple rodent surgeries.
- Open gloving may be used for changing gloves but has a much greater risk of contamination
- Extend hands from sleeves.
 - Contamination risk may be lessened by keeping the fingers of the assisting hand below the gown cuff.
- Grasp the inside of the glove's cuff with the assisting hand.
- Pull glove over the hand and gown sleeve.
 - Do not un-roll the glove cuff.
- Slip the gloved fingers beneath the cuff of the other glove.
- Slide hand into new glove and pull over hand and sleeve.
- Taking care not to touch contaminated surfaces, unroll the glove cuffs over the gown sleeves.
- Adjust the glove as needed.

- When changing gloves during a procedure, it is preferable to have a sterile assistant put the gloves on the surgeon rather than open glove.
- Wipe gloves free of powder after donning.

Section 4.6.5: Aseptic Techniques

- **Sterile Surgical Packs:**

- Non-sterile personnel should open the outer wrap, taking care not to contaminate the inside of the outer wrap or the inner wrap. Non-sterile personnel should not lean over the sterile inner wrap.
- Sterile personnel should open the inner wrap and either use the inner wrap as part of the sterile field or remove the instruments from the pack.

- **Surgical Sleeves Or Foil Packs:**

- Non-sterile personnel should open these using an aseptic hand-off technique to the surgeon.
 - Sleeves and foil packs should not be opened directly over the sterile field, sterile personnel can remove the item from the sleeve or the non-sterile person can drop it onto the sterile instrument table field.

- **Sterile Fluids**

- When opened, fluid should be poured from the bottle into a waste basket to flush possible contaminants from the bottle mouth rim.
 - Sterile personnel can pass the bowl under the stream until the bowl is filled.
 - Fluid should continue being poured until the bowl is removed from the stream; this prevents draining of fluid along the non-sterile outer surface of the bottle into the sterile bowl.
- Fluids can be taken from a bottle or bag with a septum using a needle and syringe.
 - Wipe the septum clean with a 70% Isopropyl alcohol wipe.
 - A non-sterile person should hold the bottle or bag at a downward angle.
 - The sterile person pushes the needle through the septum and aspirates fluid.
 - The needle is potentially contaminated and should be discarded.

Section 4.6.6: Breaches in Aseptic Techniques

- If the drape becomes contaminated, cover with fresh drapes.
- If a glove or gown is or becomes damaged or punctured, replace it immediately; evaluate any instruments that might have been handled for contamination.
- If the incision site becomes contaminated, remove visible contaminants and lavage with large quantities of sterile isotonic fluid.
 - Subsequent irrigation with povidone iodine or chlorhexidine solution may be helpful.
 - In any of these cases or when a break is discovered after the procedure is completed, antibiotics may be used after consultation with a veterinarian.
 - Pay careful attention to the animal for 2-3 weeks post-surgery and observe for any signs of infection such as erythema, swelling, signs of pain and/or discomfort, abnormal discharge, loss of function and inappetence or reduced urine/fecal output along with any abnormal behavior.

Section 4.6.7: Rodent Surgical Techniques

- Rodents such as mice and rats can develop infections.
- Rats are the most common model for infection in antibiotic testing.
- Small incisions, quick surgeries, and a good immune system coupled with a fast metabolism may allow less stringent aseptic conditions.
- Attention to aseptic technique is still required.
- Sterile gloves, drapes, and surgical preps are recommended.
- Sterile gowns or sleeves may be useful.

Section 4.6.8: Operating Room (OR) Conduct

- **Behavior in the OR:**

- The number of personnel in the OR should be kept to a minimum.
- Unnecessary movement disturbs air currents and can increase airborne contaminants.
- Traffic in and out the OR should be kept to a minimum
- Non-sterile objects such as equipment and non-sterile gloved hands should not be passed over sterile fields.
- Non-sterile personnel should avoid sterile areas.
- Attention should always be paid to the maintenance of a sterile field.
 - All personnel should always be watching for and bringing attention to any compromise in sterility/aseptic technique.
 - When passing other sterile personnel, pass back-to-back
- When not using them, surgeons must keep hands above waist level.
 - Clapping the hands reduces the chance of inadvertently brushing them against a non-sterile object
- Consider everything below the level of the table non-sterile.
 - This includes gown portions, equipment cables, suction hoses, dropped instruments, etc.
 - Only the front of the gown from above the waist to the shoulders is to be considered sterile.
- Instruments which purposefully (i.e., scissors cutting drapes and those coming into contact with the contaminated underside) or accidentally (i.e., dropped off the sterile field) become contaminated should be immediately discarded from the sterile field and the sterile surgical table.

Section 4.6.9: Standard Operating Room Conduct

- The OR team should always face the sterile field and never turn their backs to sterile surfaces.
- Surgeons should sit only when the entire surgical procedure will be performed seated.
- Surgeons should not touch or lean over non-sterile surfaces.
- Arms and hands should remain in front of the gown, below the shoulders and above the waist. Never fold arms, hands may be clasped in front.
- Surgeons should remain close to the surgical field & not move around.
- Gown sleeves are considered sterile from 2 inches above the elbow extending down to the cuff.
 - The back of the gown is considered non-sterile
- Anything below the edges of instrument or surgery table tops are considered non-sterile.
 - Do not touch anything below the level of the waist or instrument or surgery tables.
- Surgeons should not lean against the OR table, walls, or other instrumentation.
- Sterile instruments should never fall below edge of sterile OR table.
 - Lift instruments up - do not drag them.
 - If any doubt exists regarding sterility of an instrument or item, consider it contaminated.
- All used sponges or disposables should be dropped in kick buckets and not placed on the OR table drapes or back on top of the sterile instrument table.
- Keep all sterile surfaces dry.

- **During Surgery Avoid Excessive:**

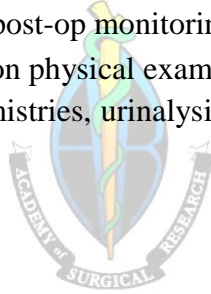
- Movement: human or other (shaking drapes, towels etc.).
- Traffic: In and out of the operating room.
- Talking (proportionally increases contamination potential).
- Limit the number of people to a minimum (room size dependent to avoid increasing activity as described above).
- Do not leave sterile field unattended.
- Keep door closed at all times and limit transit.
- Non-scrubbed staff should follow all general guidelines for OR conduct mentioned above and stand aside to allow scrubbed staff to pass.
 - Pass in back of and never in front of scrubbed-in surgeons and staff.
 - Never pass between the scrubbed-in staff, the sterile field or sterile areas and never reach over a sterile field or sterile area.
 - Never lean over, against or touch sterile areas.
 - Face sterile fields to reduce risk of accidental contamination.



Part 5: Peri-Operative Care

Section 5.1: Pre-Anesthetic Evaluation

- A thorough history should be recorded and a complete physical exam performed before anesthesia.
- The purpose of the pre-anesthetic evaluation is to determine a patient's physical status.
- Physical status refers to the presence or absence of disease, severity of pain (if present) and the level of stress; specifically, the patient's medical condition and the overall efficiency and function of organ systems.
 - The goal is to determine any deviations from the norm that will affect anesthetic uptake, action, elimination and safety.
 - Nervous, cardiopulmonary, hepatic, and renal systems are the most important.
 - The information is used to determine what drugs should be administered and approximate dosages.
- A physical exam should include:
 - Attitude, physical condition, conformation and temperament.
 - Palpation, percussion and auscultation.
 - Parameters such as heart rate (HR), respiratory rate (RR), temperature, capillary refill time (CRT), mucous membrane color (MM), and quality of pulse should be collected/evaluated. These values will also provide baselines for intra-op and post-op monitoring.
 - Laboratory tests should be done based on physical exam and history findings. Common tests include:
 - Complete blood counts, blood chemistries, urinalysis, blood gases, clotting time and platelet counts, ECG, and radiography.



Section 5.2: Fasting

- Generally for 12-18 hours in most species with water available ad libitum.
- Not advised in small mammals, birds, and neonates, which may become hypoglycemic.
- Fasting is not generally necessary in rabbits, rodents and ruminants.
- Rumen tympany can be prevented by passing a stomach tube.
 - If fasting is required for a specific procedure, ruminants need to have food withheld for 24-48hrs and water withheld for 12-24hrs.
 - Use shorter times for small ruminants and longer times for large ruminants.
 - Do not fast neonates as they are not “true ruminants” yet.
 - Prolonged fasting, combined with anesthesia, can result in rumen stasis

Section 5.3: Fluid Therapy

- Surgical anesthesia and procedures may lead to dehydration.
- Fluids are usually administered IV, but can also be given SC, orally, or IO (intra-osseous).
 - IO administration is used in cases of severely dehydrated or traumatized patients with poor or inaccessible veins/arteries that need rapid fluid absorption into the blood.

- Administration of IV fluids during anesthesia helps maintain adequate blood pressure (BP), body temperature, and urine production while providing an available route for drug administration.
- Fluids should be warmed ($\sim 37^{\circ}\text{C}$) to prevent hypothermia.
- Common maintenance rate for Lactated Ringers Solution/Isotonic saline is 5-10 ml/kg/hr.
 - 10-15 ml/kg/hr should be used for procedures that involve opening a major body cavity, or may result in excessive bleeding.
 - Higher rates are recommended for ruminants due to hyper-salivation.

Section 5.3.1: Crystalloid Solutions

- Any solution of crystalline solids that are dissolved in water.
 - **Lactated Ringers Solution**
 - Closely approximates electrolyte concentrations of extracellular fluid.
 - Is isotonic so that it does not induce fluid shifts.
 - Since it is isotonic it will not replace blood loss on a 1:1 basis, will “replace” blood on a 3:1 basis.
 - May be administered rapidly in large volumes to re-expand the extracellular fluid volume.
 - **Isotonic Saline (0.9%)**
 - Does not meet free water and electrolyte needs for maintenance purposes.
 - May lead to dilution of extracellular electrolytes and buffers with excessive use
 - May be used to correct hyponatremia (low sodium concentration in the blood) or metabolic alkalemia.
 - **Hypotonic Saline (0.45%)**
 - May be used as a hydrating solution.
 - May be used for maintenance purposes when supplemented with dextrose, potassium chloride, or both.
 - Becomes isotonic when supplemented with 2.5% dextrose.
 - **Hypertonic Saline (3% - 5%)**
 - Promotes rapid sodium replenishment (hyponatremia).
 - Useful in management of shock (esp. hemorrhagic).
 - 4-6 mL/kg of 7.5%
 - Should be given IV.
 - **Dextrose Solutions (2.5% - 50%)**
 - Provide source of free water for dehydration treatment.
 - Not effective as plasma expanders.
 - Hypertonic dextrose solutions may be used as a caloric supplement.

- **Sodium Bicarbonate**

- Hypertonic solution of sodium bicarbonate in sterile water for injection.
- Treats metabolic acidosis.
- Produces sodium retention, so use cautiously in patients with congestive heart failure or edema.

Section 5.3.2: Colloidal Solutions

- Suspensions of large molecular weight particles, which tend to remain within the vascular compartment.
- Increases intravascular colloid osmotic pressure, which decreases further water movement out of the intravascular space, and may draw water from the interstitial space into the intravascular space.
- Used to expand vascular volume or treat acute hypo-proteinemia.

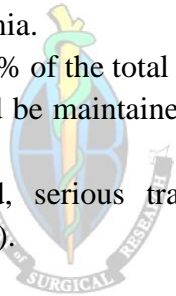
Examples:

- **Plasma**

- Used fresh to treat coagulopathies (canine plasma may be stored at 2°C for up to 30 days).
- Stored at -70°C, can be used to treat vascular volume deficits or hypo-proteinemia.
- Must be gradually thawed and warmed to 37°C prior to infusion.

- **Whole Blood**

- Should be used to treat severe anemia.
- Treat blood loss greater than 10-15% of the total blood volume.
- Peri-operatively, hematocrit should be maintained above 21-25% to ensure adequate delivery of oxygen (O₂) to peripheral tissues.
- If blood types are not matched, serious transfusion reactions can occur (hemolysis or agglutination depending on species).



- **Dextran Solutions**

- Low to average molecular weight polysaccharides produced from bacterial enzymatic action on sucrose.
- Can be used for vascular volume expansion when blood products are not available.
- Have no O₂ carrying properties and care must be taken to not reduce hematocrit to critical levels.

- **Hetastarch (Hydroxyethyl Starch)**

- Increases the volume of blood plasma that can be lost from bleeding or severe injury.
- Hydroxyethyl ether groups are added onto the glucose groups of amylopectin starch.
- Non-pyrogenic solution of 6% Hetastarch in 0.9% saline.
- Comprised of polymers ranging from 10,000 to 1,000,000.
- The smaller polymers are eliminated through the kidneys (40% within 24hrs), while the larger molecules are slowly degraded by serum amylase until they are small enough to be excreted.
- This results in a sustained ability to maintain vascular volume as compared to dextran solutions.

Section 5.4: Airway Management

- Safe anesthesia includes assuring the patients' airway remains patent with adequate ventilation and oxygenation.
- Supplemental O₂ may need to be provided during the pre-anesthetic, induction, maintenance, and recovery phases via face mask, nasal cannula, flow-by, O₂, tenting or chamber:

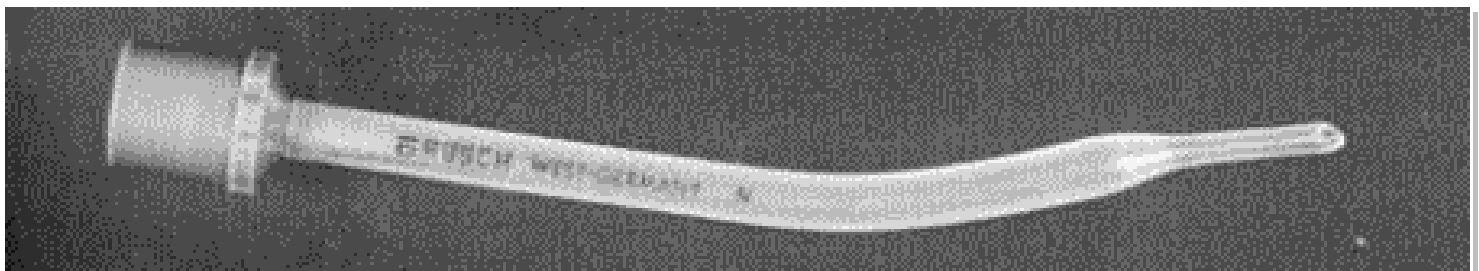
Section 5.4.1: Face Mask

- Low-tech method used to deliver gas (O₂, inhalant anesthetics, etc.) to the animal's respiratory system and not to the general environment.
- Does not provide an air tight seal and allows leakage of inhalant anesthetics into the surrounding environment, providing a source of exposure to personnel.
- Does not protect the patient's airway and will allow aspiration and obstruction to occur.
- Does not allow use of positive pressure ventilation.

Section 5.4.2: Endotracheal Tube

- Maintains a patent airway, protecting against both aspiration and obstruction.
- Protects airway from foreign material during oral surgery and dental procedures.
- Allows use of positive pressure ventilation.
- Effective delivery of O₂, inhalant anesthetics, and test compounds.
- If cuff is properly inflated, provides air tight seal
- Provides easy access to perform suction of trachea or bronchi.
- Decreases anatomical dead space if the tube is of correct size.
- May be made of polyvinyl chloride, silicone, plastic, or rubber.
- Red rubber not recommended due to a propensity for cracking, difficulty in cleaning, and opacity; other materials are less porous, more durable, and clear, allowing for visualization of condensation.

○ Cole Endotracheal Tube



- Un-cuffed.
- Has a “shoulder” that leads to a thinner tip.
- Shoulder should “sit” against the arytenoid cartilages, forming a “seal.”
- Only the smaller portion of the tube (the tip) should be passed into the larynx and trachea.

- Shoulder should not enter or contact the larynx to avoid pressure on laryngeal cartilages and cause laryngeal dilation.
 - Choice of a proper diameter (laryngotracheal portion of tube) should create a seal, provided that it remains positioned properly.
 - Movement of the tube in either direction can either cause damage (too deep) or result in an improper seal (too shallow)
- **Murphy Endotracheal Tube**
 - Cuffed.
 - Has an opening, called a Murphy eye or side hole, in the wall opposite the bevel, which allows gas flow even if the end hole is occluded.
 - Provides a better seal than the Cole tube and does not require as precise placement.
 - The cuff should be inflated with the smallest amount of air that will create a seal at an airway pressure of 15-20 mmHg, depending on whether or not positive pressure ventilation is planned.
- **Cuff Inflation**
 - The proper technique of inflating the cuff is to inject air into the cuff while listening for leakage of air while the reservoir bag is squeezed to provide a pressure reading of 15-20 mm Hg in the airway. Infusion of air should stop as soon as the passage of gas is no longer heard.
 - Over inflation of the cuff can cause it to rupture or cause trauma to the airway (ischemic injury, mucosal damage, pressure necrosis, and ultimately tracheal strictures).
- **Other Endotracheal Tube Considerations**
 - Some may be reinforced or armored with wire/plastic to prevent kinking when the patient's head and neck are flexed, or if the breathing tubing needs to be placed off to the side.
 - Reinforced tubes may have smaller interior lumens depending on the brand, which can increase airflow resistance and should not be used unnecessarily.
- **Intubation Procedure (Basic Technique):**
 - Specific procedure will vary for some species.
 - Induce anesthesia (a sufficient depth must be reached to reduce gag reflex).
 - Place animal in an appropriate position (dorsal, sternal or lateral recumbence, depending on the species and individual preference).
 - Dorsal recumbence may be preferred for swine and primates.
 - Open the animal's mouth.
 - An assistant may be utilized to help steady the animal and/or hold the mouth open.
 - Gently pull the tongue forward and out.
 - Care needs to be taken to not pull the tongue out too far, especially in monkeys, or injury can result.
 - Care needs to be taken to not pull the tongue over the lower incisors too hard as this can cut the under surface of the tongue
 - Apply topical lidocaine spray or liquid to the larynx to prevent laryngospasm (optional).
 - Additionally, or alternatively, lidocaine/xylocaine jelly may be applied to the tip of the endotracheal tube.

- Visualize the epiglottis and glottis. In most species, a laryngoscope may be helpful in providing proper visualization. The tip of the laryngoscope blade must be placed at the base of the epiglottis and used to pull the tongue out, not push it down, which would actually hinder visualization. Do not use the blade directly on the epiglottis as this can cause trauma.
- Gauge the appropriate distance to advance the tube prior to intubation by holding the tube, or a second tube of the same size, against the animal so that the tip is at the approximate location of the thoracic inlet, and noting the depth mark on the tube at the level of the animal's incisors.
- Introduce the endotracheal tube into the trachea and advance until the tip is at the approximate level of the thoracic inlet.
- If the tube is placed too deep, the tip could pass into one bronchus, which would interfere with proper ventilation.
- An internal stylet to stiffen the tube may be useful in some species and with silicone tubes, but ensure the stylet does not extend past the distal opening of the tube as injury to the trachea may occur.
- Secure the tube in place (tape, gauze, or rubber bands may be used).
- Inflate the cuff, if applicable, as described above.

○ **Laryngoscopes**

- Useful for visualizing the glottis and allowing easier intubation, preferred by most anesthetists.
- Provides illumination, means for extending/depressing the tongue, and leverage for opening the mouth in NHPs.
- The blade should not be used to directly manipulate the epiglottis as this may cause trauma. If the epiglottis is found to be behind the soft palette (seen in species with long soft palettes like canine and swine), the tip of the endotracheal tube should be used to gently sweep the epiglottis down, not the endoscope blade.
 - **Two styles of blade:**
 - Straight: pediatric and adult sizes (Miller, Wisconsin, and Soper).
 - Curved: pediatric and adult sizes (Macintosh, and Bizarri-Guiffrida).

● **Species Specific Concerns For Intubation**

- **Large Animals (e.g., Horses, Cows, Sheep, and Goats)**
 - Usually are eating prior to induction since they are not normally fasted, so may require flushing of debris from the mouth to allow visualization and to prevent introduction into the bronchi.
 - Lubrication of the tube with water soluble lubricants is helpful.
 - Visualization may be difficult due to the distance from the mouth to the epiglottis.
 - Specially made laryngoscopes may be helpful.
- **Cats**
 - Pressure under the neck will shift the soft palate and obscure the view.
 - Assure proper depth of anesthesia prior to attempting to intubate.
 - Use of benzocaine-containing topical anesthetic sprays to facilitate intubation is contraindicated due to increased risk of methemoglobinemia.

- **Rabbits**
 - Present a very small glottis with difficult visualization from the mouth.
 - Extending the head back is helpful during blind intubation.
 - Carefully observe condensation or listen for breath sounds while slowly advancing tube to guide placement. If condensation stops, slightly back the tube up, redirect until condensation is again visible, and re-advance.
 - Following a guide cannula may be useful.
 - LMA is good alternative.
 - Endoscope guided intubation is extremely successful.
- **Rodent**
 - Small size makes visualization difficult.
 - Using a guide catheter or retrograde guide tube may helpful.
 - Use of an intubation board or table is helpful, along with a specially modified otoscope used as a “laryngoscope.”
- **Swine**
 - Intubation is potentially dangerous due to the false pockets, or “pseudo-pharynx”, which are highly vascularized pouches outside the trachea; if irritated they may bleed profusely.
 - Prone to laryngospasm.
 - Sharp angle from the mouth to the trachea may cause slight resistance to passing the tube.
 - Gently twisting the tube while advancing is beneficial.
 - Lubrication of the endotracheal tube is important; xylocaine gel provides lubrication and local analgesia to help prevent laryngeal spasms.
 - Dorsal recumbency may straighten the pathway for the endotracheal tube and make intubation easier.
- **Ruminants**
 - Will regurgitate rumen when anesthetic depth becomes too light, so prompt intubation is imperative.
 - Once intubated, lower head below chest level and/or place a rumen tube and collection bag.
 - Rumen tube will also prevent rumen distension from gas build up during anesthesia.
- **Alternate Methods of Intubation**
 - **Guide-Tube Technique**
 - Place a thin guide catheter (such as a 5-8 French urinary catheter or appropriate sized cardiovascular guide wire) into the trachea, thread an endotracheal tube over it into the trachea, and remove the guide catheter.
 - The guide-tube/wire should not be forced as the trachea is easily torn.
 - **Tracheostomy (Retrograde Intubation)**
 - After surgically prepping the skin over the trachea, insert a VENICATH style needle and catheter through the skin and into the trachea, proximal to the larynx.
 - Advance the catheter portion into the trachea until it is visible in the mouth.

- Thread an endotracheal tube over the VENICATH into the trachea, remove the VENICATH, and finish advancing the endotracheal tube.
- Secure the endotracheal tube in place.

○ **Laryngeal Mask Airway**



- An alternative to face masks and endotracheal tubes, developed for use in human pediatric patients weighing < 5 kg.
- LMA Unique™ Size 1 is the most commonly used.
- Once inserted properly, the tube lays flat against the laryngeal opening forming a direct end-to-end junction between the upper airway and an artificial tube for supplying gas to the bronchial tree.
- Insert the LMA with the cuff perpendicular to the teeth.
- Once past the teeth, twist the LMA 90 degrees to position the dorsal black line on the tube of the LMA at the midline, with the convex side against the hard palate.
- Continue to advance until unyielding resistance is encountered.
- Over inflation of the cuff could cause lingual cyanosis.
- Good alternative for rabbits.

○ **Endoscopic Guided Intubation**

- Laryngoscopy with a flexible or rigid endoscope can be useful for intubation in patients with abnormal anatomy or pathology.
- Can be placed inside the endotracheal tube to directly guide intubation.
- Can be placed orally beside the endotracheal tube to view the tube entering the glottis.

Section 5.5: Thermoregulation

- Extremely important throughout the entire surgical procedure, including the preoperative, intra-operative and postoperative periods.
- Accomplished via heating blankets (water circulating, warm air blankets) and/or heated tables, warm IV fluids and intra-op fluids (saline); additionally, covered extremities can help maintain body temperature during surgery.
- Most anesthetic agents depress the thermoregulatory centers and metabolism, which leads to accelerated body heat loss.
- Small animals, such as rodents, have a higher surface-to-body weight issue than larger animals, and are therefore more susceptible to hypothermia.
- Normothermic patients tolerate anesthesia better and recover faster.
- Body temperature should be monitored continuously to avoid hypothermia or hyperthermia.
- Hypothermia can interfere with normal platelet activity, blood, and heart rate.

Section 5.6: Post-operative Care & Recovery

Section 5.6.1: Small Animals

- Place in lateral recumbency.
- Vital signs should be recorded at 15 minute intervals until conscious and extubated (non-rodents).
- Rodents should be checked every 15-20 minutes until mobile.
 - If placed into a cage to recover, care should be taken to assure that the animal does not bury its nose against a corner or into the bedding, both of which can occlude the airway.
- Thermoregulation via water circulating heating pads, heat lamps, warm air blankets, or incubator should continue until the animal can regulate its own body temp.
- Turn from left lateral to right lateral recumbence and vice versa every 15-30 minutes to prevent atelectasis and fluid accumulation from developing in the lower lung.
- Remove endotracheal tube when swallowing reflex returns.
- If animal is not intubated, pull tongue forward to preclude blocking the pharynx.
- If animal is returned to home cage, remove water and food pans until animal has recovered.
- IV fluids at a maintenance rate may be continued until the animal is conscious, if recovery is prolonged.
- Oxygen therapy via a mask or nasal O2 is helpful, especially following a thoracotomy.
- Administer post-op analgesics and sedatives as needed.
- Do not place recovering animals with conscious animals as conscious animals may harm unconscious animals, especially with pigs, mice, and rats.

Section 5.6.2: Large Animals (Livestock)

- Special care needs to be taken with horses and cows as they can severely harm themselves, and personnel, while struggling during recovery.
 - Remove animal to a padded room/stall, if available.
- Bandage and pad all limbs prior to anesthesia and keep in place until recovery is complete.
- Food and water should be removed.
- Oxygen and suction should be readily available.
- Vital signs should be recorded routinely until the return of coughing, swallowing and righting reflexes.
- Ruminants should be maintained in sternal recumbency and have their head held higher than their chest to prevent regurgitation and aspiration of rumen contents.



Part 6: Pre-Anesthetic Agents & Anesthetic Adjuncts

- ▶ Aid in handling the patient by reducing stress/anxiety and inducing sedation.
- ▶ Provide analgesia and muscle relaxation.
- ▶ Decrease airway secretion and salivation.
- ▶ Obtund autonomic reflex responses.
- ▶ Decrease gastric fluid volume and acidity.
- ▶ Suppress/prevent vomiting.
- ▶ Decrease anesthetic requirements.
- ▶ Promote smooth induction and recovery from anesthesia.

Section 6.1: Anticholinergics

- Block certain acetylcholine (neurotransmitter) receptors.
- Reduce secretions (oral and respiratory).
- Prevent vagal inhibition (bradycardia) and gastrointestinal stimulation (inhibits intestinal peristalsis).
- Reduce vagus nerve response (vomiting and laryngospasm).
- Relieve cholinergic mediated bronchoconstriction and promote bronchodilation.
- Dilate pupils and reduce tear secretions.
- Treatment of choice for opioid, xylazine, and vagal reflex induced bradycardia.
- Cause sinus tachycardia, which is problematic for patients with CV disease.

• **Atropine Sulfate**

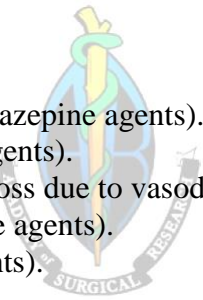
- Decreases oral, respiratory, and pharyngeal secretions.
- Increases anatomic and physiologic respiratory dead space.
- Suppresses vagal influence on the heart.
- Decreases lacrimation.
- Produces long lasting mydriasis and cycloplegia.
- Increases incidence of cardiac dysrhythmia and sinus tachycardia in dogs.
- Contraindicated with tachycardia, constipation, and obstruction.
- May cause thick mucus secretions in cats.
- Rabbits may have atropine esterase, which destroys large amounts of atropine and limits effectiveness.
- Repeated doses should not exceed a total dose of 2 mg.
- Not recommended in ruminants due to increased saliva viscosity, short duration, and the increased incidence of bloat.

- **Glycopyrrolate**

- Synthetic quaternary ammonium muscarinic antagonist.
- Decreases volume and acidity of gastric secretions, intestinal motility, and tracheal, bronchial, and pharyngeal secretions.
- Prevents bradycardia caused by vagal reflexes or other pre-anesthetic/anesthetic drugs (alpha 2-agonists and opioids).
- Reduced diffusion over blood-brain and placental barriers in comparison to atropine
- Lasts longer than atropine sulfate.
- Effective in rabbits.
- Lasts longer than atropine but has a longer onset of action in ruminants.

Section 6.2: Tranquilizers

- Relieve anxiety.
- Reduce need for restraint.
- Quiets and calms the animal.
- Decreases anesthetic dosages.
- Reduce vomiting.
- Have no analgesic effects.
- Recovery from anesthesia may be smoother.
- Reduce histamine release (allergy).
- Promote skeletal muscle relaxation (benzodiazepine agents).
- May promote vasodilation (phenothiazine agents).
- May cause hypotension and excessive heat loss due to vasodilation.
- May lower seizure thresholds (phenothiazine agents).
- Act as anticonvulsants (benzodiazepine agents).



- **Acepromazine maleate**

- Phenothiazine derivative.
- Potent neuroleptic agent with low toxicity.
- Decreases anesthetic requirements in most species.
- Decreases stroke volume, cardiac output (CO) and mean arterial pressure (MAP) by 20-25%.
- Lowers incidence of opioid induced vomiting when given 15 minutes before administration.
- Total dose in dogs should not exceed 3 mg.
- May reduce or prevent malignant hyperthermia in swine.

- **Droperidol**

- Butyrophenone tranquilizer.
- Alpha-adrenergic antagonist.
- May prevent epinephrine induced dysrhythmia.
- Decreases barbiturate doses.
- Primarily used as a component of Innovar-Vet in a mixture with fentanyl (extremely effective combination).

- **Diazepam (Valium)**
 - Benzodiazepine.
 - Anticonvulsant.
 - Rapidly passes blood-brain and placental barriers.
 - Should be injected slowly to prevent venous thrombosis, pain, and cardiotoxicity.
 - Not recommended for intramuscular injection (painful).
 - Potentiates the action of most anesthetics and opioid analgesics.
 - High doses cause slight decrease in respiration, BP, and CO and increase HR.
 - Relatively low toxicity.
 - Care should be used when mixing with other agents due to possible precipitation.
 - Safely combined with ketamine as an induction agent in dogs.
 - Sedation varies between species.
 - Unreliable (variable) sedation in dogs (may actually cause excitement and sedation).
 - Marked sedation in rabbits, rodents, sheep, and pigs.
 - Provides good muscle relaxation.

- **Midazolam**
 - Benzodiazepine.
 - Anticonvulsant.
 - Excellent sedation and muscle relaxant in ferrets, rabbits, swine and birds.
 - Shorter duration of action and clearance than diazepam.
 - May cause behavioral changes in dogs and cats.
 - Pacing, vocalization.
 - Nonirritating and suitable for IM injection.
 - Can be mixed with other pre-anesthetic agents.

- **Reversal agent for Benzodiazepines: Flumazenil.**
 - Reverses CNS action (sedation) of benzodiazepines.
 - Rapid action 24 minutes.
 - Specific antagonistic action.
 - Reversal is not accompanied by anxiety, tachycardia, or hypertension.

Section 6.3: Opioids

- Opioids are analgesics that will depress the CNS and lower the amount of anesthetic agents required.
- Cornerstone of pre-emptive pain treatment in veterinary medicine.
- Will not cause unconsciousness at therapeutic doses.
- Can be addictive.
- Most are controlled substances and require extensive documentation per DEA regulations.

- **Opioid Side Effects:**

- Emesis, except in horses, rabbits, ruminants, rodents and swine. Rarely seen in the immediate postoperative period.
- Hypothermia in most species but may cause hyperthermia in cats, horses, swine, and ruminants.
- May cause excitement and hyperactivity in cats, horses, goats, sheep, pigs, and cows.
- Depresses the cough center and respiratory system.
- Mydriasis in species that exhibit excitation, and meiosis in those becoming sedate after opioid administration.
- Bradycardia can occur via vagal stimulation.
- Stimulates defecation in dogs initially then predisposes to ileus and constipation.
- Can cause urinary retention.

- **Morphine sulfate**

- Major pharmacologic effect is analgesia.
- Useful analgesic in dogs, cats, horses, and rats.
- Induces a rapid and marked increase in serotonin synthesis.
- Depresses respiratory, cough, and vasomotor centers.
- Does not affect motor function.
- Decreases basal metabolic rate and body temp.
- Stimulates the vomiting center.
- Causes variable effects on the brain in some species (excitement).
- Metabolized in the liver and eliminated in urine.
- Used infrequently in ruminants and swine in the clinical setting.

- **Meperidine hydrochloride (Demerol, Pethidine)**

- Analgesic effect 1/10th that of morphine.
- Rapidly excreted, lasting < 1 hour.
- Reduces salivary and respiratory secretions.
- Does not cause vomiting.
- Rapid IV administration not recommended (may cause hypotension & convulsions).
- SC administration 30 minutes prior to anesthesia.
- Has “notable” local anesthetic ability.

- **Methadone hydrochloride (Methadone, Dolophine)**

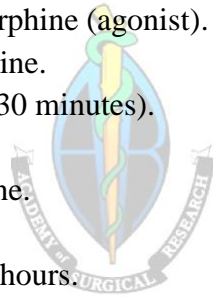
- Synthetic opioid unrelated to morphine.
- Reversed with opioid antagonist.
- Stimulates respiration rate.
- Analgesia lasts 2 to 6 hours.
- Decreases barbiturate dose by ~50%.
- Not commonly used in North America for peri-operative period.

- **Oxymorphone hydrochloride** (Numorphan)
 - Synthetic opioid comparable to morphine in its analgesic efficacy and duration of action.
 - 10 times more potent than morphine.
 - Decreases barbiturate dose by ~33 - 66%.
 - Can be used to provide effective epidural analgesia.
- **Hydromorphone (Dilaudid)**
 - Synthetic opioid.
 - Similar efficacy, potency, duration and side effects to oxymorphone.
 - Less expensive and more available than oxymorphone.
 - Sedative/restraining agent, analgesic, and pre-anesthetic.
 - Commonly used in dogs, cats and nonhuman primates.
 - May cause hyperthermia, ataxia, hyperesthesia, and behavioral changes in cats.
- **Fentanyl citrate**
 - 250 times more potent than morphine.
 - Rapid onset of action.
 - Short duration with peak at 30 minutes.
 - Depresses respiration and may persist for hours.
 - CV stability is excellent.
 - Causes vagal mediated bradycardia unless countered (atropine).
 - Due to shorter action, commonly administered as a continuous infusion.
 - May be used in combo with benzodiazepine to induce general anesthesia in canine patients with CV instability.
 - Available in a transdermal patch.
- **Carfentanil citrate**
 - 10,000 times more potent than morphine.
 - May be administered by applying to buccal or nasal mucosa.
 - Used primarily for capture of wild animals.
- **Sufentanil**
 - Thienyl analog of fentanyl.
 - 5 to 10 times as potent as fentanyl.
 - Elimination half-life is 2 to 2.5 hours.
 - May induce bradycardia.
 - Provides unpredictable anesthesia, bradycardia, hypoventilation, and poor muscle relaxation in dogs when used alone.
 - When combined with potent tranquilizers and glycopyrrolate it is an effective neuroleptanesthetic agent.

- **Alfentanil**
 - 1/5th to 1/10th as potent as fentanyl.
 - Has more rapid onset of action than fentanyl or sufentanil.
 - Oripavine derivative.
 - 80 to 1000 times more potent than morphine (SC).
 - Can be antagonized with nalorphine or diprenorphine.
 - Used primarily for the capture of wild animals.

- **Butorphanol tartrate** (Torbugesic/torbutrol)
 - Synthetic agonist-antagonist opioid.
 - 3 to 5 times as potent as morphine.
 - Less respiratory depression than morphine.
 - Commonly used in combination with xylazine, detomidine (cattle and horses), acepromazine, or midazolam.
 - Antagonizes sedative effects of morphine and oxymorphone.

- **Buprenorphine** (Buprenex)
 - Partial mu opioid agonist.
 - 25 to 30 times more potent than morphine (agonist).
 - Maximum analgesic effect < morphine.
 - Onset of action relatively slow (20-30 minutes).
 - Causes respiratory depression.
 - Reversed by naloxone and naltrexone.
 - IM administration lasts 6-12 hours.
 - Epidural administration lasts 18-24 hours.
 - Mostly excreted unchanged in feces (protein bound).
 - Reaches a “ceiling” where additional doses have little effect.



Section 6.4: Alpha-2-Adrenergic Agonists

- Most widely used class of sedatives in veterinary medicine.
- Produce sedation, muscle relaxation, and analgesia.
- Can be used alone or in combination with opioids to provide sedation for diagnostic and minor surgical procedures.
- In combination with ketamine provides surgical anesthesia for brief, minor procedures.
- Not addictive.
- Act as anticonvulsants.
- Have a wide range of drug interactions.
- Barbiturate, inhalant, and dissociative anesthetic doses should be lowered when used in combination with alpha-2-adrenergic agonists.
- Reversible with alpha-2-antagonists, such as yohimbine and atipamezole.

- **Xylazine hydrochloride (Rompun)**
 - First alpha-2-agonist used in veterinary medicine.
 - Acts as a sedative and analgesic.
 - Most common sedative/analgesic in horses and cattle.
 - Combined with ketamine acts as a short term surgical anesthetic.
 - May be combined with butorphanol to improve analgesia and sedation.
 - Maximum effect occurs in 10 to 15 minutes (IM) or 3 to 5 minutes (IV).
 - Duration of analgesia is < 1 hour.
 - IV administration induces brief period of hypertension and reflex bradycardia followed by longer lasting decrease in cardiac output and arterial pressure.
 - IM administration has less drastic effects.
 - Has poor efficacy in swine.
 - Higher doses prolong effects but do not generally increase the degree of sedation.
 - May cause emesis in cats and dogs.
 - Increases urine output in some species.
 - Causes mydriasis.
 - Excited animals (anxiety, pain) may cause decreased effectiveness.
 - Painful procedures should be limited to 10 to 15 minutes after the onset of sedation.
 - IV overdose or arterial administration may cause seizures and collapse.
 - Can produce 2nd degree heart block.
 - Relatively harmless arrhythmia originating at or below the AV node.
 - Has a significant local anesthetic effect.
 - Epidural administration creates more profound and longer lasting effects than lidocaine.
 - Reduces secretion of insulin in the pancreas, leading to hyperglycemia.
 - Not usually harmful except in dehydrated patients where hyperglycemia can lead to transient osmotic diuresis.

- **Detomidine**
 - Developed originally for use in horses and cattle.
 - Similar CV effects as xylazine.
 - Commonly combined with opioids for enhanced sedation and analgesia.
 - May be used as a pre-anesthetic or combined with ketamine for anesthesia.

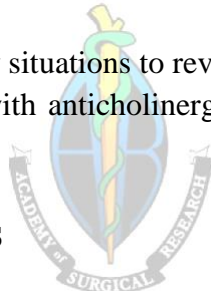
- **Medetomidine**
 - Sedative – analgesic.
 - Developed for use in small animals.
 - Administered IV or IM.
 - More potent and longer lasting than the other alpha-2-adrenergic agonists.
 - Rapid onset of sedation, analgesia and muscle relaxation after IM administration.
 - Decreases injectable and inhalant anesthetic requirements.
 - Decreases urine specific gravity and increases urine production.
 - BP and respiratory rate are decreased in a dose dependent manner.

- **Dexmedetomidine**
 - Twice as potent as medetomidine, and can be used at half the dose of medetomidine.
 - Pre-anesthetic, providing sedation and analgesia.
 - Similar side effects as medetomidine.

Section 6.5: Alpha-2-Adrenergic Antagonists

– Used as reversal agents for alpha-2-agonists.

- **Yohimbine**
 - Reverses xylazine.
- **Tolazoline**
 - Reverses the sedative and CV effects of xylazine in ruminants.
- **Atipamezole**
 - Highly selective alpha-2-receptor antagonist, 200-300 times more selective than yohimbine.
 - Reverses the effects of medetomidine in many species.
 - Administered IM.
 - IV doses may be used in emergency situations to reverse CV effects.
 - Should not be used concurrently with anticholinergics, since both can cause dramatic increases in HR.



Section 6.6: Neuroleptanalgesics

- Combination of a neuroleptic (tranquilizer/sedative) and a potent opioid.
- Used to provide pronounced sedation and analgesia to allow minor surgical procedures.
- Fentanyl citrate/droperidol (Innovar-Vet) is the primary example.
- Induces intense analgesic actions with relatively short durations.
- Produces sedation, analgesia, immobilization, respiratory depression, hypotension, and bradycardia.
- Poor muscle relaxation.
- Provides a wide margin of safety and easy recovery.
- Partially reversed with opioid antagonists.

Section 6.7: Muscle Relaxants & Neuromuscular Blocking Agents

- **THESE AGENTS DO NOT PROVIDE ANALGESIA OR UNCONSCIOUSNESS.**
- Provide superior muscle relaxation as an adjunct to general anesthesia.
- Allow easier intubation and ventilation, improves CV anesthetic management, prevents movement of the eye during ocular surgery, and provides less muscle resistance in long-bone orthopedics and abdominal surgery (reduces anesthesia dose required to minimize tension).
- Are expressly prohibited for use without an anesthetic by *The Guide*.
- Usually require mechanical ventilation due to paralyzed diaphragm and intercostals muscles.

- Create more difficult anesthesia management.
- Twitching, muscle tone, and respiratory signs for maintenance of anesthesia are minimized.
- When paralytics are being used the anesthetist should monitor HR, BP, ECG, and arterial blood gas to gain information on the animal's physiologic state.
- An inadequately anesthetized animal will show signs of tachycardia, arrhythmias, hypertension, and acidosis.
- Mydriasis and lacrimation may be present.
- Horses will sweat if light.
- Anesthesiologist may also monitor the response of a peripheral nerve to an electrical stimulus to monitor the effect of the paralytic.
- Interact with some antibiotics, lithium compounds, local anesthetics, barbiturates, quinidine, propranolol, calcium antagonists, diuretics, immunosuppressant, and corticosteroids.
- Interact with receptors at the neuromuscular junction.
- Interfere with transmission of signal from motor neuron to muscle.

Section 6.7.1: Centrally Acting Muscle Relaxants

- **Guaifenesin** (glyceryl guaiacolate)
 - Used as a muscle relaxant in large animals.
 - Minimal effect on respiratory muscles.
 - May be combined with xylazine, ketamine, thiopental, and pentobarbital.

Section 6.7.2: Depolarizing Neuromuscular Blocking Agents

- **Limited transfer across placenta.**
 - Mimic the action of acetylcholine, by binding to and stimulating the receptor, causing depolarization.
 - Unlike acetylcholine, they are not susceptible to breakdown by acetylcholinesterase.
 - Not antagonized by acetylcholine.
 - Increased amounts of agents at the neuromuscular junction will not prolong the block.
 - Cause initial depolarization of the end plate, which lasts from minutes to hours.
 - Prevent the motor neurons from repolarizing and firing again.
 - Large doses, repeated doses, or prolonged administration may create a phase II block normally seen with non-depolarizing agents.
- **Succinylcholine**
 - Must be refrigerated.
 - Rapid onset.
 - Provides excellent muscle relaxation.
 - Causes marked fasciculation (twitching) for approximately 30 minutes before muscles relax.
 - Rapidly hydrolyzed in plasma by pseudocholinesterase, so only a small amount of the injected amount reaches the neuromuscular junction.

- Effect of the drug is terminated by diffusion away from the neuromuscular junction and into the extracellular fluid.
- Has several undesirable side effects.
- Initial muscle fasciculation and extensor rigidity may cause muscle pain and stiffness and microscopic muscle damage.
- May cause hypertension, tachycardia, sinus bradycardia, cardiac arrhythmias, and cardiac arrest.
- Increased intraocular pressure.
- Increased blood serum potassium.
- Action prolonged by pregnancy and hepatic disease.
- Can be potentiated by inhalation and local anesthetics.
- Cats, swine, and ponies are resistant.
- Increases intracranial pressure (cats and dogs) despite thiopental or pentobarbital anesthesia.

Section 6.7.3: Non-depolarizing Neuromuscular Blocking Agents

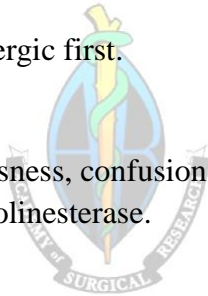
- Compete with acetylcholine for receptors.
 - Do not cause muscle fasciculation prior to paralysis.
 - Are characterized by a progressive weakening of muscle contractions, resulting in flaccid paralysis.
 - Have a slow onset of action.
 - Will have prolonged action if hepatic or renal function is impaired.
 - Large doses or prolonged administration time can result in prolonged effects.
 - **Two categories:**
 - Steroid analogs: pancuronium, vecuronium, pipecuronium, and rocuronium
 - Benzylisoquinoliniums: curare, tubocurarine, metocurine, gallamine, atracurium, doxacurium, and mivacurium.
-
- **Pancuronium**
 - Lasts 40 to 60 minutes.
 - Comparatively long acting.
 - Causes increased HR (vagal blockade).
 - Prolonged administration will result in a difficult reversal.
 - Mostly excreted in the urine, some through biliary excretion.
 - Metabolites have a weak effect.
 - **Vecuronium**
 - No CV effects at normal effective doses.
 - Chemically similar to pancuronium, lacking one methyl group, which removes a positive charge.
 - More potent and shorter acting than pancuronium.
 - Prolonged with renal failure.
 - Does not affect HR.
 - Relatively fast recovery.
 - Widely used.

- **Pipecuronium**
 - Long acting.
 - Twice the duration of pancuronium and 2-4 times more potent.
 - Has a rapid onset of action.
 - May be retained in the kidneys for days.
 - Does not affect HR at up to 100 times the therapeutic dose.
- **Rocuronium**
 - Derived from vecuronium, and is 20% as potent as vecuronium.
 - Primary route of elimination is via metabolism in the liver, with a small amount excreted through the kidneys.
 - Has rapid onset of action.
 - Increased doses hasten onset but will also prolong the duration of activity.
 - Rapid recovery.
- **Curare (d-Tubocurarine)**
 - Long acting.
 - Increases HR.
 - Metabolized in the liver and excreted by the kidneys.
 - Small proportion is excreted in bile.
 - Causes release of histamine.
 - Causes vasodilation, hypotension, and tachycardia.
- **Metocurine**
 - Much improved safety margin over curare.
 - Relies on renal excretion with 2% excreted in bile.
- **Gallamine**
 - Relatively impotent.
 - Long acting.
 - Consistently produces tachycardia.
 - Is the only non-depolarizing relaxant that crosses the placenta.
 - Relies on renal excretion.
- **Atracurium**
 - Must be refrigerated.
 - Unstable molecule, which breaks down by itself at body temperature.
 - pH and temperature dependent (Hofmann elimination).
 - An intermediate muscle relaxant.
 - Not prolonged by renal and hepatic disorders.
 - Widely used.

- **Doxacurium**
 - Long acting.
 - Does not have autonomic side effects.
 - Does not cause histamine release.
- **Mivacurium**
 - Lasts slightly longer than succinylcholine and 1/2 the duration of vecuronium.
 - Does not have autonomic effects.

Section 6.7.4: Reversal Agents

- Have little effect if a large dose of a non-depolarizing neuromuscular paralytic agent has just been administered.
- Best used when spontaneous recovery of muscle strength has begun.
 - **Anticholinesterases**
 - Edrophonium, neostigmine, pyridostigmine.
 - May cause bradycardia, sinus arrest, bronchospasm, miosis, intestinal hyperperistalsis, and salivation.
 - Should administer an anticholinergic first.
 - **4 Aminopyridine and Guanidine**
 - Causes CNS stimulation (restlessness, confusion, and convulsions).
 - Best combined with an acetylcholinesterase.



Part 7: Anesthesia Basics

Section 7.1: Definitions

- **Analgesia:** Freedom from or absence of pain.
- **Local Analgesia:** Loss of sensation in a defined body area.
- **Regional Analgesia:** Loss of sensation to a larger though limited body area than described with local anesthesia (e.g. paralumbar nerve blockade).
- **Anesthesia:** Derived from the Greek “anaesthesia” meaning insensibility, it describes the loss of sensation to the entire or part of the body; a state of controllable, reversible insensibility in which sensory perception and motor responses are both markedly depressed.
- **General Anesthesia:** Drug induced unconsciousness that is characterized by controlled reversible depression of the CNS and analgesia. A patient is not aroused by noxious stimuli in this state. Sensory, motor and autonomic reflexes are attenuated.
- **Balanced Anesthesia:** Induced by a multiple drug approach in which drugs are targeted to specifically attenuate individual components of the anesthetic state (consciousness, analgesia, muscle relaxation, and autonomic reflexes).
- **Dissociative Anesthesia:** a form of general anesthesia, but not necessarily complete unconsciousness, characterized by catalepsy, catatonia, and amnesia, such as that produced by ketamine.
- **Surgical Anesthesia:** The stage/plane of general anesthesia that provides unconsciousness, muscular relaxation, and analgesia sufficient for painless surgery.
- **Tranquilization:** A state of behavioral change, wherein anxiety is relieved and the patient is relaxed, although aware of its surroundings.
- **Sedation:** State characterized by central depression accompanied by drowsiness where the patient is unaware of its surroundings, but responsive to painful manipulation.
- **Narcosis:** Drug induced state of deep sleep from which the patient cannot be easily aroused
- **Hypnosis:** Condition of artificially induced sleep, or a trance resembling sleep, resulting from moderate depression of the CNS from which the patient is readily aroused.

Section 7.2: Types of Anesthesia

- **Inhalation:** Anesthetic gasses or vapors inhaled in combination with O₂.
- **Injectable:** Anesthetic agents administered intravenous (IV), intramuscular (IM), subcutaneous (SC), intraperitoneal (IP), and intrathecal (IT).
- **Oral and Rectal:** Anesthetic agents administered into the gastrointestinal tract (liquid anesthetics or suppositories).
- **Local:** Anesthetic agents topically applied or locally injected into or around a surgical site or a large nerve trunk supplying a specific region.
- **Electronarcosis:** Passing an electric current through the cerebrum to induce deep narcosis.
- **Transcutaneous Electric Nerve Stimulation:** (TENS, TNS, TES) Local analgesia induced with low intensity, high frequency electric stimulation of the skin via surface electrodes.

- **Acupuncture:** An ancient Chinese system of analgesia using fine needles inserted at defined locations.
- **Hypothermia:** Local or general body temperature lowered to supplement anesthesia and decrease analgesic drug administration (primarily used in neonates and CV procedures).

Section 7.3: General Anesthesia

- Is a reversible process.
- Dosed based on the “average, normal, healthy” animal.
- Modified based on experience and the individual animal’s responses.
- Response relies on metabolism, uptake and distribution (pharmacokinetics) of the anesthetic, genetics, sex and age of the animal, and any preexisting disease or pathology.
- Providers must be familiar with methods of action, dangers, equipment required of the various agents as well as the condition of the animal, desired experimental outcome and effects of the surgical procedure to determine which agent is the best choice.
- Results from the action of the anesthetic on the brain and spinal cord.
- Ultimate effect is dependent upon the drug’s ability to cross the blood-brain barrier.
- The perfect general anesthetic agent:
 - Does not depend on metabolism for its termination of action and elimination.
 - Permits rapid induction, quick depth alteration, and rapid recovery.
 - Does not depress cardiopulmonary function.
 - Is not a tissue irritant.
 - Is inexpensive, stable, noninflammable, and not explosive.
 - Requires no special equipment.

Note: The Perfect Anesthetic Agent: DOES NOT EXIST!

- General Anesthetics Are Divided Into Two Categories:
 - **Injectable Anesthetics:**
 - Enter the blood stream for transport to target tissues.
 - Require redistribution.
 - Generally are detoxified in the liver and excreted via the kidneys.
 - Are metabolized based on first order kinetics.
 - A constant fraction is metabolized in a given period.
 - Offer less control over the anesthetic process (i.e., anesthesia lasts until drug is metabolized or reversed).
 - **Inhalation Anesthetics:**
 - Enter the blood stream from the lungs.
 - Are primarily eliminated via the lungs.
 - Depend on relevant partial pressures and pressure gradients for intake and elimination.
 - Offer more control over the anesthetic process due to faster responses to changes in administration.
 - Median Alveolar Concentration (previously “Minimal Alveolar Concentration,” a.k.a. MAC) is:

- The end-tidal concentration of inhaled anesthetic at 1 atmosphere that produces immobility in 50% of subjects exposed to a noxious stimulus, such as an incision.
- Used to test physiological reactions to various stimuli and compounds on susceptibility to anesthetic agents.
- Affected by age, hypothermia, anemia, disease, and administration of other depressant drugs.

- **Effects of Metabolism on General Anesthesia:**

- The higher the metabolic rate, the more anesthetic required.
- Small animals have a higher basal metabolic rate (BMR) per unit of surface area than larger animals. The smaller the animal the larger the dose per unit of body weight necessary for anesthesia.
- Fat is a relatively non-metabolizing tissue; therefore, more fat = lower metabolic rate = less anesthetic. **Note:** Adipose tissue may absorb some anesthetic agents and prolong recovery time by acting as a reservoir for the agent.
- Basal metabolic rate increases with activity; therefore, higher activity = higher metabolic rate = more anesthetic.
- Disease or pathology = lower metabolic rate = less anesthetic.
- Increasing age = decreasing basal metabolic rate (BMR) = less anesthetic. **Note:** As an exception, newborns have lower BMRs than adolescents and young adults.
- BMR of males is ~7% higher than that of equivalent females.
- Recent feeding may increase BMR = more anesthetic.

Section 7.4: Stages of General Anesthesia

– Physiological Effects Of Anesthesia Are Separated Into 4 Stages:

- **Stage I** (Stage of voluntary movement)
 - Lasts from initial anesthetic administration to the loss of consciousness.
 - Tachycardia, hypertension, and irregular or increased respirations may be present due to epinephrine release.
 - Patient may hold breath.
 - Pupils dilate.
 - Struggling may be present.
 - Progressive ataxia is noted.
 - Some analgesic effects may be present at the transition from Stage I to Stage II
- **Stage II** (Stage of delirium or involuntary movement)
 - Loss of voluntary control as central nervous system (CNS) becomes depressed.
 - Lasts from the onset of unconsciousness until resumption of a regular breathing pattern.
 - Reflexes appear primitive and exaggerated.
 - Reactions to external stimuli include: struggling, breath holding, tachypnea, and hyperventilation.
 - Continued catecholamine release causes a strong, fast heartbeat.
 - Cardiac arrhythmias may occur.
 - Pupils dilate widely.

- Nystagmus commonly occurs in horses.
 - Eyelash and palpebral reflexes are present.
 - Vocalization may occur.
 - Excessive salivation and vomiting may occur.
 - Laryngeal spasm may occur in susceptible species.
 - Stimulation of any kind should be avoided.
- **Stage III** (The stage of surgical anesthesia)
 - Characterized by unconsciousness with progressive depression of the reflexes.
 - Ventilation becomes slow and regular, with progressive decrease in rate and depth.
 - Muscles relax.
 - Swallowing and vomiting reflexes are lost.
 - Progressive bradycardia.

Note: Stage III is divided into 3 or 4 planes (depending on the reference source).

- **Plane 1** (Light)
 - Persists until eyeball movement ceases.
 - BP returns to normal.
 - Strong pulse.
 - Respiratory rate and depth begin to decrease.
 - Pupils become less dilated.
 - Eyeballs may rotate.
 - Eyelash and palpebral reflex present.
 - Slight reaction to surgical manipulation.
 - Decreased jaw tone.
- **Plane 2** (Medium)
 - Surgical anesthesia.
 - Stable respiration and pulse rate.
 - No laryngeal reflexes.
 - Adequate muscle relaxation and analgesia for most surgical procedures.
 - Hypotension increases.
 - Capillary refill time begins to slow.
 - Palpebral reflex diminishes.
 - Strong corneal reflex.
 - Eyeball rotates ventrally.
 - Abdominal muscle tone minimal.
 - Jaw tone minimal.
 - Pedal reflex absent.
 - Probability of cardiac dysrhythmia low.
 - Acceptable for most surgical procedures.

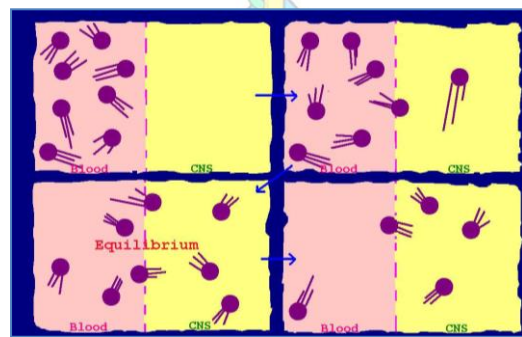
- **Plane 3 (Medium - Deep)**
 - Deep surgical anesthesia.
 - Decreased intercostal muscle function.
 - Weak corneal reflexes.
 - Diaphragmatic breathing present.
 - Increased respiration rate.
 - Decreased tidal volume.
 - Profound muscle relaxation present.
 - Centered and dilated pupils.
 - Bradycardia intensifies.
 - Hypotension continues to increase.
- **Plane 4 (Deep)**
 - Dysrhythmia probability begins to increase.
 - Respirations slow and irregular; diaphragmatic.
 - Lowered HR.
 - Cyanosis seen.
 - Widely dilated pupils and unresponsive to light.
 - Flaccid muscle tone.
 - Jaw tone lost.
 - Sphincter control lost.
- **Stage IV (Overdose)**
 - CNS extremely depressed.
 - Respirations slow and cease.
 - Pulse is weak or imperceptible.
 - BP at shock level.
 - Capillary refill time is greatly increased.
 - Mucous membranes pale.
 - Pupils widely dilated.
 - Cardiac dysrhythmia probability at highest level.
 - All reflexes and muscle tone lost.
 - Death is eminent unless corrective measures are taken.
 - Withdraw anesthetic.
 - Provide oxygen
 - Initiate artificial respiration.



Section 7.5: Anesthesia Pharmacokinetics

- General anesthesia is produced by the action of an anesthetic on the brain and spinal cord.
- Anesthetic action revolves around plasma concentrations of the anesthetic agent.
- All anesthetic agents not administered directly into the cerebral spinal fluid, are carried to the CNS via blood.

- The body can be divided into various compartments differentiated by blood supply and tissue-blood partition coefficients.
 - **Vessel Rich:** Brain, Liver, Heart, Kidney
 - **Intermediate:** Muscle, Skin
 - **Vessel Poor:** Adipose and residual tissue
- Binding to plasma protein, which interferes with penetration of cellular membranes, and absorption by tissues, which store, metabolize, and excrete drugs, effect the concentration of drugs at their site of action.
- After introduction to the blood stream, the drug enters various tissues based on perfusion, capacity for the drug, and the partial pressure gradient between the blood and tissue.
- Concentration of drug in blood and tissues is generally a factor of partial pressure gradients.
 - **Partial Pressure Gradients:**
 - The random motion of molecules will move them from areas of high concentrations into areas of lower concentrations.
 - This is not active; simply there are more molecules to randomly move into the lower concentration areas than there are to move back out.
 - Eventually, the system reaches equilibrium (both areas have an equal number of molecules with equal amounts moving back and forth).
 - However, permeability differences between two areas will result in a higher concentration on one side of the membrane versus the other.



- **Blood-Brain Barrier:**
 - The ultimate effect of any general anesthetic is contingent upon its ability to cross the blood-brain barrier.
 - Permeability characteristics are similar to cellular membranes.
 - Penetration of non-lipophilic, ionized, or protein bound drugs is limited.

Section 7.5.1: Effects of Anesthetic Route on Pharmacokinetics

- **Intravenous (IV) Administration**
 - Eliminates the absorptive phase, allowing a quicker onset of action than other routes.
 - Plasma concentration of the drug falls rapidly as it is taken up by vessel-rich tissues such as the brain, allowing for a quick onset of anesthesia.
 - Following the pressure gradient, the drug reenters the blood from these tissues and is redistributed to muscle, fat, and vessel poor tissues.

- Duration of action is shorter than with other injectable routes but the drug is present in the body for longer periods than with inhalants.
- **Other administration routes: IM, SC, IP, etc.**
 - Absorption into the blood plasma is required.
 - The gradual increase in plasma levels causes a more gradual flow of drug into the brain, resulting in a delay in onset of effect, but a longer lasting effect compared to IV administration.
 - Typically requires a higher dose than when the same drug is given IV.
 - Redistribution/metabolism of the drug begins while the drug is still being absorbed into the plasma.
- **Inhalation**
 - Inhalants are volatile, organic compounds.
 - Molecules are smaller in size than injectable agents.
 - Permeate blood stream, tissues, and blood-brain barrier more quickly.
 - Inhalation anesthetics are primarily exhaled rather than bio-transformed.

Section 7.5.2: Elimination

- Circulation distributes drugs to vessel-rich organs able to metabolize, eliminate, or excrete them.
- The liver is primarily responsible for biotransformation/metabolism.
- The kidneys are primarily responsible for excretion; lungs are responsible for elimination of gases.
- Biotransformation rate is determined by drug concentration at the site of metabolism.
- Most drug metabolism follows First Order Kinetics i.e., a constant fraction of drug is metabolized in a given period.
- In the event of saturation, Zero Order Kinetics is followed i.e., a constant amount of drug is eliminated.
- Species variation exists in biotransformation/metabolism.
- Modifying factors:
 - Fear, struggling, fever, increases in CO, and decreases in the time drug remains in circulation, increases the time the drug remains in equilibration within tissues/blood.
 - Shock increases blood flow to the brain and thus decreases potential for redistribution, dilution of the drug, bio-distribution, and excretion, thus causing rapid induction and prolonged recovery.
 - Hypercarbia and hypocarbia.

Section 7.6: Anesthetic Issues with Disease & Pathology

Section 7.6.1: Cardiovascular (CV) Dysfunction

- Most pre-anesthetic and anesthetic agents cause CV depression.
- Animals with CV dysfunction are more prone to fluid overload and arrhythmias.
- Since they frequently have poor oxygenation to begin with, these patients should be pre-oxygenated for 5-7 minutes prior to anesthetic induction.

- Drugs that may induce tachycardia or large changes in vascular resistance should be used with extreme care and only when there is no alternative.
- Alpha-2-adrenergic agonists should be avoided in patients with impaired cardiac output.

Section 7.6.2: Pulmonary Dysfunction

- Most pre-anesthetic and anesthetic agents cause pulmonary depression.
- Pulmonary dysfunction may be caused by diaphragmatic hernia, pneumothorax, hydrothorax, pneumonia, pulmonary edema, atelectasis, or obstruction.
- The anesthetist must perform a careful balancing act between lowering doses, primarily pre-anesthetic drugs, to limit further compromise, while also preventing anxiety.
 - Acepromazine combined with butorphanol can be used in low doses to provide enough sedation.
- Using mixed agonist-antagonist opioids, instead of pure agonist opioids, minimizes respiratory depression.
- Atropine and glycopyrrolate will decrease airway resistance, but will increase the viscosity of airway secretions.
- Phenothiazine tranquilizers have minimal effect on ventilation.
- Regional anesthesia is gaining in popularity in these cases when possible.
- Pre-oxygenate for 5-7 minutes prior to anesthetic induction, if the animal's condition allows the extra time.
- If general anesthesia is necessary, intubation and ventilation are essential.
- Rapid induction of anesthesia following sedation may be required to gain quick control of the airway via intubation and positive pressure ventilation.
- Best achieved by IV administration of thiopental, propofol, etomidate, or ketamine.
- Induction via facemask may cause excessive struggling.
- Anesthesia is best maintained with inhalant anesthetics and positive pressure ventilation.
- Caution should be used with nitrous oxide since it can increase the severity of a pneumothorax, and it should be discontinued if cyanosis is present.

Section 7.6.3: Neurologic Disease

- Usually refers to spinal cord and to a lesser extent intracranial disorders.
- Cerebral Blood Flow (CBF) and Intracranial Pressure (ICP) are regulated in normal, conscious animals; anesthetics can interfere with this regulation.
- ICP and CBF increases in head trauma patients, so the loss of regulation from anesthesia can cause further damage.
- Isoflurane, sevoflurane, etomidate, and barbiturates provide some cerebral protection.
- When used for anesthetic management, the direct effect of opioids on CBF and ICP are minimal, though end CO₂ or blood gas levels should be monitored and the patient ventilated if necessary to prevent hypercapnia.
- Hyperventilation (end tidal CO₂ levels of 30-35mm Hg) often eliminates volatile anesthetic-induced increases in CBF.

- Nitrous oxide causes the greatest increases and should be avoided in animals having neurosurgery.
- Blood pressure should be monitored closely, prior to and during anesthesia; if elevated prior to anesthesia, it should not be allowed to drop during anesthesia.
- Fluids should be restricted to the minimal amount necessary to maintain adequate circulating volume and cardiac output.

Section 7.6.4: Renal Disease

- All anesthetic agents are likely to decrease the rate of filtration by decreasing renal blood flow.
- Renal ischemia may occur during anesthesia due to systemic hypotension or renal vasoconstriction.
- Effects of anesthesia may terminate at the conclusion of surgery, but some patients do not fully regain the ability to regulate urine production for several days.
- Lower doses of barbiturates and other injectable drugs may be required due to a state of acidosis.
- Potassium (K⁺) levels may be elevated (hyperkalemia).
- Patients having a serum potassium concentration higher than 5.5-6 mEq/L should not be anesthetized prior to lowering the levels.
- Elevated K⁺ levels may be seen on the ECG in a peaked T wave, prolonged PR interval, wide QRS complexes, and loss of P wave.
- Administration of succinylcholine can cause K⁺ to rise to life-threatening levels.
- Patients should be monitored for post-operative oliguria.
- Chronic renal failure can lead to anemia; patients undergoing anesthesia should receive a transfusion if hematocrit is lower than 18-20%.
- Nephrotoxic drugs, such as NSAIDs, should be avoided.
- Mean arterial pressure (MAP) should be maintained above 70-80 mmHg to preserve renal blood flow.
- Central venous pressure (CVP) should be monitored to prevent volume overload and monitor myocardial function; it should be maintained at 3-5 cm of water.

Section 7.6.5: Hepatic Disease

- Anesthetics may affect hepatic blood flow by changing the vascular tone of the hepatic artery and/or portal vein.
- Halothane decreases portal vein blood flow but has little effect on hepatic artery flow.
- Isoflurane decreases portal vein blood flow but increases hepatic artery flow, with a net increase in overall blood flow.
- Sevoflurane and desflurane are associated with decreased total hepatic blood flow.
- Decreased blood flow may delay the elimination of drugs.
- Acepromazine, thiobarbituates, droperidol and alpha-2-adrenergic agents should be avoided in patients with moderate to severe liver disease.
- Phenothiazine (acepromazine) or butyrophenone (droperidol) tranquilizers may cause hypotension.
- Propofol, ketamine, and inhalation anesthetics are generally the safest.

Section 7.6.6: Gastrointestinal (GI) Disease

- A damaged GI tract may release toxins into the blood stream.
- May cause decreased cardiac function and ventilation (bloat or gastric dilation-volvulus).
- Metabolic alkalosis may occur from gastric sequestration of hydrogen ions.
- In advanced disease, metabolic acidosis may occur from decreased cardiac output and poor ventilation resulting in increased lactate production and cardiac arrhythmias.
- Serum electrolytes, pH, and bicarbonate concentrations should be measured prior to surgery.
- Fluid therapy may be used to correct acid/base imbalances.
- Avoid large doses of arrhythmogenic anesthetic agents (such as thiobarbituates and halothane) and alpha - 2-agonists.
- Xylazine may cause decreased gastro-esophageal sphincter pressure and increased GI reflux, decreased intestinal motility, and decreased cardiac output.
- Nitrous Oxide is contraindicated prior to gastric decompression due to the increased intragastric volume and pressure.
- Neuroleptanalgesic combinations, propofol, and diazepam/ketamine are good choices for induction.
- Maintenance with inhalants such as isoflurane or sevoflurane is recommended.

Section 7.7.7: Endocrine Disorders

- Diabetes, Addison's disease, Cushing's syndrome, hypothyroidism, and hyperthyroidism are common examples.
- The anesthetic regimen is not as important as proper treatment of the condition itself.
- The patient should be stabilized prior to anesthesia when possible.
- Pre-anesthetic and anesthetic agents should be selected for the shortest recovery time and/or easiest reversibility.

Part 8: Injectable Anesthetic Agents

- ▶ Each agent has relatively specific effects within the CNS.
- ▶ A combination of drugs is generally required to adequately affect all necessary body systems.
- ▶ Intravenous agents, other than ketamine, only provide mental depression and require the administration of analgesics and/or inhalation anesthetics to provide all of the components of general anesthesia.
- ▶ Has the advantage of allowing specific physiologic targeting based upon the choice of anesthetic drugs.
- ▶ The effects of injectable agents in general are variable by individual.
- ▶ This variability is not as drastic with inhalant anesthetics.
- ▶ Doses are a guide, not an absolute; when given intravenously, need to be given to effect.
- ▶ Remember, opioids ARE NOT anesthetics, but will reduce the anesthetic dose required.

Section 8.1: Barbiturates

- First prepared by Conrad and Gutzeit in 1882.
- Contain a pyrimidine nucleus.
- The parent compound, barbituric acid, has no hypnotic activity.
- Divided into 4 groups based on duration of action:
 - **Ultra short acting:** Hexobarbital, Kemithal, Thiamylal, Thiopental
 - **Short acting:** Cyclobarbital, Cyclopal, Pentobarbital, Secobarbital
 - **Intermediate acting:** Allylbarbituric acid, Amobarbital, Aprobarbital, Butabarbital, Butallylonal, Butethal, Hexethal, Probarbital, Propallylonal, Vinbarbital
 - **Long acting:** Barbital, Diallylbarbituric acid, Mephobarbital, Phenobarbital
- Short and ultra-short duration barbiturates are used for clinical anesthesia.
- Intermediate and long duration barbiturates are used for sedation and control of seizures.
- Act directly on CNS neurons, in a manner similar to gamma-aminobutyric acid (GABA).
- Inhibit synaptic actions of some neurotransmitters.
- Poor analgesia at safe doses.

Section 8.1.1: Effects of Administration

- **Hypnotic Doses**
 - Little effect on respiration.
 - Little effect on basal metabolic rate.
- **Anesthetic Doses**
 - Respiration is depressed.
 - Cardiovascular depression, both centrally and peripherally.
 - Reduced cardiac output CO and stroke volume.

- Increased HR.
- Decreased BP.
- Depressed basal metabolic rate.
- Lowered body temp.
- Crosses cell walls and the placenta.
- Cerebrospinal fluid contains less protein for binding than plasma and hence has lower barbiturate concentration at equilibrium.
- Decreased blood pH (< 7.4, acidosis), will increase the amount of barbiturate which can penetrate cell membranes and produce deeper anesthesia; higher pH (alkalosis caused by hyperventilation or administering alkalinizing agents) decreases effectiveness and lightens anesthesia.
- Ultra short acting barbiturates are redistributed faster, NOT metabolized faster, than the short acting barbiturates.
- **The “Glucose Effect”**
 - During recovery from barbiturate anesthesia, glucose administration will lead to re-anesthetization.
 - Species variation is seen.
 - Guinea pigs, chickens, pigeons, rabbits, and hamsters are susceptible.
 - Dogs are intermediate.
 - Mice, rats, goldfish, and tadpoles are not susceptible.

Section 8.1.2: Administration

- IV administration is the preferred route; allows dosing “to effect.”
 - First 1/2 to 1/3 of calculated dose is rapidly injected (slow injection may cause the animal to go through excitement).
 - Remainder of dose is given slowly to effect.
 - Recommended administration is through a catheter.
- Perivascular administration will result in “barbiturate slough.”
 - Takes 2 to 4 weeks to heal and will scar.
 - Lidocaine or 2% procaine (1-2 ml) may be infiltrated into the area to prevent vasospasm, aid in dilution and absorption of the barbiturate, and change the acidity to help minimize damage.
 - Saline may also be infused to further dilute the barbiturate.
 - Corticosteroids, NSAIDs, and the use of hot packs may also help.
- IP and IM administration are not widely employed, except when used in rodents.
 - Does not allow dosing “to effect.”
 - Can be quite painful.
- IM or IT injections may be indicated for wild animals.
- Oral administration is variable and usually used for sedation.

Section 8.1.3: Oxybarbiturates

- **Phenobarbital Sodium**

- Long-acting.
- Effective anticonvulsant.
- Considerably cheaper than any of the newer drugs.
- Excreted slowly in urine and tends to be cumulative.
- Oral loading dose should be administered first followed by a daily maintenance dose.
- Overdosage causes loss of motor coordination.
- In treatment of strychnine poisoning, it should be given IV to effect until muscle relaxation is seen.

- **Pentobarbital Sodium**

- Use in cats and dogs widespread by 1940.
- Currently has been replaced by inhalation and balanced anesthesia.
- During induction, sub-anesthetic doses will often cause CNS stimulation and pre-anesthetic excitement.
- After the initial IV dose, arterial BP decreases and HR increases for 10 to 20 minutes.
- Given to effect.
- Anesthetic doses lead to decrease in systolic BP, stroke volume, pulse pressure, central venous pressure, PaO₂, pH, and body temperature.
- HR, PaCO₂, and peripheral resistance increase after 1.5 hours.
- Cardiac output will decrease.
- MAP decreases during induction, but returns to “awake” values in ~30 minutes.
- Deep anesthesia depresses renal function.
- Effect produced by high doses may closely resemble those of shock.
- Freely crosses the placenta; high doses may cause high mortality among newborns.
- With IP injection, a portion of the drug is absorbed by the portal system and is subjected to immediate destruction in the liver.
- Complete recovery usually occurs in 6-18 hours, but may last as long as 72 hours.
- No longer used in North America for small companion animals, cattle, and horses due to prolonged recovery and marked respiratory depression.
- Whining, shivering, running motions, and thrashing may occur during recovery (delirium).
- Advised to use tranquilizers for the recovery period.

- **Methohexital Sodium (Brevital)**

- Ultra short acting.
- Contains no sulfur atom.
- Duration of action due more to redistribution than metabolism.
- Lethal dose 2.5x greater than median anesthetic dose.
- Main danger of overdose is respiratory failure.
- Solution stable for as long as 6 months at room temperature.

- Recovery is quick but difficult (muscle tremors/violent excitement) even with pre-anesthetic sedation.
- Dogs are ambulatory ~30 minutes after injection.
- Good drug for induction.
- Causes transient apnea; must be ready to intubate and support respiration.
- Best followed by inhalant anesthesia for maintenance.

Section 8.1.4: Thiobarbiturates

• Thiopental Sodium

- First thiobarbiturate to gain popularity as an anesthetic agent for animals.
- Should be stored refrigerated.
- Is unstable in aqueous solutions and as the solutions age, they become turbid and crystals precipitate, causing a loss of activity, but not increased toxicity.
- Produces ~12 different metabolic products that are excreted in urine.
- 86% is excreted within 4 days.
- Initially creates a marked respiratory depression.
- Five minutes post-administration an increase in HR, aortic pressure, peripheral vascular resistance, and left ventricular pressure occur.
- Arrhythmias are accentuated by xylazine, halothane, methoxyflurane, and epinephrine.
- Cardiopulmonary depressive effects are reduced if administered along with a lidocaine bolus (11 mg/kg).
- Pronounced hyperglycemia is seen during prolonged thiopental anesthesia.
- Has a cumulative effect with repeated doses, leading to possible prolonged anesthesia.
- Contraindicated for use in neonates and in feline porphyria.
- Commonly mixed with 5% guaifenesin for equine anesthesia.
- Has ultra-short action due to rapid redistribution and localization in fat.

• Thiamylal Sodium

- Anesthetic potency in dogs is about 1.5 times that of thiopental.
- Normal saline suggested as a diluent.
- Solutions stable for up to 14 days.
- Less cumulative than thiopental.
- Tolerance with repeated injections not noted.
- More arrhythmogenic than thiopental.
- Less cardiovascular effects than thiopental.
- Single bolus provides ~15 minutes of surgical anesthesia.
- May be used alone or in combination with guaifenesin in horses and cattle.
- May produce apnea.
- Very safe and nontoxic.

Section 8.2: Non-barbiturate Anesthetic Drugs

Section 8.2.1: Neurosteroids

- **Althesin**
 - Combination of the steroids alphaxalone and alphadolone acetate.
 - Exceptionally high therapeutic index while having little cumulative effect.
 - Anesthetic duration varies among species.
 - Work by enhancing GABA-mediated neurodepression.
 - Should not be used along with barbiturates.
 - Neutral pH.
 - Does not cause damage or pain with perivascular administration.
 - IM administration produces variable results.
 - Onset in 6 to 12 minutes and 15 minute duration.
 - Produces good muscle relaxation.
 - Additional doses are not cumulative.
 - Side effects include urination, defecation, muscle tremors, paddling, salivation, and hyperesthesia.
 - May cause edema of the feet, ears, and muzzle (cats), or allergic reaction consisting of a decrease in blood pressure and wheals at the injection site (dog), but is usually transient.
 - Causes violent recovery in horses, prevented by prior administration of xylazine.
- **Alfaxan-CD**
 - Neurosteroid that does not cause histamine release.

Section 8.3: Miscellaneous Injectable Anesthetics

– Chloral Hydrate, U.S.P.

- May be administered orally or IV/IP if made into a solution.
- Oral administration may cause vomiting.
- Small amount excreted unchanged in the urine.
- Depresses the cerebrum.
- Sub-anesthetic doses do not affect motor and sensory nerves.
- Is a good hypnotic but poor anesthetic.
- Amount needed for anesthesia is close to the lethal dose.
- Produces deep sleep that lasts for several hours.
- Has weak analgesic action.
- Respiration and BP decreases.
- No longer used very often due to availability of safer and more effective drugs.
- Perivascular administration is irritating.
- Doses vary extensively.

- **Chloralose**
 - Produced by heating anhydrous glucose and trichloroacetaldehyde in a water bath to produce alphachloralose.
 - Produces minimal CV depression and better maintains active reflexes.
 - Provides less depression of neuronal function of the cortex than pentobarbital.
 - Valuable for long duration, non-survival experiments.
- **Magnesium Sulfate**
 - Globally depresses CNS.
 - May be used for euthanasia but only if administered AFTER the animal is rendered unconscious with another agent.
- **Metomidate (Hypnodil)**
 - A hypnotic with muscle relaxant properties.
 - Induces sleep without analgesia.
 - General anesthesia can be produced by combining it with neuroleptics or analgesics.
 - Apnea may occur with rapid IV injection.
 - Often used as a sedative-anesthetic for fish.
- **Etomidate**
 - Enhances the action of GABA.
 - Single injections produce relatively brief dose-related hypnosis.
 - Does not depress CV or respiratory centers or cause histamine release.
 - Does not trigger malignant hypothermia in swine.
 - Good induction drug for neurosurgical procedures.
 - Decreases cerebral metabolic rate of oxygen consumption.
 - Has an anticonvulsant property.
 - May have brain-protective properties following episodes of global ischemia.
 - Venous pain during injection is common (humans).
 - May be a preferred drug for induction of traumatized patients or those with CV or respiratory difficulties, cirrhosis, intracranial lesions, or those requiring C-sections.
 - Long term infusion not recommended.
- **Propofol**
 - Is not related to barbiturates or steroid anesthetics.
 - Is supplied as an emulsion in soybean oil, glycerol, and egg lecithin.
 - Will support microbial growth and endotoxin production.
 - Original formulation needs to be discarded 6 hours after opening.
 - Now available in a formulation with preservatives that allows it to be kept for 28 days.
 - Rapid uptake into the CNS promotes rapid induction.
 - Rapidly redistributed from the brain and metabolized from blood.

- Large volume of distribution due to lipophilic nature.
- Promotes quick and smooth recovery.
- Has minimal analgesic activity at sub-anesthetic doses (sedative/hypnotic).
- Animal will respond to painful stimuli even under anesthesia, unless pre-treated with an analgesic.
- Acepromazine “onboard” will decrease the required dose.
- Decreases intracranial pressure.
- Repeated doses in cats may cause injury to red blood cells.
- Not recommended for use in rabbits due to low margin of safety
- Relatively expensive.
- Complaints of pain with IV injection common in humans.
- No damage to tissue when injected perivascular.
- Minimal fetal depression when used for C-sections.
- **Tricaine Methanesulfonate (MS222)**
 - Used for anesthesia of amphibians and fish by bathing, gill spraying, or injection.
 - May be autoclaved.

Section 8.4: Dissociative Anesthetics

- Used to interrupt ascending transmission from the unconscious to the conscious parts of the brain rather than creating generalized brain center depression.
- Characterized by a cataleptoid state in which the eyes remain open with a slow nystagmic gaze, hypertonus, and muscle movement unrelated to surgical stimulation.
- Cerebral vasodilators.
- Cause an increase in cerebral blood flow and intracranial pressure - undesirable for patients with head trauma, brain tumors, ocular lesions or CNS disease.
- Caution in animals that have significant renal or hepatic dysfunction.
- Provide intense but short duration somatic analgesia; poor visceral analgesia.
- **Ketamine**
 - Schedule III controlled substance.
 - Most common dissociative injectable.
 - Least potent dissociative.
 - Produces dose related unconsciousness and analgesia.
 - Bolus IV injection rapidly crosses the blood brain barrier.
 - Has a rapid onset of action.
 - Lasts approximately 15-20 minutes with one bolus IV dose.
 - Termination of effect due to rapid redistribution.
 - pH is 3.5, so this may lead to some tissue irritation after IM injection.
 - SC injections may cause severe irritation and tissue trauma.
 - Primary effect is at the thalamoneocortical projection system.

- Does not induce seizures, except in susceptible species/individuals, and may be an anticonvulsant in low doses.
- Analgesic effects greater for somatic pain than visceral pain.
- Increases cerebral blood flow, intracranial pressure, cerebral spinal fluid pressure, HR, MAP, and cardiac output.
- Causes transient decrease in respiratory rate.
- Hallucinatory behavior may be evident during recovery, especially in non-human primates.
- Dogs and horses show extensive hepatic metabolism before elimination.
- Can lead to hepatic damage with repeated doses
- Eliminated mostly unchanged via the kidneys in cats.
- Prolonged sleep time in animals with renal insufficiencies.
- Skeletal muscle tone not affected, and may be increased in some species.
- Often combined with a tranquilizer or sedative to decrease muscle tone.
- Survival rate for “shocky” animals better than with Halothane.

- **Telazol**

- Schedule III controlled substance.
- Combination of a dissociative (tiletamine) and a benzodiazepam (zolazepam).
- Supplied as a lyophilized powder; stable for 4 days at room temp and 2 weeks refrigerated after reconstitution.
- Onset of action 6-8 minutes on average when administered IM and 60-90 seconds IV.
- Duration of anesthesia approximately 20-30 minutes in dogs and 40-50 minutes in cats.
- Has a wide margin of safety.
- Induction and recovery are rapid and smooth.
- Swallowing, coughing, pedal, corneal, and vomiting reflexes are retained.
- Good muscle relaxant.
- Has a lingering analgesic effect.
- May cause increase in HR and respiratory rate.
- There is an initial increase in systolic BP, with a slight drop in pressure within five minutes. The systolic BP remains at this decreased level throughout the duration of the anesthetic effect. Diastolic pressure increases throughout this same period.
- May be combined with ketamine and/or xylazine.

Part 9: Inhalation Anesthesia

- ▶ Differ from all other anesthetic agents because they are administered through and mostly eliminated from the lungs unchanged.
- ▶ They favor rapid and predictable changes in anesthetic depth since metabolism is not required.
- ▶ Require specialized equipment for delivery.

Section 9.1: Characteristics

- All but nitrous oxide are organic compounds.
- Subdivided into:
 - Aliphatic hydrocarbons (Halothane).
 - Ethers (2 organic radicals connected by an O₂ atom).
 - Enflurane, methoxyflurane, isoflurane, sevoflurane, desflurane.
- It was discovered that the lack of an ether group leads to an increased risk of cardiac arrhythmias.
- Because of this, all modern inhalants (newer than halothane) are ethers.
- Halogenation (the addition of fluorine, chlorine, or bromine) was found to increase potency.
- Fluorinated compounds vary greatly in safety, reactivity, and potency.
- Gas and vapor are the two physical forms of inhaled anesthetics.
 - **Gas:** An agent that exists in gaseous form at room temperature and sea level atmospheric pressure (N₂O).
 - **Vapor:** The gaseous state of a substance, which is a liquid at ambient temperature and pressure (all others).
- Inhalant anesthetics are composed of molecules bouncing about at high speed.
- Impact of molecules bouncing against container walls and against each other creates pressure.
- Quantities of inhalants are commonly expressed as a concentration (percentage of the agent in relation to the whole gas mixture).

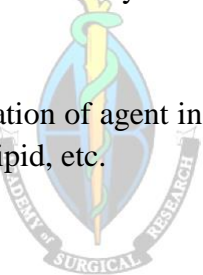
Section 9.1.1: Governing Laws of Physics

- **Boyle's Law:** Decreasing the volume of a given amount of a gas increases the pressure.
- **Charles's Law:** Increase in temperature, without increasing the volume, will result in increased pressure.
- **Dalton's Law of Partial Pressure:** The total pressure of a mixture of gases equals the sum of the partial pressures of all of the gases present in the mixture.

Section 9.1.2: Factors Effecting Inhalant Anesthetics

- **Vapor Pressure**
 - All molecules are in constant random motion.
 - Some in the surface layer will break free and enter the vapor phase (vaporization or evaporation).

- Will progress to equilibrium in a closed container at a constant temperature.
- These molecules exert force like a gas.
- At any specific temperature there is a maximum amount of vapor that can exist for a given liquid volume (saturated vapor pressure).
- Primary difference between gas and vapor is that a gas can mix with another gas in concentrations up to 100%.
- Vapor can only exist in concentrations up to the ceiling imposed by the vapor pressure.
- **Temperature**
 - Heat imparts more energy to liquids, allowing more molecules to escape and thus increasing amount of vaporized liquid.
 - Boiling Point
 - Temperature where vapor pressure is equal to atmospheric pressure.
 - Liquid becomes a gas.
- **Solubility**
 - Molecules randomly bounce into liquid.
 - Continues until equilibrium outside and inside the liquid is present.
 - Important because agent solubility in body fluid and tissue determines anesthetic potency, effectiveness, and pharmacokinetics.
 - Partition Coefficients
 - Difference between the concentration of agent in one liquid/area and another at equilibrium, e.g., blood/brain, lungs/blood, blood/lipid, etc.



Section 9.1.3: Pharmacokinetics

- Goal is to place an adequate partial pressure of anesthetic in the brain to cause the desired level of CNS depression.
 - Agents move down a series of partial pressure gradients to the target tissue as well as other tissues.
- Agent is delivered in oxygen to the alveoli.
- Must reach an appropriate inspired concentration, which is a factor of circuit volume.
- The larger the circuit volume, the longer it takes the concentration of gas leaving the vaporizer to be reflected in the animal.
- Solubility of the agent in the circuit materials will also have an effect.
- The greater the amount of agent delivered to the alveoli (function of respiration rate and pressure) the greater the alveolar ventilation.
- Low blood solubility requires less amount of agent to reach blood equilibrium and then start passing to other tissues.
 - Less solubility means the agent will readily leave the blood for other tissues.
 - Low blood solubility = rapid induction, more precise control of anesthetic depth, and rapid recovery.
 - Once in the blood, agent must travel to target tissues.
 - Greater vascularity in certain tissue, the greater amount of blood available for agent transfer.
 - Function of cardiac output.

Section 9.1.4: Biotransformation

- Some agent is metabolized.
- May help in recovery (older agents).
- Amount of metabolism varies from agent to agent.
- May cause acute and chronic toxicities in certain organs (liver and kidneys).

Section 9.1.5: Minimum Alveolar Concentration (MAC)

- The amount of agent required to produce immobility in 50% of healthy subjects.
- Inversely proportional to potency.
- Refers to % at the alveoli, not at vaporizer or in circuit.

Section 9.2: Historical Inhalant Anesthetics

- Specific inhalant anesthetics that are no longer used due to safety concerns:
 - Flammable/explosive
 - Toxic

Examples:

- **Chloroform**
 - May cause liver failure
- **Cyclopropane**
 - Explosive
- **Fluroxene**
 - Hepatotoxic
- **Trichloroethylene**
 - Hepatotoxic, cardiotoxic and neurotoxic when used with soda lime
- **Ether** (Diethyl ether)



Note: Replaced due to flammability.

- The principal inhaled anesthetic agent prior to development of the later nonflammable agents.
- Concentrations used for anesthesia are explosive.
- Patients will release sufficient quantities of ether to be flammable or explosive even after death.
- Highly irritating to the respiratory tract.
- Can cause laryngospasm.
- Can cause pre-existing, chronic, sub-clinical respiratory disease to develop into an acute, severe infection.

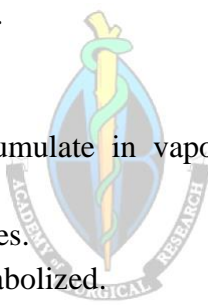
Section 9.3: Modern Inhalant Anesthetics

- **Nitrous Oxide (N₂O)**
 - New cylinders contain ~ 95% liquid.
 - As gas escapes, more liquid converts to gas until all liquid is removed.
 - Pressure does not drop until all of the liquid has been converted to gas.

- At this point, the tank is only 25% full.
- Weight should therefore be used to track usage.
- Is not a potent anesthetic by itself but is useful as an adjuvant to other anesthetics.
- Decreases induction time and the amount of accompanying anesthetic needed.
- MAC is $> 100\%$ (200% for dogs).
- To prevent hypoxia, only 75% of inspired air can be N_2O (3:1 ratio with O_2).
- Has rapid onset of action due to low blood solubility.
- CV and respiratory effects are minimal.
- Little or no effect on liver and kidney function.
 - Use care in patients with initially compromised function.
- May transfer to organs or body areas and cause pneumothorax, a blood embolus, or a pressure increase in the middle ear.
- When administration of N_2O is stopped, it is rapidly transferred from the blood into the lungs, displacing O_2 (diffusion hypoxia). To prevent this, O_2 should be continued after N_2O is stopped.
- Interferes with CO_2 monitoring.

– Halothane

- No longer distributed in North America.
- Susceptible to decomposition.
- Thymol is added for stability.
- Thymol is less volatile and will accumulate in vaporizers and cause malfunction unless they are regularly cleaned.
- Does not have strong analgesic properties.
- Up to 50% of inspired halothane is metabolized.
- Maybe hepatotoxic.
- Has high volatility.
- Moderate induction and recovery time.
- Causes respiratory depression.
- Depresses myocardial muscle and sensitizes it to the effects of catecholamine.
- Implicated in malignant hyperthermia.
- Moderate relaxation of vascular smooth muscle.
- Increases cerebral blood flow (vasodilation).



– Methoxyflurane

- No longer available in North America.
- Popular 1960-1990.
- Has low volatility and high blood solubility.
- Safe in non-precision systems.
- Potent analgesic effects, with some post-operative analgesia provided.
- Extensively metabolized (~70).
- Can cause renal damage with prolonged anesthesia.

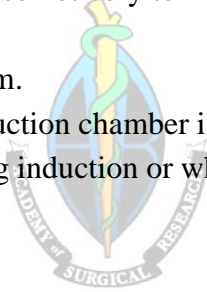
- Respiratory depressant.
- Slow onset and recovery.

– **Enflurane**

- Rarely used in veterinary clinical or laboratory animal anesthesia.
- Remains in limited use elsewhere.
- Produces cardiac and respiratory depression similar to halothane.
- Lowers the threshold for seizures and causes malignant hyperthermia in susceptible species.
- Small amount of metabolism occurs, so is less toxic than halothane.

– **Isoflurane**

- Low solubility and high potency.
- Rapid induction and recovery.
- Less CV effects than halothane.
- Greater safety margin than halothane.
- Potent coronary vasodilator.
- Hyperventilation prior to administration will limit cerebral blood flow increases.
- Minimal amount of metabolism occurs, so not very toxic to kidneys or liver.
- Is irritating to mucous membranes.
- Can cause irritation to respiratory system.
- Can cause ocular irritation when an induction chamber is used.
- Some species will become apneic during induction or when light.



– **Desflurane**

- Only of limited use in vet medicine.
- Effects similar to isoflurane.
- May cause tachycardia and respiratory irritation.
- Has lower solubility in blood than isoflurane, halothane, or methoxyflurane.
- Allows rapid equilibrium for quick and precise changes in depth of anesthesia.
- Very rapid induction and recovery.
- Has a low boiling point and thus requires a special heated vaporizer.
- Expensive.

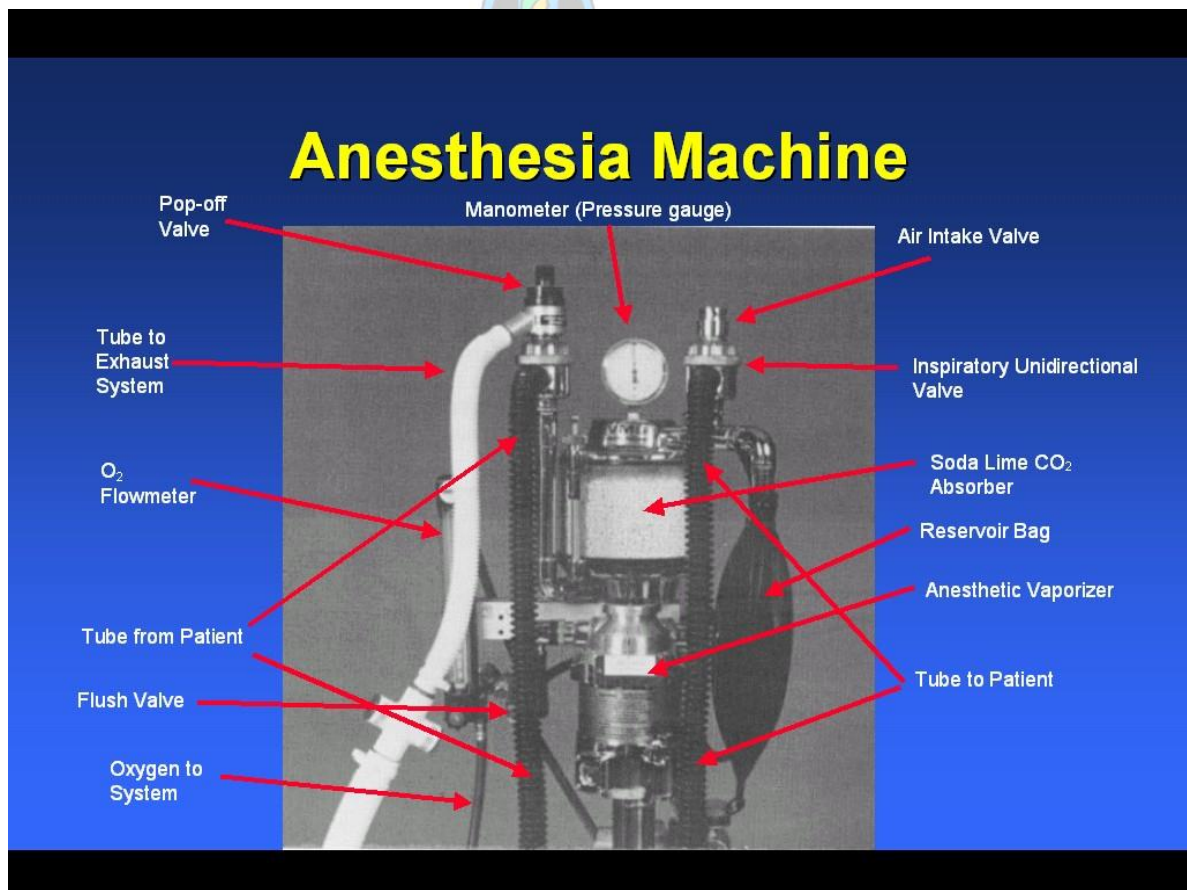
– **Sevoflurane**

- Effects similar to isoflurane.
- Has lower solubility in blood than isoflurane, halothane, or methoxyflurane.
- Allows rapid equilibrium for quick and precise changes in depth of anesthesia.
- Very rapid induction and recovery.
- The most volatile anesthetic.
- With the exception of desflurane, it has the fastest induction and recovery.
- Less of a respiratory irritant than desflurane and isoflurane.
- Can raise intracranial pressure and cause respiratory depression.

Section 9.4: Equipment

Section 9.4.1: Anesthetic Delivery Systems

- Inhalant anesthetic agents commonly require a vaporizer for delivery of the agent.
- Three methods of vaporization:
 - Flow-Over: carrier gas is directed over the surface of the liquid anesthetic, wicks may be used to increase surface area.
 - Bubble-Through: gas is carried below the surface of the liquid through a diffuser that disperses bubbles of carrier gas through the liquid anesthetic.
 - Injection: vaporizers deliver a known amount of liquid anesthetic of pure vapor into a known volume of gas to deliver accurate concentrations.
- Ether, methoxyflurane, and chloroform may be administered via a soaked cotton mask, gauze, or placing small animals in a chamber with anesthetic soaked gauze; however, this method is dangerous as it is difficult to control administration and depth of anesthesia.
- Animals may also be placed in a chamber where anesthetic gas is introduced from an anesthetic machine which should either be attached to a scavenging system for collection of waste gasses or the animal should be anesthetized in a ventilated fume hood
- Ideally, animal is induced via an injectable anesthetic, and then maintained with gas anesthetic

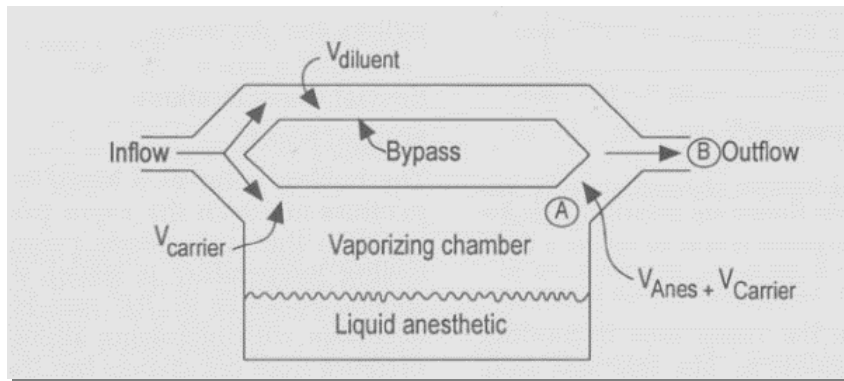


Section 9.4.2: Location of Vaporizers

- **Vaporizers can be located out of the breathing circuit (VOC) or in the circuit (VIC).**
- **Vaporizer Out of Circuit (VOC system).**
 - The most common style of anesthesia machine.
 - Allows more precise control over the concentration of the inhalant gas administered to the animal.
 - **Gas Passage Through a VOC System:**
 - Gas, typically oxygen, is delivered via a tank to the anesthesia machine through a regulator.
 - Oxygen passes through a flow meter, allowing adjustment to the flow rate and pressure flowing through the system.
 - Oxygen then passes through an anesthetic vaporizer where the agent is introduced in known concentrations into the oxygen stream (or other carrier gas).
 - Oxygen/anesthetic mix passes through a unidirectional inhalation valve into an inhalation breathing tube.
 - An air intake valve above this valve allows air to enter the system if oxygen flow is disrupted.
 - A reservoir bag is attached below to meet peak inspiratory demand and compliance during exhalation and allows assisted or controlled ventilation.
 - With a double circuit ventilator the reservoir bag is replaced with a tube leading to the ventilator bellows for collection and pumping of the air through the breathing circuit.
 - Oxygen/anesthetic mix is passed into the animal via inhalation or ventilator pressure.
 - Waste gas is exhaled through the exhalation breathing tube.
 - Overflow gas passes through a pop off valve to an exhaust system.
 - The pop off valve allows the system pressure to be adjusted.
 - With ventilators, outflow goes to the ventilator for pressure requirements and a scavenging system is attached to it.
 - The rest of the gas passes through an absorber where CO₂ is absorbed before the gas mixture continues the circle.
 - A manometer measures the pressure in the breathing system.
 - > 20-25 mm Hg is potentially dangerous as it may prevent CO₂ absorption.
 - >25-30 mm Hg may cause trauma to the lungs
- **Vaporizer In Circuit (VIC system)**
 - The vaporizer allows anesthetic to be absorbed into the oxygen stream more passively than with a VOC system.
 - Unpredictable output.
 - Does not allow precise control of the agent concentration in the oxygen and thus to the patient.
 - Interesting in that the faster the animal breathes, whether spontaneously or with the use of positive pressure ventilation, the animal gets an increased amount of anesthetic agent delivered over a given time period.
 - Animal begins to recover, breathes faster and gets more anesthesia as the concentration in the gas mixture increases without any operator adjustment.
 - **Passage of gas through a VIC system:**
 - Oxygen is delivered via a tank to the anesthesia machine through a regulator.

- Oxygen passes through a flow meter, allowing adjustment to the rate and pressure of oxygen through the system.
- Oxygen passes through a unidirectional inhalation valve and then through the vaporizer.
- Oxygen/anesthetic mix passes into an inhalation breathing tube and to the patient.
- Exhaled gases pass through the exhalation breathing tube through a unidirectional exhalation valve into the reservoir bag.
- Excess gas leaves via the exhaust system and remaining gases go through the SODASORB[®] canister where CO₂ is removed before being re-introduced into the system.

Section 9.4.3: Vaporizers

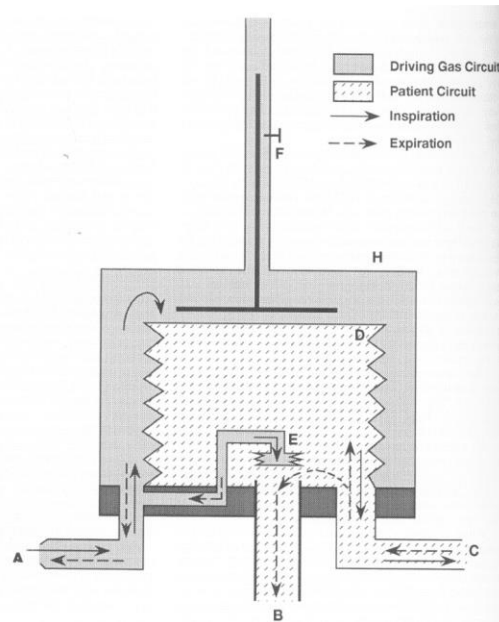


- Can be agent specific or multipurpose.
- Physics of vaporization.
 - Heat energy is required for vaporization.
 - Latent heat of vaporization: the number of calories needed to change 1 gram of liquid to vapor.
 - This heat requirement causes cooling of the anesthetic during vaporization.
 - Vapor pressure of an anesthetic is the partial pressure of the anesthetic gas above the liquid at equilibrium.
 - Vapor pressure varies with temperature.
- Uncontrolled cooling limits the vaporizer's output.
- Vaporizers are typically made using materials with a high specific heat that supplies heat to the liquid and retards cooling.
- High thermal conductivity also passes heat from the room to the liquid.
- Copper and bronze are most commonly used due to favorable values of heat production and transmission.
- Vaporizers must compensate for flow, temperature, and pressure.
- Material supplies a "heat sink."
- Some vaporizers may be heated to provide the higher amounts of heat energy required to vaporize the anesthetic agent (desflurane).
- Various methods of backpressure compensation are used.

- **Tec Precision Vaporizers**
 - Specifically designed for Halothane or Isoflurane.
 - VOC, concentration calibrated, variable bypass, flow-over, thermo-compensated, agent specific, and high resistance.
 - Examples include Fluotec Mark 3, Pentec Mark 2, and Isotec 3 vaporizers.
 - Output is nearly linear over range of concentrations and flow rates typically used.
 - The Tec 6 and Tec 6 Plus vaporizers are other examples of a precision vaporizer specifically made for desflurane. It is classified as a dual circuit, injection, supplied heat, agent specific and high resistance.
- **Ohio Calibrated Vaporizer**
 - Variable bypass, flow-over with wick, automatically temperature compensated, agent specific, VOC, and high resistance.
 - Earlier model to the Tec3 and Tec4
 - Manufactured specific for isoflurane, halothane and sevoflurane administration.
 - Tilting up to 20° while in use or 45° while not in use does not cause problems.
 - May cause discoloration of liquid anesthetic.
- **Siemens Vaporizer**
 - Concentration-calibrated, injection-type, non-thermocompensated, agent-specific, and plenum (high resistance) unit.
 - Not used extensively in veterinary anesthesia.
 - Designed to couple with a Siemens ventilator.
- **Measured Flow Vaporizer**
 - Verni-Trols and Copper Kettles:
 - Flowmeter controlled vaporizers formally popular in humans.
 - Measured flow, bubble-through, high resistance, VOC, temperature compensated, and multipurpose.
 - Requires calculations for setting flow rates.
 - Infrequently used now due to imprecision, but some models are still in facilities
 - **Stephens Simple Vaporizer**
 - Variable bypass, flow-over, non-temperature compensated, VIC, low resistance and multipurpose.
 - Non-precision, non-calibrated.
 - Vaporization chamber made of glass.
 - Suitable for methoxyflurane or ether, but not for isoflurane or halothane.
 - No method for controlling temperature of the liquid so the output is highly dependent upon the ambient temperature.
 - Major advantage is relatively low cost
 - Major disadvantage is unknown and variable output.

Section 9.4.4: Mechanical Ventilators

Note: The letters in the following description refer to the figure below: Gas enters (A), compresses bellows and forces gas along circuit into patient system (C). Overflow gas from the patient exits via pop off valve (E) to scavenger (B) Adjustment of tidal volume control (F).



- **Bellows may be ascending or descending**
 - Ascending is safer as it will collapse if the circuit is opened, or has a slow leak, while a descending bellows will continue functioning and the operator may not know there is a problem.
- **Intermittent Positive Pressure Ventilation (IPPV)**
 - Airway pressure is maintained above ambient pressure during inspiration and falls to ambient pressure to allow expiration.
- **Conventional Positive Pressure Ventilation (CPPV)**
 - Form of IPPV where a preset tidal volume is delivered at a preset frequency.
- **Positive End Expiratory Pressure (PEEP)**
 - End expiration pressure is maintained higher than the ambient pressure.
- **Continuous Positive Airway Pressure (CPAP)**
 - Airway pressure is maintained above ambient pressure during spontaneous respirations.
- **Intermittent Mandatory Ventilation (IMV)**
 - Used during weaning from a ventilator
 - Allows spontaneous breathing while providing assisted breathing via decreased tidal volumes and/or rates.
 - The periodic “sigh bagging” that the anesthetist provides is also termed IMV.

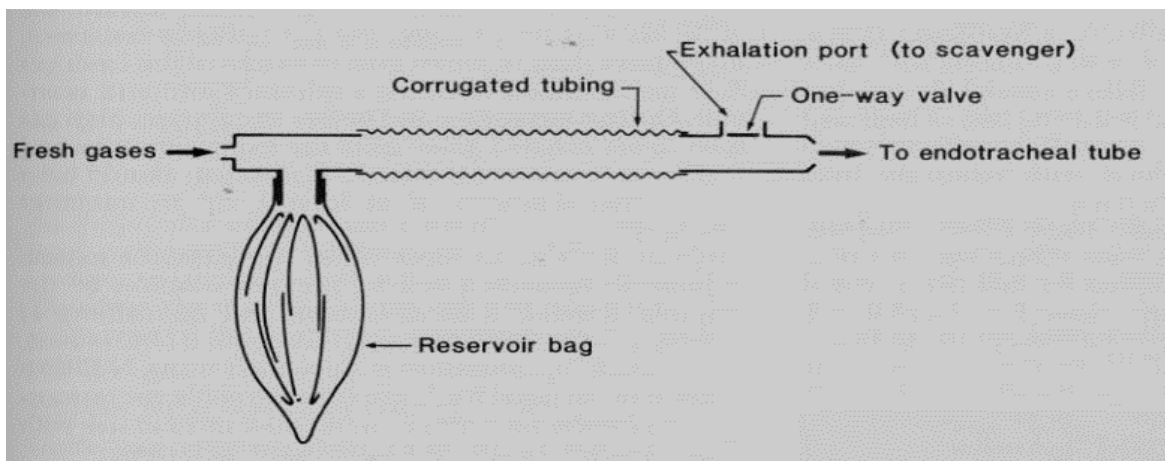
Section 9.4.5: CO₂ Absorber

- Absorbs CO₂ before gas passes back to the patient side of the circuit.
- Canister should be large enough to contain a gas volume equal to or greater than the patient's maximum tidal volume around the granules.
- Commonly filled with sodium lime or barium hydroxide lime.
- Lime will expend itself and stop absorbing CO₂.
- Length of usable time for a specific canister can vary depending on flow rates and percentage of time the system was used with spontaneous breathing vs. mechanical ventilation.
- Lime may be impregnated with an indicator, which will change color as the granules are expended.
- Color can fade overnight, but lime is still expired.
- Necessary to keep track of time used to assure change out prior to saturation.
- Lime will also heat up if working properly (heat line) due to the chemical reaction associated with absorbing CO₂.

Section 9.4.6: Breathing Systems

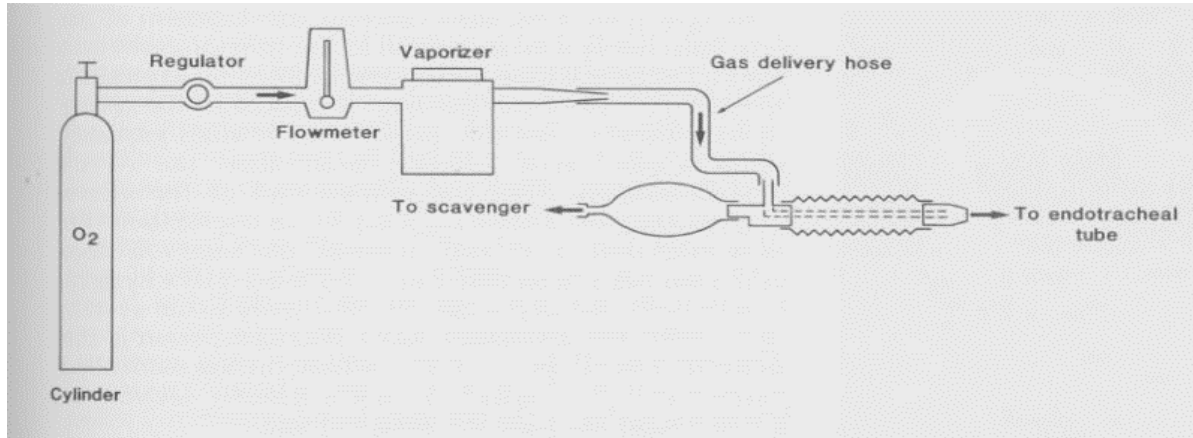
- **Circle Breathing Systems (Re-breathing Systems)**
 - **Closed Circle Systems**
 - Low flow of anesthetic gases and oxygen to the patient and system.
 - Oxygen flow into the system approximates the patient's oxygen consumption.
 - Consumption varies depending on the patient's metabolic rate, body weight, body surface area, temperature, level of anesthesia, and type of anesthetic.
 - Observation of the reservoir bag is used in practice to adjust the oxygen flow
 - Under inflation = need to increase flow
 - Over inflation = decrease flow
 - Flow must be sufficient to ensure proper function of the vaporizer.
 - Nitrous oxide generally **not** used in a closed breathing system.
 - Potential for developing hypoxic gas mixtures with low inflows of oxygen.
 - Completely dependent upon CO₂ absorption.
 - More economic, retain heat and humidity and are less likely to expose personnel to waste gases.
 - **Low-Flow Circle System**
 - Oxygen flow rate greater than the patient's oxygen consumption but less than 22 mL/kg/min.
 - **Advantages:** economical, reduces waste gas and retains heat and moisture.
 - **Disadvantages:** Inadequate delivery of anesthetic is possible from a concentration-calibrated, variable bypass vaporizer during mask induction or during transition from a short-acting injectable anesthetic induction to maintenance via inhalation anesthetic.
 - Use higher flow rates for the first 15 to 30 minutes of anesthesia followed by change to low flow technique.
 - Suggested flow rate for small animals is 10-15 ml/kg/minute.

- **Semi-closed Circle System**
 - Fresh gas flow exceeds the uptake of oxygen and anesthetic by the patient.
 - Traditional flow ranges from 22 to 44 ml/kg/min.
 - Significant amount of excess gas eliminated through pop-off valve.
 - Flow rate should equal patient's oxygen consumption times 3.
 - Nitrous can be used safely.
 - For spontaneous breathing patients, use the system that produces the least resistance to gas flow.
- **To-and-Fro System**
 - Carbon dioxide-absorbent canister located between the endotracheal tube connector and a reservoir bag.
 - Suitable for both large and small animals.
 - Disadvantages are there is a greater potential for inhalation of alkaline dust from the absorbent and it is cumbersome.
- **Mapleson Systems**
 - Do not use chemical absorbent for CO₂ but instead rely on high flow rates.
 - Requires more gas and promotes hypothermia and drying of the respiratory system.
 - Commonly called non-rebreathing systems, but there may be some rebreathing.
 - Dependent on air flow to prevent rebreathing.
 - Do not have valves preventing rebreathing.
 - Useful for smaller species where the dead space volume of a standard circuit is too high.
 - **Two Main Styles; Magill and Bain Coaxial Systems.**
 - **Magill System**
 - ♦ Efficient during spontaneous ventilation.
 - ♦ Fresh gas flow should approximate the patient's minute volume.
 - ♦ Volume of the tubing and bag should be equal to or greater than the patient's tidal volume.



- **Bain Coaxial System**

- ♦ A tube within a tube.
- ♦ Inner tube supplies fresh gases and the external tube removes exhaust gases.
- ♦ Pop-off valve incorporated in the bag.
- ♦ Recommended flow rate range is between 100 and 150 ml/kg/min.



- Ayre's T-Piece and Norman Mask Elbow Systems
 - Classified as Mapleson F systems or Mapleson E systems (without reservoir bag).
 - One end attaches to the endotracheal tube connector and the other end attaches to an expiratory tube.
 - If a reservoir bag is present, the system is called a Jackson-Rees system.
- **Systems With Non-Rebreathing Valves**
 - **Stephens-Slater System**
 - Mainly historical.
 - Contains two one-way valves, which had a tendency to stick.
 - Minimal dead space and resistance to respiration.
- **Resuscitation Bags**
 - Facilitate resuscitation and transport of apneic or anesthetized patients.
 - Allows patient to inhale room air and exhale from exhalation port.

Section 9.4.7: Scavenging Systems

- Exposure to waste gasses is a significant concern and poses a potential health risk.
- Scavenging systems:
 - Gather waste gasses from the system, typically the portion exiting from the pop off valve.
 - An interface prevents transfer of pressure changes in the scavenging system to the breathing system.
 - Are either active or passive.
 - Passive systems rely on the flow of gases within the breathing circuit to push waste gasses into the scavenging system.

- Active devices typically have drawn fans or vacuum, which provide low negative pressure to actively draw waste gasses into the scavenger, are generally safer, and allow less anesthetic gas to be released into the room.
- Both may eliminate waste gasses by venting into the external environment or by passing the waste gas through activated charcoal, which absorbs anesthetic gases.
- Activated charcoal does not absorb nitrous oxide.
- Active devices are generally safer and allow less anesthetic gas to be released into the room.
- Charcoal canisters must be weighed prior to initial use and again after each usage.
- Failure to do this may result in anesthetic gases being vented into the room, exposing personnel.
- Saturation occurs after the canister reaches a predetermined weight given by the manufacturer.

Section 9.4.8: Gas Cylinders

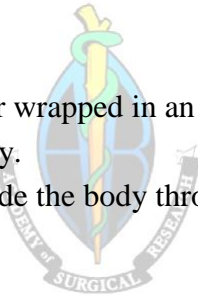
- Gas in tanks is under high pressure.
- Pressure levels of full tanks vary depending on the gas.
- Require use of regulators to access.
 - Regulators are specific for each type of gas and cannot be interchanged due to the thread pattern on the connectors.
 - Regulators allow the pressure of the gas to be reduced to a level acceptable to the anesthesia machine, between 37-50 PSI.
- Gas from large tanks is delivered to the anesthesia machine either remotely via a pipeline, which terminates in a gas specific threaded or “pinned” connector, or directly via high pressure hoses.
- Anesthesia machines are also equipped with hanger yokes for small cylinders (E-tanks) of one or two types of gas (oxygen and nitrous oxide, for example).
 - The “E” tanks that connect through the hanger yokes use a pin-safety index to prevent accidental interchange of gasses.
- **Safety Concerns**
 - Oxygen and nitrous oxide gasses support combustion.
 - Sudden release of gas from a broken cylinder may cause injury or propel other pieces of equipment so as to cause injury.
 - Tanks are typically unbalanced and possess a small base, and if they fall and become damaged, they can become a rocket-like projectile.
 - Tanks should be chained to a wall or cart at all times, and never be left unsecured.
 - Valve stems should be capped when not attached to gas lines or a regulator.
 - Tanks should be stored away from emergency exits and high traffic areas.
 - While tank colors are NOT universally standardized and may vary in color from manufacturer to manufacture, in the US the following code is typical:
 - Green = oxygen
 - Blue = nitrous oxide
 - Yellow = room air
 - Black = nitrogen

- Grey = carbon dioxide
- Do not go by the color to identify unlabeled tanks. Unlabeled tanks should not be used.
- **Oxygen (O₂)**
 - Anesthetized patients can have decreased respiration so room air (compressed medical grade air) won't provide sufficient to maintain appropriate oxygenation.
 - Can be supplied in gaseous form or as a highly pressurized liquid.
 - A full tank of, regardless of the size, has a pressure of ~2200 PSI.
 - When full, an "E" tank contains about 700L of gaseous, and an "H" tank contains about 7000L.
 - The pressure is proportional to the volume, so that an "E" tank with 1100 PSI of pressure contains around 350L of oxygen.
- **Carbon Dioxide (CO₂)**
 - Usually used for rodent immobilization or euthanasia.
 - May be mixed with oxygen for less irritation.
- **Nitrogen (N₂)**
 - Used for powering drills and other equipment.
 - **Medical Grade Air** Mix of gasses similar in composition to normal room air.
- **Nitrous Oxide (N₂O)**
 - Has an anesthetic effect, but no analgesic effects.
 - Used primarily mixed with oxygen to decrease the MAC of the inhalant anesthetic being used.
 - The pressure in a full N₂O cylinder is about 750 PSI at ambient temperatures, and contains both liquid and gas, with ~ 95% of the volume being liquid.
 - As the liquid is vaporized, the cylinder cools and frosting may occur.
 - The pressure is not directly proportional to the volume.
 - Content can be determined based on weight.

Part 10: Physical Methods Of Anesthesia

Section 10.1: Hypothermia

- Metabolism is lowered.
- Heart, brain, liver, and some other vital organs can survive for longer periods at low temperatures without a portion or all of their blood supply (the colder an animal becomes, the less oxygen is required by a given organ).
- May be general or local.
- Shivering must be controlled initially by another anesthetic agent.
- Heart may be stopped for 30 minutes with use of cardioplegic solutions without damage.
- Risks:
 - Profound depression of CNS and vital organs.
 - May cause severe drop in blood pressure.
 - Small lab animals can be cooled to 0°C and recover.
 - Below 28°C heart muscle may show ventricular fibrillation, which will rapidly deplete cardiac muscle stores.
 - Prolongs clotting time.
- Three methods:
 - Immersion: Patient placed in ice water or wrapped in an ice water re-circulating blanket.
 - Pour iced saline slowly into a body cavity.
 - Extracorporeal: Blood is circulated outside the body through a heat exchanger (cardiopulmonary bypass) then back to the body.



Section 10.2: Electronarcosis

- Electrodes are applied to the head delivering electrical currents through the cerebrum.
- Activates opioid and/or non-opioid control centers in the brain.
- Induction characterized by convulsions unless paralytics are administered.
- Endotracheal intubation should always be performed.
- Hyperthermia caused by disturbance of the thermoregulatory center commonly seen.
- Skin burns and brain lesions have been found.
- Produces severe stress.
- Difficult to monitor and ethically questionable.

Part 11: Local & Regional Anesthesia

- ▶ Local anesthetics are a group of chemically related compounds that reversibly bind sodium channels and block impulse conduction in nerve fibers.
- ▶ Include solutions, gels, creams, and aerosols for selective application:
 - topical
 - infiltration of an incision site
 - plexus nerve block
 - epidural
 - regional nerve block
 - spinal anesthesia
- ▶ Classification based on:
 - Potency, which is effected by the size of the molecule and how lipophilic it is.
 - Speed of onset (more lipophilic = quicker onset).
 - Duration of anesthetic effect (increases with increased lipid solubility).
 - Ester-linked (short half-lives, allergic reactions may occur).
 - Low potency, short duration: Procaine, chlorprocaine.
 - High potency, long duration: Tetracaine.
 - Amide-linked (very stable, rely on enzymatic degradation of the liver).
 - Intermediate potency, short duration: Articaine.
 - Intermediate potency and duration: Lidocaine, Mepivacaine, Prilocaine.
 - Intermediate potency, long duration: Ropivacaine.
 - High potency, long duration: Bupivacaine, Levobupivacaine, Etidocaine.
 - Speed of onset associated with lipid solubility and acid dissociation.
 - Rate of vascular absorption varies with vascularity of the injection site and the physicochemical and pharmacological properties of the drug.

Section 11.1: Topical Anesthetics

- Includes lidocaine (2-5%), proparacaine (0.5%), tetracaine (0.5-2%), butacaine (2%), and cocaine (4-10%).
- Effective when applied to mucous membranes.
- Available as injectable but also provided in topical formulations (creams, ointments, gels, powders, and aerosols).
- 14-20% benzocaine (Cetacaine and other brand name gels and sprays) have been implicated in causing methemoglobinemia (hemoglobin is oxidized and unable to carry oxygen), and should be used sparingly.
 - Recent literature suggests that prilocaine may also cause methemoglobinemia.
 - Used to aid in intubation.
 - Lidocaine is a better choice.
- Ethyl chloride will freeze small areas when applied to intact skin, and cause loss of sensation.
 - Should only be used for small areas of skin since freezing large areas can potentially cause frostbite.

- Proparacaine (0.5%) is recommended as a local ocular anesthetic.
- Procaine cream penetrates skin.
- EMLA cream (lidocaine and prilocaine) requires 45-60 minutes for penetration of the skin.

Section 11.2: Infiltration

- May be used on muscles exposed at the surgical site.
- May be used for injectable local anesthesia.
- Most reliable and safest method.
- Lidocaine is the most common local anesthetic.
- Injected SC or ID.
- Shown to have a dose-dependent inhibition of bacterial growth.
- Injected at the intended incision site prior to cutting.
- Used frequently with epinephrine in dental extractions to decrease bleeding.
- Mepivacaine or procaine (w/o epinephrine, which may cause local ischemia and necrosis) may also be used.

Section 11.2.1: Field Block

- Skin is blocked first and then anesthetic infiltrated into deeper areas.
- Used to anesthetize large areas of skin.
- For skin biopsies and removal of small growths within the outer layers of skin.

Section 11.2.2: Local Nerve Block/Plexus Block (nerve plexus)

- Lidocaine is commonly used.
- Injection is given in the vicinity of a main nerve serving a region such as an arm, leg, face, or chest.
- Useful for minor procedures
- Useful to provide analgesia post-operatively
- Animals should be sedated.

Section 11.2.3: Ring Block

- Inject around the circumference of a limb to provide analgesia for the distal portion.

Section 11.2.4: IV Regional Anesthesia (Bier Block)

- Used to anesthetize an extremity for procedures lasting < 90 minutes.
- An IV catheter is placed in the limb vessel.
- A tourniquet is placed proximal to the surgical site.
- The limb is desanguinated by wrapping it tightly with an Esmarch bandage while being elevated to prevent blood from flowing into the limb.
- The tourniquet is then tightened

- Lidocaine is injected into the IV catheter.
- Sensation returns 5-15 minutes after removal of the tourniquet, analgesia lasts up to 30 minutes.
- < 90 minutes duration appears safe, longer than that can lead to ischemic injury.

Section 11.2.5: Epidural

- Lumbosacral (L7-S1) is the common site of epidural administration.
- Excellent for procedures caudal to the umbilicus.
- Useful for cesarean section as it will not depress the infant's systems.
- Allows for a conscious animal to care for babies.
- Check for cerebral spinal fluid or blood flow into needle prior to injection.
- Blood indicates puncture of the central venous plexus.
- Cerebral spinal fluid indicates subarachnoid puncture.
- Drop of saline in the hub of the spinal needle should be "sucked" in.
- Lidocaine or bupivacaine commonly used.
- May be infused continuously via threaded catheters.

Section 11.2.6: Intercostal Nerve Block

- This affects at least two adjacent intercostal spaces because of nerve supply overlap.
- Injection should be at the caudal border of the rib near the intervertebral foramen.

Section 11.2.7: Intrapleural Regional Analgesia

- Useful for reducing pain after trauma to ribs or a thoracotomy.
- Can also be used to treat acute and chronic pain originating from thoracic and upper abdominal structures.
- Injected into the pleural space by either intermittent or continuous administration via a catheter.
- Ineffective if miss-administered into an adjacent space.

Section 11.2.8: General Muscle Block

- Injected into muscles that will be cut, separated, or subjected to extensive manipulation during surgery.

Part 12: Patient Monitoring During Anesthesia

Section 12.1: Reasons To Monitor Anesthesia

- Patient homeostasis is compromised by the administration of anesthetic drugs and the resulting unconscious, recumbent, and immobile state.
- Intra-operative monitoring focuses on insuring an optimal anesthetic depth with minimal physiological impact.
- Allows early notice of trends, which may develop into life threatening conditions.
- Ultimately gives the anesthetist the information to provide better and more precise anesthetic administration
- Assures an appropriate level of anesthesia to minimize detrimental effects of both light and excessively deep levels.
 - Light levels can lead to awareness, pain, and movement.
 - Deep levels cause hypoventilation, hypoxemia, reduced cardiac output, hypotension, inadequate tissue perfusion, hypothermia, and prolonged recovery.
- Anesthetic level represents a balance between the amount of drugs administered, the amount of surgical stimulation, and the severity of any pre-existing illness.
- Anesthetic requirements change over time with an overall decreasing trend within a single anesthetic experience.
 - These changes occur due to variations in the surgical stimulation, the gradual filling of redistribution sites, and variations in body temperature.
- Anesthetists should repeatedly try to decrease the amount of anesthetic administered during the course of a surgical procedure.
 - Keep the animal in a light to medium level of anesthesia; that is, deep enough to avoid conscious perception and provide muscle relaxation yet light enough to maintain desirable physiological parameters.

Section 12.2: Evaluating Depth of Anesthesia

- Recent history of anesthetic dosing.
- Large doses should be associated with a deep level of anesthesia.
- Lower doses over time should be associated with a lighter level of anesthesia in general.
- Spontaneous movement is a reliable sign of a light level of anesthesia, unless paralytics have been given.
- See Section 7.4 for physiological signs seen with specific levels/planes of anesthesia.
- Monitoring trends in physiological parameters, especially heart rate, blood pressure, and respiration, aid in evaluating anesthetic depth, as well as checking reflexes.

Section 12.3: Proper Monitoring

- Evaluate muscle tone and reflexes.
- Signs may vary between species and individuals.

- These signs can vary from minute to minute during a procedure.
- Information should be evaluated based on the animal's reactions and parameters at that instant.
- Previous readings are useful for trends but should not be relied on over "current" readings.
- General anesthetic doses are dependent on the induction drug given, effect, duration of action, amount administered, and the animal's health condition.
- Anesthetist must be aware of the effect of the induction drugs used, approximately when they will wear off, and that at that time the patient will need more anesthetic.
- Anesthetist must know whether or not the patient received analgesia pre-operatively as this will affect the amount of anesthesia needed

Section 12.3.1: Adequate Analgesia

- If the animal is sufficiently anesthetized (unaware/detached from external stimuli) then it may be concluded that sufficient analgesia is present.
- However, some anesthetics provide poor analgesia while loss of consciousness is present, and require additional analgesics, propofol for example.
- Paralytics may cause an animal to appear anesthetized on cursory exam, but it can still feel pain and is aware of surroundings (increasing blood pressure and heart rate is a good indicator of pain in this case)
- Light anesthesia may not completely suppress reflexes or spontaneous movement even though analgesia is achieved.

Section 12.3.2: Adequate Immobilization

- Based on muscle tone.
- Defined based on needs of the surgical procedure.
- Intraocular procedures, thoracic procedures, long bone fracture repair procedures, and laparotomies generally need complete muscle relaxation.
- Some muscle tone is permissible in minor, non-invasive procedures.
- Amount of allowable muscle tone also depends on what the surgeon is doing and what point the procedure is at (incision, abdominal retraction, cautery, suturing).
- Neuromuscular blocking agents may be safer than overly deep anesthesia, as long as proper depth and analgesia are assured.

Section 12.3.3: Physiological Effects of Anesthetic Drugs

- Should be the focus of intra-operative monitoring.
- Watch for excessive bradycardia, arrhythmias, cardiac depression, vasodilation, hypotension, hypoventilation, hypoxemia, or hypothermia.
- Pre-anesthetic exams (baseline values) should provide clues as to which conditions are already present as well as to alert the anesthetist to potential trouble areas.

- Specific physiologic values should be evaluated by looking at the parameter's previous trends, combined with other parameters, and with consideration of the patient's history.
- The goal is to maintain physiological values as close to pre-operative levels as possible.

Section 12.4: Monitoring Respiration & Ventilation

Section 12.4.1: Definitions

- **Respiration:** The total process whereby oxygen is supplied to and utilized by body cells and CO₂ is eliminated by means of concentration gradients.
- **Ventilation:** Movement of gas in and out of the alveoli.
- **Eupnea:** Normal quiet breathing.
- **Dyspnea:** Labored breathing.
- **Tachypnea:** Increased breathing rate.
- **Hyperpnea:** Fast and/or deep respiration, indicating "over respiration".
- **Polypnea:** Rapid and shallow (panting) breathing.
- **Bradypnea:** Slow regular respiration.
- **Hypopnea:** Slow and/or shallow breathing, indicating "under respiration".
- **Apnea:** Transient or longer cessation of breathing.
- **Cheyne-Stokes Respirations:** Increase in rate and depth, and then become slower, followed by brief periods of apnea.
- **Biot's Respirations:** Groups of quick, shallow inspirations followed by regular or irregular periods of apnea.
- **Kussmaul's Respirations:** Deep and labored breathing pattern, frequently associated with severe metabolic acidosis
- **Apneustic Respirations:** Occurs when an animal holds an inspired breath at the end of inhalation for a short period before exhaling.
- **Tidal Volume (VT):** Volume of air inspired or expired in a single breath.
- **Inspiratory Reserve Volume (IRV):** Volume of air that can be inspired over and above the normal tidal volume.
- **Expiratory Reserve Volume (ERV):** Amount of air that can be expired by forceful expiration after a normal expiration.
- **Residual Volume (RV):** Air remaining in the lungs after the most forceful expiration.
- **Minute Respiratory Volume or Minute Ventilation (VE):** VT times Respiratory Frequency (f); the volume of gas either inspired or expired per minute
- **Pulmonary Capacities:**
 - **Inspiratory Capacity (IC):** tidal volume plus the IRV; the amount of air that can be inhaled after a normal expiration and distending the lungs to the maximum amount.
 - **Functional Residual Capacity (FRC):** ERV plus RV; the amount of air in the lungs after a normal expiration.

- **Vital Capacity (VC):** IRV plus VT plus ERV; the maximum amount of air that can be expelled from the lungs after first filling them to maximum capacity.
- **Total Lung Capacity (TLC):** IRV plus VT plus ERV plus RV; the maximum volume to which the lungs can be expanded with the greatest possible inspiratory effort, or by full inflation to 30 cm H₂O.

Section 12.4.2: Respiration Basics

- Gas Transfer: the passing of gasses across a membrane.
- Anatomical Dead Space: Portion of the tidal volume (Vt) that reaches only the upper airway and trachea-bronchial tree, this is referred to as the dead space volume (VD anat).
- Respiration is dependent on a pressure gradient between alveoli and outside atmosphere.
- During inspiration active muscular effort is used to expand the thoracic wall and contract the diaphragm.
- Expiration is a passive process where the chest wall returns to a normal position.
 - Exception is the horse, where abdominal muscle contraction is used during expiration (biphasic mode of exhalation).
- Air flow is dependent on the diameter of the passages.
 - Smaller the diameter, the greater the resistance to flow.
- Alveolar air is the critical component.
- Gas is transferred to/from the blood via pressure gradients, allowing the absorption of oxygen and the elimination of carbon dioxide.
- Hypercapnia: elevated PaCO₂ causing respiratory acidosis.
- Hypocapnia: lowered PaCO₂ causing respiratory alkalosis.
- Eucapnia: normal PaCO₂.
- Hypoxia: abnormally low oxygen in the lung, blood, and/or tissues, resulting in abnormal organ function or cellular damage.
- Hypoxemia: insufficient oxygenation of the blood to meet metabolic requirements.
- Apneic threshold: the PaCO₂ level at which ventilation becomes zero; where spontaneous ventilatory effort ceases.
- Under general anesthesia, nasal and pharyngeal musculature relaxes and the cough reflex is abolished.
 - this may allow obstruction especially in brachycephalic dogs.
- Normal respiratory rates vary between species.
- A change in breathing rate is a sensitive indicator of an underlying change in the status of the patient.
- Bradypnea (slow regular respiratory rate) – sign of deep anesthesia or hypothermia.
- Tachypnea (accelerated breathing) – causes can include:
 - Too lightly anesthetized
 - Too deeply anesthetized
 - Hypoxemia
 - Hypercapnia
 - Hyperthermia
 - Hypotension
 - Atelectasis

- Postoperative recovery phase or pain
- Drug induced (opioids)
- Arrhythmic breathing patterns are usually the effect of a medullary respiratory control problem.
 - However, some abnormal patterns may be normal in certain species.
 - A Cheyne-Stokes pattern (cycling between hyperventilation and hypoventilation) is normal in horses but may be a sign of congestive heart failure or other heart or brain disorders in most species.
 - Apneustic breathing (inspiratory hold) may be seen in healthy cats, dogs, and most species anesthetized with ketamine.
- Respiratory volume may be estimated visually, by reservoir bag inflation, or by using a ventilator or ventilometer.
- Normal tidal volume is 10-20 mL/kg/respiration.
- Normal total minute ventilation (TMV) is 150-250 mL/kg/min in dogs.
- Alveolar minute volume may range from 20-70% of TMV.
- Arterial CO₂ and O₂ levels may be analyzed by taking arterial blood and measuring with a blood-gas analyzer.
 - Venous blood has a tissue bed between it and the lungs where gas exchange takes place and thus is not a good measure of respiratory function.
 - Samples should be run immediately or stored in ice water.
- **Partial Pressure of CO₂ (PaCO₂)**
 - Measures ventilatory status of the patient.
 - Normal range between 35 and 45 mmHg.
 - PaCO₂ > 60 mmHg indicates excessive respiratory acidosis and may warrant mechanical ventilation.
 - PaCO₂ < 20 mmHg may be a sign of severe respiratory alkalosis and decreased cerebral blood flow.
 - Venous CO₂ is usually 3 to 6 mmHg higher than arterial CO₂.
 - PaCO₂ may be estimated by measuring end tidal CO₂.
 - A lowered blood CO₂ level is hypocapnia.
 - Most often caused by hyperventilation.
 - An elevated level is hypercapnia.
 - May be caused by:
 - ◆ Excessive anesthetic depth.
 - ◆ Intracranial disease or cervical disease.
 - ◆ Airway obstruction.
 - ◆ Thoracic or abdominal restrictive disease.
 - ◆ Pleural space filling disorder (air or fluid).
 - ◆ Terminal pulmonary parenchyma disease.
 - ◆ Improper ventilator settings.
 - ◆ Hyperthermia.
 - ◆ Recent bicarbonate therapy.
 - Normal CO₂ level is eucapnia

- **End tidal CO₂ (ETCO₂):**

- Measures the CO₂ sampled from the breathing circuit at the end of an exhalation.
 - Accuracy is subject to mechanical factors with the breathing circuit, such as volume, dead pockets, tubing diameter, gas flow, etc.
 - Usually somewhat lower than PaCO₂.
 - Plateau with a drop to the right may indicate a leak in the circuit as the pressure of inspiration is not held.
 - Animals with ETCO₂ over 30-40 mmHg will usually breathe on their own.
 - Towards the end of the procedure, the animal should be weaned off the ventilator to restart spontaneous respiration.
 - Gradually slow the rate and/or volume to increase ETCO₂ to > 30 to 40 mmHg.
 - During open-skull procedures (craniotomies), values between 18 and 20 mmHg will help prevent brain swelling.

- **Partial pressure of O₂ (PaO₂)**

- Measures the oxygenating efficiency of the lungs.
- Is a measure of the oxygen dissolved in the blood and is related to hemoglobin saturation (SaO₂) but is not the same thing.
- Usually 80 to 110 mmHg if breathing room air (21% O₂).
- Animals breathing 100% oxygen will have values around 500 mmHg in small animals and > 200 mmHg in horses.
- Hypoxemia occurs at PaO₂ < 80 mmHg.

- **Pulse Oximetry (SpO₂)**

- Measures the percentage of oxygenated hemoglobin and heart rate.
- Sensor transmits infrared light on tissue and records the absorption either of light passing through the tissue to a receiver on the other side (transmission) or reflected back to the sensor (reflectance), depending on the type of sensor
- Other tissues also absorb light and thus pulse oximeters have a variety of computational ways to interpret the data.
- Is broadly accurate for SaO₂.
 - Normally SpO₂ is 90-95% in spontaneously breathing animals and 95-100% in ventilated animals when on 100% O₂.
- SpO₂ readings are susceptible to lowering by positional factors (slipping away from tissue, thick tissue, pigment), vasoconstriction, drying of contact surface, and confusion with respiratory artifact or movement.
- If an animal becomes hypotensive, the pulse waveform will first become smaller, and then will be lost.
- Some arrhythmias can be detected both by looking at the pulse waveform and by listening to the accompanying tone (regular heart beat = regular tone).
- The pitch of this tone changes in correlation with the oxygen saturation on most monitors; the higher the pitch, the higher the saturation.

- HR in anesthetized dogs is usually ~ 60-100 bpm.
- HR in anesthetized cats is usually ~100 bpm.
- **Venous Admixture**
 - Collective term for all of the ways blood can pass from venous return to arterial supply without being properly oxygenated (hypoxemia).
 - Equipment problems
 - Decreased oxygen inspiratory supply
 - Hypoventilation
 - Bronchoconstriction
 - Atelectasis
 - Inhalation toxicity (diffusion impairment)
 - Anatomic right-to-left shunt.

Section 12.5: Cardiovascular Monitoring

**Section 12.5.1: Electrocardiogram (ECG) **

- **Monitors electrical impulse as it is conducted through the cardiac tissue.**
 - P Wave is the transmission of the impulse from the sino-atrial (SA) node through the atria.
 - QRS Complex is the ventricular depolarization that precedes contraction.
 - T Wave is ventricular repolarization.
 - PR Interval lasts from the beginning of atrial excitation to the beginning of ventricular excitation.
 - QT Interval is the period of ventricular depolarization and repolarization.
 - U Wave.
 - Uncertain origin.
 - Relatively uncommon.
 - More frequently seen in larger species.
- **Abnormalities observed include:**
 - **Tachycardia:** accelerated heart beat (typically >25% of normal). Rates > 160 -180 bpm in cats and dogs.
 - **Bradycardia:** slowed heart beat (typically >25% of normal). Rates < 60 bpm in dogs, 90 bpm in cats, and 20 bpm in horses.
 - **Heart Block:**
 - Indicates impaired electrical transmission through the AV node.
 - 1st degree: increased PR interval.
 - 2nd degree: blocked P wave.
 - 3rd degree: dissociation of P wave and QRS complex.

- **Common Arrhythmias:**

- Arrhythmias are abnormal depolarization, repolarization, and/or contraction of the heart as seen with an ECG

- **Sinus Tachycardia**

- P wave seen more closer than normal after the T wave.
- May be described as “T on P”.
- Somewhat common and not typically dangerous except in compromised patients or if it reflects inadequate coronary blood flow.

- **Sinus Arrhythmia**

- Described as a “regular irregularity”
- Common in beagles
- Frequently seen in animals on a ventilator
- Heart rate increases with inspiration and slows with expiration
- Not concerning

- **Premature ventricular contractions (PVCs)**

- Extra, abnormal heartbeats indicating dangerous arrhythmias
- Commonly caused by hypoxemia and/or hypercarbia and traumatic myocarditis
 - ♦ Can also be seen when inserting jugular catheters if the catheter is placed too deep.
 - ♦ When placing an indwelling jugular catheter, observe the ECG for PVC’s and back it out if observed
- Single PVC’s are not usually a problem but a series may result in decreased cardiac output and coronary perfusion and may lead to ventricular fibrillation.
- Some species, such as pigs, are more susceptible to PVS’s than other species and should be pre-treated with anti-arrhythmic drugs when performing coronary procedures

- **Ventricular Fibrillation**

- Indicates cardiac arrest is eminent.
- Is a pulseless arrhythmia with irregular and chaotic electrical activity and ventricular contraction in which the heart immediately loses its ability to function as a pump.
- Little or no blood is pumped from the heart.
- Sudden loss of cardiac output, with subsequent tissue hypoperfusion, creates global tissue ischemia, putting brain and myocardium most at risk.
- Primary cause of sudden cardiac death.
- Can be counteracted by electrical current (defibrillation).
 - ♦ Defibrillation is not always effective and may cause burns and permanent damage to the heart.
 - ♦ Need to consider if resuscitation attempts are a viable option or if animal is automatically disqualified from the study protocol.

Section 12.5.2: Peripheral Perfusion Monitoring

- Capillary Refill Time (CRT) and Mucous Membrane Color
 - Measures the time required for refilling blanched mucus membranes.

- Observe the color of mucus membranes.
- CRT should be 1-2 seconds and gums (when not pigmented) should be pink.
 - Other sites to observe color are tongue, buccal mucous membrane, conjunctiva of the lower eyelid, and the mucous membranes about the prepuce or vulva.
 - Pale membranes indicate poor perfusion, blood loss, or anemia.
 - Purple/blue membranes indicate cyanosis.
- If peripheral perfusion is low, pulse oximeters and indirect blood pressure monitors will most likely not work.

Section 12.5.3: Central Venous Pressure (CVP)

- Luminal pressure of the intrathoracic vena cava.
- CVP is the relationship between central blood volume and central blood volume capacity.
- Central blood volume is determined by venous return and cardiac output.
 - Measured via catheters placed via the left jugular vein into the anterior vena cava.
 - May stimulate ectopic pacemaker activity.
- Normally 0-10 cmH₂O in small animals; 15-30 in laterally recumbent horses and 5-10 in dorsally recumbent horses.
- Low or below range values indicate hypovolemia and suggest a rapid bolus of fluids to be administered.
- Above range values indicate hypervolemia and fluid therapy should be stopped.
- Important measurement when heart failure is a concern.
- Does not predict or indicate level of cardiac output or stroke volume.

Section 12.5.4: Arterial Blood Pressure

- Effected by the blood volume and blood volume capacity.
- Arterial blood volume is determined by cardiac output and systemic vascular resistance.
- Primary indicator to assess cerebral and coronary perfusion.
- Systolic pressure is determined by stroke volume and arterial compliance.
- Diastolic pressure is determined by systemic vascular resistance and heart rate.
- Mean pressure is the average pressure and most important because it represents the mean driving pressure for organ perfusion.
 - Can be estimated by the following formula: (diastolic pressure – systolic pressure)/3.
- Peripheral artery pulse amplitude quality may not closely match central arterial blood pressure.
- Methods of monitoring include:
 - **Indirect Blood Pressure**
 - **Sphygmomanometry**
 - Monitored with an occlusion cuff placed around an appendage over an artery and a method to hear or detect the flow of blood.
 - Cuff should be 40% as wide as the circumference of the limb and placed snugly around the limb.

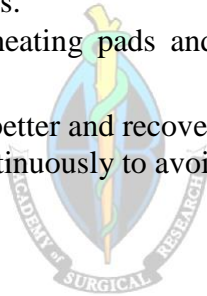
- If applied too tightly, the cuff will partially occlude blood flow (prior to being inflated) and an artificially lower measurement will be obtained.
 - If applied too loosely, the cuff will require increased pressure for contact and the measurement obtained will be artificially high.
 - Cuff should be inflated until it occludes the flow of blood (cuff pressure exceeds the systolic pressure).
 - As the cuff pressure is gradually decreased, blood will begin to flow intermittently (in a pulsatile fashion). At this point, the cuff pressure is just below the systolic pressure, the flow of blood will start to be detected, and the needle of the manometer will begin to oscillate; this reading corresponds to the systolic pressure.
 - The cuff pressure continues to be decreased. When steady blood flow is detected, and a pulse is palpated below the cuff, the reading obtained corresponds to the diastolic pressure.
- **Doppler Ultrasound**
- A piezoelectric crystal is placed over the artery.
 - It transmits energy whose frequency changes based on the movement of the underlying tissue.
 - Uses reflected sound waves to see how blood flows through a blood vessel.
 - The movement of blood cells causes a change in pitch of the reflected sound waves.
 - Also uses a pressure cuff to occlude blood flow.
 - As the cuff pressure is decreased, the point at which blood can be heard pulsing through the artery is the diastolic pressure.
 - As the cuff pressure continues to be decreased, the point at which the sound change occurs (becomes steady and not pulsatile) is the systolic pressure.
 - Closely correlates with direct arterial measurements.
- **Oscillometry**
- Measures the fluctuation of pressure in the cuff as it is slowly deflated.
 - Provides a digital reading of systolic pressure, diastolic pressure, mean, and heart rate.
 - Is the standard style for mechanical, automatic blood pressure monitors.
- **Direct Blood Pressure**
- Involves placement of a catheter into an artery either surgically or percutaneously.
 - Needs to be attached to a monitoring device, such as a transducer attached to equipment, which converts the pressure wave into a digital signal.
 - Fluid filled catheters generally need to be flushed with heparinized saline or other solution to prevent clot formation at the tip of the catheter.
 - The catheter must be made of material with low compliance so that the pressure wave is passed without loss of amplitude.
 - Solid state catheters have no lumen but rather a pressure sensor that transmits the signal electronically, so no flushing is needed.
 - Gives a continuous reading of pressure.

Section 12.5.5: Cardiac Output

- More relevant to systemic perfusion (flow) than a pressure value.
- Reduced by hypovolemia, ventricular restrictive disease, decreased contractility, bradycardia, tachycardia, arrhythmias, retrograde flow (regurgitation), and stenosis.
- Generally obtained via thermodilution with the placement of a Swann-Gantz catheter.
 - Chilled saline of a known temperature and volume is flushed into the artery and the rapidity of the resultant temperature change is measured.

Section 12.6: Temperature

- Anesthetized animals lose the ability to thermoregulate normally.
- Temperatures can drop due to shaving relatively large areas, the evaporation of prep solutions, evaporation at and chilling of tissues within surgical incisions, and vasodilation caused by anesthetic agents/adjuncts.
- Hypothermia will prolong anesthesia recovery.
 - Avoid hypothermia via heating blankets (water circulating, warm air blankets) and/or heated tables, warm IV fluids and irrigation fluids (saline), and covered extremities.
- Hyperthermia is also possible and dangerous.
 - May be caused by overheating with heating pads and tables or due to anesthetic reactions such as malignant hyperthermia in swine.
- Normothermic patients tolerate anesthesia better and recover faster.
- Body temperature should be monitored continuously to avoid hypothermia and hyperthermia.



Part 13: Pain Assessment & Management

Section 13.1: Definitions

- **Pain:** An unpleasant (noxious) sensory and emotional experience associated with actual or potential tissue damage.
- **Suffering:** An unpleasant emotional state that is internalized and not outwardly expressed; originating from either a physical or physiological source.
- **Distress:** The external expression through behavior or emotion of suffering that an observer can see (anxiety, fear, aggression, or hyperactivity).
- **Algology:** The science and study of pain.
- **Allodynia:** Pain caused by a stimulus that does not normally provoke pain.
- **Analgesia:** Absence, or decrease, of pain in the presence of a stimulus that would normally be painful.
- **Analgesic:** Drug(s) that induce analgesia.
- **Anesthesia:** Absence of all sensory modalities, can be local, regional, or general.
- **Anesthetics:** Drugs that induce regional or general anesthesia.
- **Causalgia:** Syndrome of prolonged burning pain, allodynia, and hyperpathia after a traumatic nerve lesion, often combined with vasomotor and sudomotor (sweating) dysfunction and later trophic changes.
- **Central Pain:** Pain associated with a lesion of the CNS.
- **Chronic Pain:** Pain that persists for longer than the expected time frame for healing or pain associated with progressive disease.
- **Deafferentation Pain:** Pain caused by loss of sensory input into the CNS, as occurs with avulsion of the brachial plexus or other types of peripheral nerve lesions, or caused by pathology of the CNS.
- **Dysesthesia:** An unpleasant spontaneous or evoked abnormal sensation, especially induced by touch.
- **Hyperalgesia:** Increased response to a stimulation that is normally painful.
- **Hypoalgesia:** Diminished sensitivity to noxious stimulation.

- **Inflammatory Pain:** Spontaneous pain and hypersensitivity to pain in response to tissue damage and inflammation.
- **Neuralgia:** Pain in the distribution pathway of a nerve or nerves.
- **Neuritis:** Inflammation of a nerve or nerves.
- **Neuropathic Pain:** Spontaneous pain and hypersensitivity to pain in association with damage to the nervous system.
- **Neuropathy:** Disturbance of function or a pathologic change in a nerve.
- **Nociception:** Reception, conduction, and CNS processing of nerve signals generated by the stimulation of nociceptors. It is the physiologic process that when carried to completion results in the conscious perception of pain.
- **Nociceptor:** Receptor preferentially sensitive to a noxious stimulus or to a stimulus that would become noxious if prolonged.
- **Nociceptor Threshold:** Minimum strength of a stimulus that will cause a nociceptor to generate an impulse.
- **Noxious Stimulus:** Stimulus that is actually or potentially damaging to tissue or is of a quality or intensity to trigger nociceptive reactions.
- **Pain Threshold:** The least experience of pain that a subject can recognize. In most cases is higher than the nociceptor threshold. Relatively constant among species and individuals.
- **Pain Tolerance:** Greatest level of pain that a subject will tolerate. Varies considerably between species and individuals and is influenced by prior experience, environment, stress, and drugs.
- **Pain Tolerance Range:** Difference between the pain detection threshold and the pain tolerance threshold.
- **Paresthesia:** A sensation of tingling, tickling, pricking, or burning of a person's skin with no apparent physical cause. Spontaneous or evoked abnormal sensation. Not painful, as opposed to dysesthesia.
- **Radiculalgia:** Pain along the distribution of one or more sensory nerve roots.
- **Radiculopathy:** Disturbance of function or pathological change in one or more nerve roots.
- **Radiculitis:** Inflammation of one or more nerve roots.

- **Reflex:** Involuntary, purposeful, and orderly reactions to stimulus. The anatomic basis for the reflex arc consists of a receptor, a primary afferent nerve fiber associated with the receptor, a region of integration in the spinal cord or brain stem and a lower motor neuron leading to an effector organ (skeletal or smooth muscle or glands).
- **Reaction:** Combination of reflexes designed to produce a widespread movement in relation to the application of a stimulus. Reactions are mass reflexes not under voluntary control and therefore do not involve the cerebral cortex.
- **Response:** Willful movement of the body or parts of the body that requires involvement of the somatosensory cerebral cortex.
- **Somatic:** Describes input for body tissues other than viscera (skin, joints, muscles and other deep tissues).
- **Somatic Pain:** General nociceptor based pain; originates from skin, joints, and muscles.
- **Visceral Pain:** Originates from abdominal organs; more “internal” pain than somatic pain, and cannot be evoked from all organs (such as the liver and kidneys).
 - Not evoked by burning and cutting.
 - Poorly localized.
 - May be from nociceptors or other receptors that may have other functions.
- **Wind-up** (hypersensitization): a cascade of events resulting from ongoing stimulation of nociceptors and activation of the N-methyl-D-aspartate receptors (NMDAs); causes hyperalgesia and opioid tolerance
 - Results from untreated pain.
 - Neurons in the dorsal horn are sensitized due to release of excessive quantities of neurotransmitters, which lowers the firing threshold of nociceptors.
 - Nociceptors do not demonstrate fatigue with repeated stimulation.
 - Rather, they display enhanced sensitivity, lowered threshold of stimulation, and prolonged and enhanced response to stimulation.
 - Following a barrage of afferent nociceptor impulses, hypersensitization of dorsal horn cells occurs, resulting in an increased rate of discharge (wind-up).
 - In short, wind-up allows increased sensitization in nerve tissue to noxious stimulus, a sensitivity that can expand the receptive field to include distant nerves.
 - This creates greater pain from a stimulus than it might otherwise cause.
 - More analgesics are needed to relieve pain once windup occurs.
 - Wind-up can be prevented through the use of local preemptive analgesics and/or the prompt or preemptive use of general analgesics.
 - In severe cases, anesthesia followed by epidural or intrathecal administration of local anesthetics may be required.
 - Peripheral nerve blockage is not as effective at this point.
 - Systemic opioids have little effect at normal therapeutic doses.

Section 13.2: Common Types of Pain

– Acute Pain

- Occurs immediately after a stimulus is received.
- Severity can vary.
- Responds well to treatment.
- Subsides once stimulus is removed.

– Chronic Pain

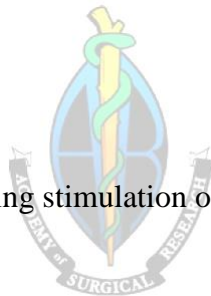
- Persists well past initial stimulus (3-6 months).
- Severity can vary.
- May or may not respond well to treatment; may require a “multi-modal” approach.
- Can result in allodynia, hyperalgesia, and opioid tolerance.

– Physiological Pain

- Is a protective mechanism.
- Causes avoidance.
- Little to no tissue injury.
- Pain stops once the stimulus is removed.

– Pathological Pain

- Results from tissue injury.
- Inflammation occurs in the area.
- Nerve damage.
- Release of neurotransmitters with ongoing stimulation of nociceptors.
- Can lead to hyperalgesia.
- Persists after the stimulus is removed.

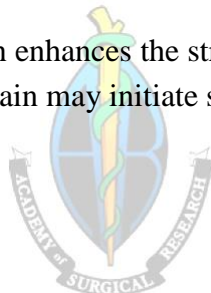


Section 13.3: Physiology of Pain

- Damaged cells release substances, which stimulate nociceptors and inflammation.
- Noxious stimuli activate nociceptors, which become sensitized with stimulation, resulting in a lowered stimulation threshold.
- Sensitized nociceptors cause the release of glutamate and neurokinins from the afferent terminals in the spinal cord.
- Activates NMDA receptors, which are implicated in hypersensitivity (wind-up)
- Afferent neurons in the spinal cord relay the signal to multiple areas in the brain, resulting in the perception of pain.
- “Gate control” occurs in the spinal cord, resulting in early inhibition of nociception, allowing escape.
- Stimulation of medullary centers result in hyperventilation, increased cardiac output, increased blood pressure, and increased secretion of catecholamines and other endocrine hormones.

- Cortisol and other hormones are released which causes increased blood glucose and ketone levels and increases the rate of metabolism and oxygen consumption.
- Magnitude and duration of these effects parallel the degree of tissue damage.
- These same physiological responses occur in properly anesthetized or unconscious patients but do not result in the sensation of pain due to a nonfunctioning cerebral cortex.
 - Administration of preemptive analgesics decreases this response.
 - Descending neurons act to modulate pain by reducing sensation.
 - Various neurotransmitters are released: glutamate, norepinephrine, serotonin, gamma-aminobutyric acid (GABA) and endorphins
 - Analgesia can be induced by blocking the nociceptive process at one or more points.
 - Causes cortically mediated increases in blood viscosity, clotting time, fibrinolysis, and platelet aggregation.
 - May lead to intense vasoconstriction, which leads to ischemia, tissue hypoxia, and release of substances toxic to the myocardium.
 - May result in renal failure.
 - May lead to muscle spasms, disuse of injured area/region, muscle atrophy, hypoventilation, weight loss, dehydration.
 - Pain also causes anxiety and fear, which enhances the stress response.
 - Severe posttraumatic or postoperative pain may initiate shock.

Section 13.4: Nociception



- Pain \neq Nociception
 - Pain is a product of higher brain center processing of signals it has received.
 - Nociception refers to the peripheral and central nervous systems processing information generated by stimulation of nociceptors by noxious stimuli.
 - Nociception can occur in the absence of pain.

Section 13.4.1: Types of Nociceptors

- **A(δ) fibers**
 - Myelinated
 - Conduct impulses rapidly
 - Trigger sensation of first pain (sharp, pricking pain)
- **C - Fibers**
 - Unmyelinated
 - Slow conducting
 - Associated with dull, burning, or longer lasting pain
 - Stimulated by chemicals released in damaged or inflamed tissues
 - High threshold under resting conditions

- Relatively insensitive to any stimuli under normal circumstances
- The release of tissue-inflammatory mediators reduces their threshold and allows them to be activated by thermal and mechanical stimuli
- Produce hyperalgesia.

Section 13.4.2: Parts of the Nociceptive Process

- There are four distinct processes involved in nociception, which can be modulated by analgesics.
 - **Transduction**
 - The translation of noxious stimuli into electrical nerve impulses at the peripheral nociceptor.
 - Can be blocked by local anesthetics by injection either at the site of injury/incision or intravenously.
 - Can be decreased by the use of NSAIDs or corticosteroids, which decrease the production of prostaglandins at the site of injury.
 - **Transmission**
 - The propagation of nerve impulses through the nervous system to the spinal cord.
 - Inhibited by local anesthetic blockade of peripheral nerve bundles, of the nerve plexus, or injection in the epidural or subarachnoid spaces.
 - Prevented by alpha-2-agonists.
 - **Modulation**
 - occurs once the pain signal reaches the spinal cord, where it stimulates the release of chemicals which aid in inhibiting the signal (endorphins) as it passes to the brain (inhibits the spinal dorsal horn cells).
 - Effected by local anesthetics, alpha-2-agonists, NMDA antagonists, and anticonvulsants.
 - **Perception**
 - The final phase and occurs only in the conscious patient; “knows” that pain is present and results in vocalization, withdrawal, and sometimes aggression; is the subjective, emotional experience of pain.
 - Interrupted by anesthesia.
 - Inhibited/altered by opioids, alpha-2-agonists, benzodiazepines, and phenothiazepines, general anesthetics.

Section 13.5: Response to Injury

- Damaged cells in traumatized tissues release numerous chemical agents which promote inflammation, which:
 - Increases permeability of capillary walls to allow infiltration of macrophages.
 - Increases blood flow to area resulting in erythema/edema.
- Neurotransmitters are released which stimulates nociceptors
- Initially acts as a protective mechanism, so that the individual will guard the area to prevent further injury.

Section 13.6: Control of Pain

- Pre-emptive Analgesia: giving analgesics prior to the noxious stimulus (surgery).
 - By blocking or inhibiting the nociceptive process before it begins, hypersensitivity is prevented
 - Decreases the amount of anesthesia and post-operative analgesia needed.
- Multimodal or “balanced” analgesia: using a combination of analgesics that impact more than one portion of the nociceptive process.
 - For example: buprenorphine and meloxicam pre-surgically, lidocaine block used prior to the incision and bupivacaine splash prior to closing incision
- Non-pharmaceutical methods may be beneficial and should be considered when possible
 - Application of ice packs during recovery
 - Splints/bandages can provide support and reduce swelling/inflammation

Section 13.7: Analgesics

- Divided into five main classes based on mode of action:
 - Opioids
 - Non-steroidal anti-inflammatory drugs (NSAIDs)
 - Local anesthetics
 - Alpha₂-adrenoceptor agonists
 - Miscellaneous drugs



Section 13.7.1: Opioids

- Also termed “narcotic analgesics” because of their ability to induce narcosis.
- Side effects:
 - Induce CNS depression accompanied by miosis, hypothermia, bradycardia, and respiratory depression in primates, dogs, rats, and rabbits.
 - May induce CNS stimulation, mydriasis, panting, tachycardia, and hyperkinesis in horses, cats, ruminants, and swine.
 - Depress respiratory and cough centers.
 - May induce nausea and vomiting.
- Mice and rats quickly develop tolerance.
- Well absorbed from GI, IV, SC, IM, IT, and transdermal (in special preparations) administration.
- Act by raising the pain threshold or decreasing the perception of pain at the CNS.
- Alter the emotional component of pain to make it more tolerable.
- Drugs of choice for severe, acute pain.
- Initially extracted from a species of poppy plant (opium and laudanum)
- Contains approximately 20 active compounds, termed opiates, including morphine and codeine.
 - The term opioid is used to describe the derivatives of the compounds purified from opium.

- Opiates and opioids bind to specific receptors and mimic the effect of endogenous opioids called endorphins.
 - Mu, delta, and kappa receptors (mostly mu (μ) but also kappa (κ))
 - Distributed in the brain, spinal cord, and peripheral system.
 - Most activity is at the mu receptor (analgesic as well as adverse side effects).
- Are controlled substances requiring special licenses and documentation of usage
- Are categorized as receptor agonists, partial agonists or mixed agonists-antagonists.
- **Agonists** – include morphine and fentanyl
 - **Morphine**
 - Active at all three receptors.
 - Most effective analgesic.
 - Typically lasts 3 to 4 hours.
 - Poor lipid solubility allows it to produce long lasting analgesia when given in the epidural or subarachnoid space, lasting 12 to 24 hours.
 - Frequently causes vomiting.
 - IV administration can lead to histamine release.
 - **Fentanyl**
 - 250 times more potent than morphine.
 - Rapid onset of action.
 - Short duration with peak at 30 minutes.
 - Depresses respiration and may persist for hours.
 - Causes vagal mediated bradycardia unless countered (atropine).
 - Due to shorter action, commonly administered as a continuous infusion during surgery.
 - May be used in combo with benzodiazepine to induce general anesthesia in canine patients with CV instability.
 - Available in a transdermal patch
 - Agonists decrease the amount of anesthesia required.
 - Are potent opioid analgesics.
 - Have more serious potential side effects than the mixed agonist/antagonists, such as respiratory depression, bradycardia, vomiting, and constipation.
 - Combined with tranquilizers for neuroleptanalgesic balanced anesthesia.
 - Can be administered intravenously, intramuscularly, via transdermal patches, and epidurally +/- local anesthetics
 - Can be reversed with naloxone
- **Mixed Agonist-Antagonist** – includes butorphanol
 - Have agonist or partial agonist activity at one or more opioid receptors and the ability to antagonize the effects of a full agonist at one or more opioid receptors
 - Butorphanol is a mu antagonist and kappa agonist
 - Butorphanol isn't routinely used for analgesia currently due to its dosing frequency
 - Less respiratory depression than full agonists
 - Can be used post-operatively to reverse the narcosis of fentanyl while still providing analgesia.
 - Has a “ceiling” effect, at which point increased doses won't have any further effect

- **Partial Agonist** – includes buprenorphine
 - Has both agonist and antagonist activity at the mu receptor.
 - Can be used to reverse pure mu agonists.
 - Buprenorphine has a relatively prolonged duration of action.
 - Also has a potential for ceiling effect.

Section 13.7.2: Non-steroidal Anti-inflammatory Drugs (NSAIDs)

- NSAIDs are weak organic acids with anti-inflammatory, analgesic, and antipyretic properties.
- Inhibit prostaglandin production by inhibiting cyclooxygenase (COX) enzymes
- Are either non-selective (inhibits both COX iso-enzymes) or selective for COX-2
- Non-selective NSAIDs have more serious side effects (gastric ulceration and renal toxicity).
- Decreased renal blood flow during anesthesia makes kidneys more susceptible to toxic effects
- Carprofen and meloxicam are COX-2 selective inhibitors which have a reasonable margin of safety when used pre-operatively

Section 13.7.3: Local Anesthetics

- Decrease or prevent Na⁺ permeability of the membrane of neurons, which stops the transfer of signals along the peripheral nerves
- Prevent central sensitization since the nociceptive signal is blocked
- Classified by duration of action
 - Lidocaine is short acting with a rapid on-set
 - Bupivacaine is long acting with a slow on-set
 - Duration of action can be extended by adding a vasoconstrictor like epinephrine
- Multiple uses and routes of administration
 - **Topical**
 - Most are applied to mucous membranes but some preparations will be absorbed through skin
 - 0.5% proparacaine is recommended for examining eyes.
 - Lidocaine and benzocaine sprays are used to assist in intubation (benzocaine has been implicated in methemoglobinemia and should be used sparingly and with caution).
 - Xylocaine jell can be used to lubricate endotracheal tubes and urinary catheters.
 - EMLA cream contains lidocaine and prilocaine and is used to numb skin.
 - **“Splash Block”**
 - Can be applied to exposed tissues prior to closure and to nerves prior to transection during amputations.
 - “Soaker catheters”, also called wound or diffusion catheters, left subcutaneously to provide an infusion of local anesthetics after major surgeries like amputations.
 - Need to be aware of infusion rates to avoid toxicity.

- **Infiltration**
 - Multiple intradermal or subcutaneous injections of local anesthetic along proposed incision line
 - May contain epinephrine (1:200,000) to increase effect and duration.
- **Field Block**
 - Used to anesthetize large areas
 - Intradermal or SQ infiltration followed by injection deeply enough to infiltrate nerves.
- **Regional Block**
 - Injection into the connective tissue surrounding a nerve.
 - Can produce loss of sensation and/or paralysis in the region supplied by the nerve.
 - Requires smaller volumes than field blocks, reducing the risk of toxicity.
- **Epidural**
 - Administered alone or in combination with other analgesics, like opioids.
 - If combined, smaller doses can be used, decreasing risks of adverse effects.
 - Can cause motor deficits at higher doses.

Section 13.7.4: Alpha₂-Adrenergic Agonists

- Stimulation of the alpha₂– adrenoceptors result in sedation, muscle relaxation, and analgesia.
- Can be reversed with alpha₂-adrenergic antagonists such as yohimbine and atipamezole.
- Includes xylazine, medetomidine, and dexmedetomidine.

Section 13.7.5: Miscellaneous Analgesics

- **Tramadol**
 - Synthetic opioid agonist, which also inhibits serotonin and norepinephrine re-uptake in the spinal cord.
 - The main metabolite has moderate opioid activity.
 - Only available as an oral formulation in the US; available as an injectable in UK.
- **Ketamine**
 - NMDA antagonist.
 - When used as a constant rate infusion (CRI) during surgery at sub-anesthetic doses, it reduces MAC and can help prevent hypersensitivity.
 - More effective treating somatic pain than visceral pain.
 - Can be administered via epidural injection.
- **Gabapentin**
 - Analogue of the naturally occurring neurotransmitter GABA.
 - Believed to increase production of GABA, which is part of endogenous inhibition of nociception.
 - Used to treat nerve pain.

Section 13.8: Pain Recognition & Assessment

- Structures involved in the sensation of pain are very similar in humans and animals.
- Reasonable to assume that if something is painful in people, is damaging or potentially damaging to tissues, and/or induces escape or adverse emotional responses in the animal's behavior (signs of distress, avoidance behavior, vocalization, and changes in body posture) it should be considered painful to the animal.
- If a procedure may result in stimuli likely to cause pain it is appropriate to administer preventative analgesics.
- Accurate selection and dosage will result in the relief of pain without severe side effects.
- Clinical analgesia is not the absence of pain but the clinical reduction of the intensity of pain to a tolerable level.
- Preoperative analgesia is highly effective because it:
 - Prevents central sensitization (wind-up).
 - Suppresses the neuroendocrine response to pain.
 - Improves tissue healing and mobility.
 - Is the most effective means of controlling postoperative pain.
- Analgesia may be achieved by obtunding or interrupting the nociceptive process.
- Recognizing & Assessing Pain:
 - In order to adequately relieve pain, you need to be able to assess the presence of pain to know if your analgesic regimen is working
 - Difficult to quantitatively measure
 - Need to be familiar with the species/strain you are working with to be able to recognize normal vs. abnormal behavior
 - Signs of pain will vary not only between various species, but between strains and individuals within a species
 - Requires careful observation and experience in the behavior of the species as well as the individual animal's behavior
 - Many laboratory species will not exhibit obvious signs of mild to moderate pain
 - There is no single sign which will always indicate a specific amount of pain universally
 - Some signs used for pain assessment may also be seen in healthy animals
 - **Cats**
 - Hissing and scratching
 - Aggression
 - Vocalization
 - **Rats**
 - Frequently vocalize when handled.
 - **Swine**
 - Normally vocalize when handled unless well acclimated

- **Signs of pain can include:**
 - Lethargy
 - Avoidance
 - Biting/licking at injured area
 - Grimacing expression
 - Eye squinting
 - Vocalization
 - Disuse of limb
 - Aggression
 - Hunched posture
 - “Writhing”
 - Abnormal posture
 - Ruffled coat
 - Decreased food/water consumption
 - Decreased elimination
 - Listlessness
 - Hiding
 - “Inwardly” focused
 - Failure to make a nest
 - Disinterest in environment
- **Physiological effects of pain can be monitored and measured:**
 - Vasoconstriction (pale mucous membranes)
 - Increased heart rate, blood pressure, and cardiac output
 - Rapid, shallow breathing (especially noted with abdominal and thoracic pain)
 - Increased plasma concentrations of epinephrine, norepinephrine, cortisol, glucose, glucagon, lipids, ketones, and amino acids
 - Dilation of pupils
 - Decreased plasma concentrations of phosphorus, magnesium, testosterone, and insulin
 - Porphyrin staining around the eyes in rats
 - Heat in the affected area
- **Physical signs of pain will vary depending on the procedure.**
 - **Orthopedic Procedures/Surgery To A Limb**
 - Decreased weight bearing ranging from limping to disuse
 - **Thoracotomy**
 - Shallow respirations
 - Decreased mobility
 - **Spinal Surgery**
 - Decreased mobility
 - Inability to rest
 - **Abdominal Surgery**
 - Shallow respirations
 - Hunched posture
 - Tucked abdomen

- **Signs of Mild to Moderate Pain:**

- All species will show avoidance to painful stimuli; when avoidance isn't possible, may show aggression.
- **Mouse:** Partially closed eyelids, rough hair coat, hunched posture, scratching, increased aggression and apprehension, vocalization when handled, self-mutilation, abdomen tucked up or pressed to the cage bottom, “writhing” or abdominal stretch, decreased nest building, isolation from cage mates.
- **Rat:** Partially closed eyelids, rough hair coat, scratching, increased aggression and apprehension, vocalization when handled, porphyrin staining around eyes and nose, “writhing” or abdominal “stretch”, abdomen tucked up or pressed to the cage bottom, failure to explore new cage/environment.
- **Guinea Pig:** Sunken and dull eyes, respiratory changes, increased timidity and sleepiness, arched back, increased vocalization when handled.
- **Rabbit:** Ocular discharge, constipation or diarrhea, depression, excessive grooming, stretched or tucked posture depending on procedure, teeth grinding, dull attitude or aggression, lack of appetite, abnormal gait, and abnormal posture.
- **Nonhuman Primate:** Masks many signs of pain, licking at site, disuse, decreased activity and food and water consumption, behavior changes, hunched posture, failure to interact with neighbors, staying on the cage bottom.
- **Dog:** Decreased alertness, stiff posture, limping, panting, licking, biting, increased aggression and vocalization, decreased appetite, isolation, “inwardly focused”, decreased activity, standing for extended period, listlessness.
- **Cat:** Increased aggression, decreased food consumption, excessive licking/grooming, limping, immobility, abnormal vocalization.
- **Pig:** Changes in gait and posture, increased handling avoidance, increased vocalization, decreased activity, decreased food consumption.
- **Sheep/Goat:** Lying with extended legs, limping, stomping feet, mild ataxia, depression, restlessness, teeth grinding, increased aggression, separation from herd, hanging head.
 - Sheep are more stoic and less prone to displaying signs of pain.

- **Signs of Severe or Chronic Pain:**

- **Mouse:** Weight loss, dehydration, soiled coat, sunken eyes, sunken or distended abdomen, hunched posture, ataxia, hypothermia, decreased vocalization, wasting of back muscles.
- **Rat:** Closed eyes, weight loss, dehydration, soiled coat, sunken or distended abdomen, ataxia, hypothermia, decreased vocalization, wasting of back muscles, incontinence, a recumbent position with tucked head, self-mutilation.

- **Guinea Pig:** Weight loss, scaly skin, dehydration, decreased timidity, unresponsiveness, excessive salivation, increased barbering, loss of righting reflex, decreased vocalization, hypothermia.
- **Rabbit:** Teeth grinding, weight loss, dehydration, wasting of lower back muscles, fecal staining, decreased night feces production, general unresponsiveness.
- **Nonhuman Primate:** Hunched or crouching posture, clenching or grinding teeth, disuse of limb, anorexia, weight loss, decreased grooming, decreased socialization, increased aggressive attention from other NHPs.
- **Dog:** Crouched or hunched posture, disuse of limb, unwillingness to move, difficulty laying down, depression, increased aggression, vocalization when handled, increased restlessness, listlessness, eyes focused “inwardly.”
- **Cat:** Hunched, crouching, or stretched posture, increased aggression, anorexia, weight loss, vocalizing, wild escape behavior, unkempt appearance, stiff gait, disuse of limb.
- **Pig:** Depression, unwillingness to move, attempts at hiding, anorexia, decreased socialization.
- **Sheep/Goat:** Rolling, frequent looks or kicks to abdomen, falling over, walking backward, rapid and shallow respirations, weight loss, teeth grinding, grunting, vocalization at handling, rigidity, an unwillingness to move, and/or disuse of limb.
- **Analog Scales:**
 - Establish parameters to score as an indicator of pain, determine what score will indicate insufficient analgesia, and have a rescue plan.
 - Needs to be species specific.
 - If dealing with a socialized species, can be used in conjunction with physiological parameters such as heart rate, respiratory rate, and/or blood pressure.
 - Should first observe the animal from outside the cage/pen, without interaction, and then after opening the cage/pen observe how the animal reacts to your presence. Need to know what the normal reactions for that species should be.

– Example of a scale that can be used for dogs:

Animal ID:	Date:		AM/PM	
Assessment Criteria/Score	0	1	2	3
Attitude and Posture - from distance, no handling	Alert, ears up, eyes bright and open, relaxed; either at the front of the cage or laying normally in relaxed posture at back of cage	Notices and watches tech, ears not fully up, less relaxed muscles, quieter; eyes open; comes to front of cage or relaxes in normal position in back of cage	Decreased activity, squinted, dull eyes, ears down; tense posture, in back of cage, doesn't lie normally, "in-wardly" focused	No interest in tech unless cage opened or animal handled; hunched posture, dull appearance; eyes very squinted or bulging
Gait and Movement - distance observation	Normal movement around cage; fully weight bearing; hops around cage; rises up on haunches	Moves slowly and carefully, but freely, around cage; not hesitant to move but may move slowly, gingerly; at least touches limb to floor	Non-weight bearing; very stiff movement, sits or lies abnormally, sits with legs placed abnormally, moves with effort and reluctantly, may need to be prompted to move	Very reluctant or unwilling to move; may fall asleep while sitting; may appear frantic
Appetite	Normal	May eat less than normal, but eating something, even if it's only treats	Has not eaten in past 24 hours	No interest in food/water/enrichment for more than 24 hours
Elimination	Normal	Decreased output over 24 hours	Decreased urine; little or no feces over 24 hours	No urine or feces over 24 hours
Total				

– Example of a scale that can be used for rabbits:

Animal ID:	Date:		AM/PM	
Assessment Criteria/Score	0	1	2	3
Attitude and Posture - from distance, no handling	Alert, ears up, eyes bright and open, relaxed; either at the front of the cage or laying normally in relaxed posture at back of cage	Notices and watches tech, ears not fully up, less relaxed muscles, quieter; eyes open; comes to front of cage or relaxes in normal position in back of cage	Decreased activity, squinted, dull eyes, ears down; tense posture, in back of cage, doesn't lie normally, "in-wardly" focused	No interest in tech unless cage opened or animal handled; hunched posture, dull appearance; eyes very squinted or bulging
Gait and Movement - distance observation	Normal movement around cage; fully weight bearing; hops around cage; rises up on haunches	Moves slowly and carefully, but freely, around cage; not hesitant to move but may move slowly, gingerly; at least touches limb to floor	Non-weight bearing; very stiff movement, sits or lies abnormally, sits with legs placed abnormally, moves with effort and reluctantly, may need to be prompted to move	Very reluctant or unwilling to move; may fall asleep while sitting; may appear frantic
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Total				

Part 14: Basic Anatomy & Physiology

Section 14.1: Skin

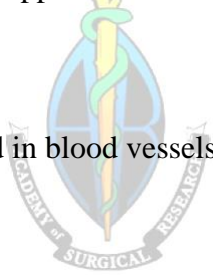
- Covers the body and connects to the mucous membranes of the digestive, respiratory, and urogenital tracts as well as the conjunctivae of the eyelids, the lacrimal duct, and the tympanic membrane.
- Acts as a physical barrier between the environment and underlying tissues.
- Assists in regulation of temperature and hydration as well as sensation.
- Consists of three main layers: the epidermis, dermis, and a subcuticular layer of adipose tissue.
- Composed of connective tissue bed containing blood vessels, lymphatics, muscles, and nerve endings covered by a stratified squamous epithelium.

Section 14.2: Muscle

- Made of hundreds to thousands of individual muscle cells called fibers.
- Muscle fibers are enclosed in connective tissue called endomysium.
- Fibers are gathered into bundles called fascicles bound by perimysium.
- Fascicles are bound together by epimysium.
- Muscles are divided into 3 types defined by appearance and function: smooth, cardiac and striated.

Section 14.2.1: Smooth Muscle

- Found in the walls of hollow organs and in blood vessels and is under the control of the autonomous nervous system.
 - No striations.
 - Cannot be voluntarily controlled.
 - Spindle shaped and without striations.
 - Makes up almost all visceral muscle except cardiac muscle.
 - Lines the interior of blood vessels.
 - Used for slow, steady contractions.
 - Involved in the movement of food and waste products in the GI tract and bladder.
 - Involved in vasoconstriction.
 - Organized into sheets of fibers surrounded with endomysium and connected by strands of collagen and elastin.



Section 14.2.2: Cardiac Muscle

- Forms the bulk of the heart and is optimized for rhythmic contractions under the control of the autonomic nervous system
 - Found only in the heart.
 - Striated (but shorter than skeletal).
 - Cannot be voluntarily controlled.
 - Works in steady, rhythmic fashion.
 - Controlled by the heart's pacemaker.
 - Short and branched.
 - Surrounded by endomysium and connected by intercalated discs.

Section 14.2.3: Striated Muscle

- Forms bundles surrounded by connective tissue envelopes largely controlled by the somatic nervous system.
- Longest muscle cell types.
- Also called skeletal muscle since this type is attached to and functions to move bones
- Can be voluntarily controlled.
- Origin is the more fixed point of muscle attachment.
- Insertion is the more movable point of muscle attachment.
- In limbs, the insertion is always distal to the origin.
- **Movement types:**
 - **Extensor** opens a joint or straightens the bone alignment.
 - **Flexor** closes a joint or angulates the bones.
 - **Adduction** moves the extremity toward the center of the body.
 - **Abduction** moves the extremity away from the center of the body.
 - **Circumduction** is the circular movement of a limb. Rotation moves a part along its long axis.

Section 14.3: Connective Tissue

- Provide routes for nerves and blood vessels
- Envelopes, separates, or connects muscles, nerves and blood and lymphatic vessels
- May blend with the periosteum of bone
- **Periosteum:** Connective tissue covering bone
- **Perichondrium:** Connective tissue covering cartilage.
- **Peritoneum:** Serous membrane largely made of connective tissue.
- **Parietal peritoneum:** Covers the abdominal, pelvic, and scrotal cavities.
- **Visceral peritoneum:** Covers the abdominal, pelvic, and scrotal organs.
- **Connecting peritoneum:** Connects organs to other organs or the parietal peritoneum.
- **Common dorsal mesentery peritoneal fold:** Incorporates most of the abdominal organs.
- **Pericardium:** Fibrous sac that envelopes the heart.
- **Mediastinum:** Fibrous sheet that separates the two sides of the thoracic cavity and incorporates the heart, thymus, vena cava, and aorta. Can be complete and form two distinct sides or incomplete, leaving an opening between the sides (as in pigs)
- **Pleurae:** Serous membranes that line the thoracic cavity and cover the lungs.
- **Meninges:** Protective membranes covering the brain and spinal column.
- **Dura mater:** Thick, fibrous, and the most superficial of the meninges.
- **Arachnoid membrane:** Delicate and lines the deep surface of the Dura mater.
- **Pia mater:** Delicate and coats the surface of the brain, spinal cord, nerve roots, and the optic nerve.

Section 14.4: Skeleton

- “The framework that the body hangs on.”
- Supports and protects the body.
- Provides attachment points for the muscles and acts as levers for motion.
- Made up of individual bones connected by ligaments and muscles.

Section 14.4.1: Bones

- General Information
 - Bone acts as a storage site for calcium and phosphorus.
 - Bone components produce both red and several types of white blood cells.
 - The skull is made of the incisive, nasal, maxilla, zygomatic, lacrimal, frontal, palatine, pterygoid, sphenoid, parietal, occipital and temporal bones.
 - Occipital bone has sagittal and nuchal crests.
 - Radius and tibia are the main weight supporters of the limbs.
- Two types of bone tissue:
 - Compact bone: Dense tissue that forms the outer shell of all bones.
 - Cortical bone: Filled with pockets and lays in between most compact bone surfaces.
 - Contains either red bone marrow or a medullary cavity (containing yellow bone marrow).
 - The medullary cavity in cortical bone as well as the internal termination of the compact bone is lined with a fibrous tissue called endosteum
- Types of bones:
 - Long bones consist of a shaft (diaphysis) with two extremities (proximal and distal epiphysis).
 - Includes all bones in the limbs except the patella and those of the wrist and ankle.
 - Short bones are roughly cube like, primarily cortical bone surrounded by a thin layer of compact bone.
 - Bones of the wrist and ankle:
 - Sesamoid bone is a short bone embedded in a tendon or joint capsule (e.g., patella).
 - Flat bones are thin bones with spongy bone called diploe encased in compact bone.
 - The sternum, the ribs, and most bones of the skull
 - Irregular bone
 - Vertebrae, pelvis, some skull bones:
 - Structure same as that of a flat bone, outside to inside.

Section 14.4.2: Joints

- Areas bones are joined by fibrous, elastic, and/or cartilaginous tissue.
 - **Ligament** – fibrous tissue connecting bone to bone.
 - **Tendon** – fibrous tissue connecting muscle to bone.
 - May be categorized by functionality or structure.
 - **Function**
 - Synarthrosis – permits no movement.
 - Amphiarthrosis – permits slight movement.
 - Diarthrosis – permits free movement.
 - **Structure**
 - Fibrous bones are joined by fibrous tissue; no joint cavities exists (skull sutures, teeth) and provide little or no movement.
 - Cartilaginous bones are united by cartilage, no joint cavity exists (epiphyseal disc, intervertebral disc), and permits compression or stretching.
 - Synovial bones are separated by a joint cavity and permits significant movement.

- Synovial joints may be plane, ball-and-socket, ellipsoidal, hinge, condylar, trochoid, or saddle joints.
- ♦ 5 main components of synovial joints:
 - ◇ Articular cartilage covering the bone at the joint.
 - ♦ Has limited regeneration capabilities.
 - ♦ Articular capsule encloses the joint in an outer fibrous capsule and an inner synovial membrane.
 - ◇ Hip and knee joints have a fatty pad between the fibrous capsule and the synovial membrane or bone.
 - ◇ Joint cavity is the potential space within the articular capsule that is filled with a nutrient and waste transporting fluid called synovial fluid.
 - ♦ Synovial fluid is a lubricant made of hyaluronic acid thinned by interstitial fluid from blood plasma.
 - ◇ Reinforcing ligaments strengthen the joint (intrinsic, extracapsular, and intracapsular).

Section 14.5: Nervous System

Section 14.5.1: Central Nervous System

• Brain

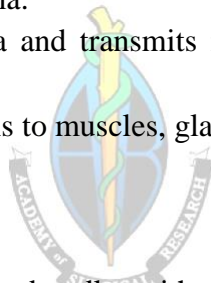
- Comprises the cerebrum, cerebellum and brain stem.
 - Cerebrum is the primary site of cognitive and sensory functions.
 - Cerebellum coordinates movement and posture.
 - Brain stem is the source of all cranial nerves except the olfactory nerves and is continuous with the spinal cord.
- Processes information received through peripheral nerves
- Sends commands
- Floats in cerebrospinal fluid which provides cushioning
 - Contains inorganic ions, protein, sugar, and a few misc. cells.
 - Derived from blood and returns to blood stream via arachnoid villi and lymphatics.

• Spinal Cord

- Extends from the brain stem through the vertebral canal.
- Conducts signals to and from the brain.
- Acts as a reflex generator.
- Processes information and discharges commands.
- Has a central canal that carries cerebrospinal fluid.

Section 14.5.2: Peripheral Nervous System

- Sensory (afferent) division conveys impulses from sensory organs to the CNS.
- Motor (efferent) division transmits impulses from the CNS to muscles and glands.
- Efferent Divisions
 - Somatic Nervous System (SNS) conducts impulses to muscle fibers and allows voluntary control.
 - Autonomic Nervous System (ANS) regulates smooth muscles, cardiac muscles, and glands.
 - ANS divided into two systems:
 - Sympathetic nervous system originates from the spinal cord between T1 and L2.
 - ♦ Accelerates the heart rate, constricts blood vessels, and raises blood pressure
 - Parasympathetic division originates from the brain stem and sacral region of the spinal cord.
 - ♦ Decreases heart rate, dilates blood vessels, and lowers blood pressure
 - Sympathetic and parasympathetic systems regulate each other.
- **Neurons**
 - Have a body (soma) that contains the nucleus and cytoplasm.
 - Dendrites are small branches extending from the soma that act as receptive sites to conduct electrical signals toward the soma.
 - The axon stems from the soma and transmits nerve impulses away from the soma to axonal terminals.
 - Axonal terminals conduct signals to muscles, glands, and other nerves.
- **Nerves**
 - Nerve fibers (neurons) are bound into bundles with perineurium to form fascicles.
 - Fascicles and blood vessels are bound into nerves by fibrous tissue called epineurium.
 - In the CNS nerves are termed tracts.
 - Nerves are highly variable in structure



Section 14.6: Cardiovascular (CV)

Section 14.6.1: Heart

- The heart is made up of 4 chambers.
 - Deoxygenated blood enters the right atrium via the vena cava.
 - Blood is then pumped through the right atrio-ventricular valve (a tricuspid valve although it consists basically of two cusps) into the right ventricle.
 - Blood is then pumped through the pulmonary valve into the pulmonary artery, to the lungs for oxygenation, back through the pulmonary veins, and into the left atrium.
 - Blood is pumped through the left atrio-ventricular (bicuspid or mitral) valve into the left ventricle.
 - Blood is pumped to the aorta and then throughout the body.

- Heart is kept supplied with blood via the right and left coronary arteries, which divide, into the various branches (right marginal branch, circumflex branch, left marginal branch, etc.) that supply the heart.
- Acts as the primary pump of the CV system.
- Contraction involves the sinoatrial (SA) node, atrioventricular (AV) node, AV bundle (Bundle of His), right and left branches, and Purkinje fibers.
 - SA node is a pacemaker that depolarizes in a sinus rhythm to begin the contraction of the atria and conducts the signal via the atria to the AV node.
 - AV node delays the impulse to allow the atria to fully contract and then transmits the signal.
 - AV bundle transmits the signal to the branches, which then transmit it to the Bundle of His, which is made up of Purkinje fibers.
 - Purkinje fibers transmit the signal evenly throughout the ventricles to ensure even contraction in a wringing manner towards the atria.
 - Contraction does not require outside stimuli but can be regulated by the autonomic nervous system.
- **Cardiac Cycle**
 - ♦ Systole is the contraction period of the heart.
 - ♦ Diastole is the resting period.
 - ♦ Mid to late diastole involves low BP in the heart, opening of the atrio-ventricular (AV) valves, and blood passively flowing through the atria into the ventricles.
 - ♦ Atrial systole involves the atria contracting.
 - ♦ Ventricular systole starts as the atria go into diastole and involves ventricular contraction, closure of the atrio-ventricular valves, and a sharp increase in ventricular pressure
 - ♦ Early diastole is where the ventricles begin to relax.
- **Cardiac Output**
 - ♦ Amount of blood pumped out by each ventricle in 1 minute.
 - ♦ HR times Stroke Volume.
 - ♦ Stroke Volume is the volume of blood pumped by the left ventricle for each contraction.
- **Heart Sounds**
 - ♦ “Lub-dub” sound results from the valves closing.
 - ♦ “Lub” is AV valve closure.
 - ♦ “Dub” is the semilunar valves closing.
 - ♦ Unusual sounds are termed murmurs.

Section 14.6.2: Vascular System

- Distribution of blood.
- The bulk (70%) of the blood is in the venous system with only 10% in the arterial system.
- Blood leaves the heart via the aorta and cardiac arteries.
- Arteries carry blood to smaller arterioles.
- Arterioles carry blood to capillaries.

- Oxygen is supplied to the tissues around the capillaries.
 - Capillaries return deoxygenated blood to venuoles.
 - Venuoles carry blood to veins.
 - Veins carry blood to the vena cava.
 - The vena cava returns blood to the heart.
- **Arteries and Veins**
 - Tunica intima is the inner surface of the vessel consisting of a single layer of endothelium with a basement membrane.
 - Tunica media is made of smooth muscle and elastic fibers.
 - Layer is much thicker and stronger in arteries.
 - Tunica adventitia is made of collagen fibers
 - Capillaries Made of endothelial cells and a sparse basal intima.
 - Primary site of oxygen exchange between the blood and body tissue.
 - **Aorta**
 - Carries all oxygenated blood from the heart.
 - Extends cranially before making a 180° half circle to proceed caudally.
 - Arbitrarily divided into the ascending aorta, aortic arch, descending aorta (thoracic and abdominal aorta).
 - **Arteries**
 - Originate from the aorta.
 - Main surgical arteries are:
 - Brachiocephalic trunk: Originates at aortic arch and feeds both common carotid arteries and the right subclavian artery.
 - Left and right common carotid arteries: Originate at the brachiocephalic trunk and branch to become the internal and external carotid arteries at the C1 and C2 vertebrae.
 - Left subclavian artery: Originates at the aortic arch.
 - Right subclavian artery: Originates at the brachiocephalic trunk.
 - Subclavian arteries: Continue as the axial arteries, which feed the forelimbs.
 - Axial arteries: Continue as the left and right brachial arteries, which feed the forelimb.
 - Celiac artery: Originates at the abdominal aorta and branches into the hepatic, gastric, and splenic arteries.
 - Cranial and caudal mesenteric: Originate at the abdominal aorta and feed the intestines.
 - Left and Right renal arteries: Originate at the abdominal aorta and feed the kidneys.
 - Left and right external iliac arteries: Branch from the termination of the abdominal aorta and continue as the left and right femoral arteries.



- **Veins**

- Return deoxygenated blood from the capillary beds to the heart.
- Main surgical veins are:
 - Left and right femoral veins: Transport blood in the hind limbs to the external iliac vein.
 - Left and right external iliac veins: Continue the femoral veins and join the common iliac when joined by the internal iliac vein.
 - Common iliac veins: Connects to the caudal vena cava.
 - Portal vein: Collects blood from pancreas, spleen, and the entire GI tract save the anal canal and connects to the liver and then to the hepatic veins that connect to the caudal vena cava.
 - Left and right external jugular: Continues the internal and external maxillary veins and connects to the brachiocephalic veins.
 - Cephalic vein: Connected to the brachiocephalic vein and provide flow from the forelimbs and is situated on the lateral aspect of the forelimb.
 - Brachial vein: Connects to the brachiocephalic vein and provide flow from the forelimbs and is situated on medial aspect of the forelimb.
 - Left and right subclavian veins: Drain into the cranial vena cava.
 - Vena Cava: Collects venous blood and is arbitrarily divided into cranial and caudal vena cava at the diaphragm before it drains into the right atrium of the heart.

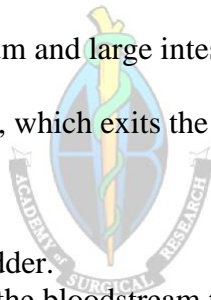
Section 14.7: Respiratory

- Transports oxygen from the outside environment to the blood stream.
- Parts of the respiratory system:
 - **Pharynx:** The main passageway from the nose and mouth.
 - **Larynx:** Musculocartilaginous organ that protects the entry to the trachea.
 - Trachea: Flexible, wall of smooth muscle surrounded by C-shaped rings of hyaline cartilage.
 - Passageway for air to the left and right principal bronchus.
 - **Bronchus:** Divides into lobar bronchi, which then divide into segmental bronchi, which further divide into the alveoli.
 - **Lungs:** Organ containing the bronchus, bronchi, and alveoli.
 - Are passive organs, inflation being due to the diaphragm.
 - Each lung lies in the pleural cavity containing a thin film of moistening fluid.
 - Becomes a true cavity in a pneumothorax.
 - Left is slightly smaller than the right due to the heart's position.
 - Made up of highly vascularized tissue filled with alveoli.
 - **Alveoli:** Site of O₂ transfer to the blood.
 - May be visualized as a collection of millions of tiny bubbles surrounded with elastic connective tissue (stroma).

- **Diaphragm:** Muscular wall that separates the thoracic and abdominal cavities and creates negative pressure in the thoracic cavity to inflate the lungs.

Section 14.8: Digestive

- Parts of the gastrointestinal system
 - **Pharynx:** Passageway from the mouth to the esophagus.
 - **Esophagus:** Passageway from the pharynx to the stomach.
 - **Stomach:** Site of storage and mixing of food and adds digestive enzymes.
 - **Small Intestine:**
 - **Duodenum:** First and most fixed portion of the small intestine as it leaves the stomach.
 - **Jejunum:** Middle portion of the small intestine.
 - **Ileum:** Last portion of the small intestine, which connects to the ascending colon portion of the large intestine.
 - **Large Intestine:**
 - **Cecum:** Does NOT connect the ileum and large intestine and is a diverticulum of the colon.
 - **Colon:** Connects to the rectum.
 - **Rectum:** Connects to the anal canal, which exits the body.
 - **Liver:**
 - Largest gland in the body.
 - Produces bile, stored in the gall bladder.
 - Releases endocrine substances into the bloodstream to assist in the metabolism of fats and sugars.
 - **Gall bladder:**
 - Stores and concentrates bile.
 - Several species of mammals (including horses, deer, rats, and laminoids), as well as several species of birds, lampreys and all invertebrates, lack a gallbladder altogether.
 - **Pancreas:**
 - Secretes pancreatic juice for digestion, produces insulin in its islet cells, and has two lobes.



Section 14.9: Filtration & Excretory

- Eliminates waste products from the body.
 - **Liver:**
 - Produces enzymes to metabolize the majority of drugs administered.
 - **Kidney:**
 - Filters blood to remove urea and produce urine.
 - Urine is carried by ureters to the bladder.

- **Bladder:**
 - Stores urine prior to urination via the urethra.

Section 14.10: Lymphatics

- Returns fluid and protein lost from blood in the capillary beds.
- Lymph nodes, spleen, thymus, and the tonsils are phagocytic and extract foreign bodies.
- Produce and circulate cells that are responsible for the body's immune response.
- **Thymus:** Composed of 2 identical lobes, located cranial-ventrally from the heart. Place where T cells mature.
- **Spleen:** Largest organ in the lymphatic system, important for keeping bodily fluids balanced by controlling the amount of red blood cells in the body. Lays parallel to the greater curvature of the stomach.

Section 14.11: Sensory Specific

- Eye: Responsible for vision.
- Ear: Responsible for hearing
- Nose: Responsible for smelling.



Section 14.12: Reproductive

- **Male**
 - **Scrotum:** Skin pouch that encloses the testis.
 - **Testes:** Male gonads that produces spermatozoa.
 - **Prostate gland:** Accessory sex gland; produces semen
 - **Penis:** Composed of the roots, body, and glans.
 - **Os penis:** Bone in the glans penis of many mammals.
- **Female**
 - **Ovaries:** Paired organs that produce ova.
 - **Fallopian tube/oviducts:** Transports ova to the uterus.
 - **Uterus:** allows passage of sperm to the Fallopian tubes/oviducts, consists of a neck and two horns,
 - **Vagina:** Dilatable canal from the uterus to the vulva.

Section 14.13: Endocrine

- Composed of glands which secrete hormones directly into the circulatory system which impact other systems
- The major endocrine glands include:
 - **Pineal gland**
 - **Pituitary gland**
 - **Liver**
 - **Pancreas**
 - **Ovaries**
 - **Testes**
 - **Thyroid gland**
 - **Parathyroid gland**
 - **Hypothalamus**
 - **Gastrointestinal tract**
 - **Adrenal glands**



PART 15: SURGICAL INSTRUMENTS

- ▶ A surgical instrument is a specially designed tool or device used for performing specific actions for carrying out desired effects during surgery and surgical manipulation of tissues.
- ▶ The nomenclature of surgical instruments follows certain patterns, such as a description of the action it performs (for example, scalpel, hemostat), the last name of its inventor(s) (for example, the “Kocher” forceps), or a compound scientific name related to a type of surgery.
- ▶ Surgical instruments are designed with a specific functional purpose for specific operative tissue manipulations.
- ▶ The purpose of this module is to illustrate some of the more common surgical instruments and instrumentation and their function.

Section 15.1: Thumb Forceps

– **Adson Atraumatic**

- Finely serrated straight tip
- Useful for delicate tissue handling
- Less invasive and traumatizing to tissues

– **Adson – Rat tooth**

- 1 x 2 teeth straight tip
- 2 x 3 teeth straight tip
- Useful for grasping tissue



– **Adson-Brown**

- 7 x 7 to 9 x 9 fine jaw teeth
- Straight tip
- Used for gripping tissue
- Requires less crushing pressure to maintain a grip

– **Mayo (Russian)**

- Straight with fenestrated oval jaw
- Useful for grasping delicate tissue

– **Rat Tooth Thumb**

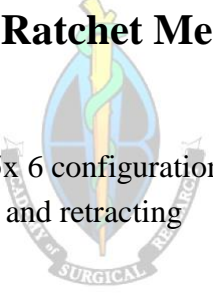
- General purpose tissue gripping forceps

– **Tuttle Thoracic Tissue**

- Used for gripping delicate and “slippery” tissues
- Fenestrated serrated ring tip distributes the pressure on the tissue
- Prevents tissue puncture
- Straight tip

- **Debakey Thoracic**
 - Large number of teeth distributes the pressure to help avoid punctures
 - Multiple tip configurations
- **Singley Tissue**
 - Fenestrated serrated ring tip distributes the pressure on the tissue
 - Prevents tissue puncture
- **Cushing Tissue**
 - Straight or bayonet shape configurations with serrated tips
 - Delicate tipped forceps for grasping around nerves
 - Not used for nerve grasping and retraction
- **Dumont**
 - Used for delicate gripping
 - Does not grip tightly
 - Multiple types, sizes and tip configurations

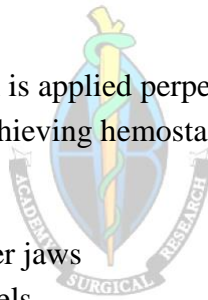
Section 15.2: Hand Forceps With Ratchet Mechanism

- 
- **Allis Tissue**
 - Teeth tightly grip soft tissue: 4 x 5 and 5x 6 configurations
 - All-purpose dense/tough tissue grasping and retracting
 - **Doyen**
 - Lightly compressive and used for delicate gripping
 - Used for intestinal compression and occlusion
 - Long, curved blades with longitudinal serrations
 - **Babcock Intestinal & Tissue**
 - Used for delicate gripping of tissue
 - Used for tissue and intestinal retraction
 - **Mixter (Thoracic)**
 - Lightweight
 - Tips curved/90°angled
 - Useful for gripping bleeding vessels at an angle
 - Useful for positioning ligatures around vessels

- **Mixer (Gallbladder)**
 - Lightweight
 - Tips curved/90°angled
 - Useful for gripping tissue at an angle
 - Useful for positioning ligatures around vessels and ducts
- **Collin Gallbladder**
 - Relatively atraumatic forceps used for retraction and gripping of the gall bladder
 - Teeth along distal edge
- **Duval Lung**
 - Light weight with serrated jaws.
 - Screw lock
 - Useful for grasping tissue

Section 15.3: Hemostatic & Vascular Forceps With Ratchet Mechanism

- **Hartman Mosquito**
 - Smaller versions of Mosquito forceps
 - Minimizes tissue slippage when tension is applied perpendicularly to the jaws
 - Useful for vascular compression and achieving hemostasis
- **Halstead Mosquito**
 - Similar to Kelly forceps but with smaller jaws
 - Useful for gripping small bleeding vessels
 - Useful for vascular compression and achieving hemostasis
- **Crile**
 - Have grooves running side to side of the jaws, all the way down blades
 - Allows less slippage when tension is applied perpendicularly to the jaws
 - Useful for vascular compression and achieving hemostasis
- **Jacobsen**
 - Fine delicate tips
 - Straight or curved
 - Useful for vascular compression and achieving hemostasis
- **Kelly**
 - Have grooves running from tip halfway down blades
 - Allows less slippage when tension is applied parallel to the jaws
 - Useful for vascular compression and achieving hemostasis



- **Rochester-Pean**
 - Have long blades with deep transverse grooves
 - Straight or curved
 - Useful for general tissue grasping, retraction or holding and compression (occlusion)
- **Rochester-Carmalt**
 - Have long blades with deep longitudinal grooves
 - Straight or curved
 - Useful for vascular grasping, retraction or holding and compression (occlusion)
- **Rochester-Ochsner**
 - Have long blades with transverse grooves
 - Straight or curved
 - Tip has 1 x 2 teeth
 - Useful for stronger tissue and vascular grasping, retraction or holding and compression (occlusion)
- **Ferguson Angiotribe**
 - Heavy duty vascular forceps
 - Jaw blades have cross-hatched faces with matching longitudinal male-female groove running blade jaw length
 - Used for hemostasis and prevention of subsequent bleeding



Section 15.4: Sponge Forceps With Ratchet Mechanism

- **Chester and Ballenger**
 - Gauze holders for application in body cavities
- **Foerster**
 - Straight or curved
 - Fenestrated blades with serrations
 - prep and sponge application

Section 15.5: Vascular Clamps

- **Cooley Cardiovascular**
 - Used for isolating sections of major vessels and used for facilitation of vascular anastomosis
 - Partial clamping will isolate sections while allowing blood flow around the clamped section
 - Ratchet mechanism
- **DeBakey Abdominal**
 - Partial clamping will isolate sections of aorta or vena cava while allowing blood flow around the clamped section
 - 1 x 2 or 2 x 3 teeth
 - Ratchet mechanism

- **Satinsky**
 - Multiple types
 - Partial clamping will isolate sections while allowing blood flow around the clamped section
 - Generally used to isolate a section of aorta to allow partial flow
 - Ratchet mechanism
- **Renal**
 - Used for clamping renal and iliac vessels
 - Left and right versions
 - Double angulation of the clamp permits placement of its handle to one side, allowing un-obstructed view of the operative field
 - Ratchet mechanism
- **Serreffines**
 - Used for clamping superficial vessels
- **Senning Bulldog**
 - Spring tension
 - Ideally suited for use in cardiothoracic surgical procedures
 - Very light
- Vascular clamps with varying degrees of tension
 - Diefenbach Bulldog
 - Straight or Curved
 - Serrated 10 x 2 mm jaws
 - Blalock Bulldog
 - Partial clamping will isolate sections while allowing blood flow around the clamped section



Section 15.6: Towel Clamps

- **Backhaus**
 - Used for clamping sterile drapes or towels together when creating a sterile field
 - May also be used to clamp sterile drapes directly to the skin
 - Ratchet mechanism
- **Roeder**
 - Have ball-stops to prevent towel slippage up the pins
 - Ratchet mechanism
- **Edna**
 - Grip towels without puncturing them due to flat pins
 - Must not be used on skin due to crush damage
 - Ratchet mechanism

- **Jones**
 - A variation on Backhaus towel forceps except has a low profile cross-action handle

Section 15.7: Scissors

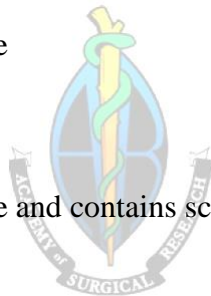
- **Operating**
 - All-purpose non-delicate cutting
 - Blunt-Blunt, Sharp-Sharp, or Sharp-Blunt Tips
 - Used for cutting suture and sterile drapes, vet-wrap, etc.
- **Metzenbaum**
 - Straight or curved
 - Useful for soft and delicate tissue cutting and dissection
- **Enterotomy**
 - One blunt and one flared blunt tip
 - Flared tip prevents tissue trauma and puncture
 - Intended for intestinal cutting
- **Iris**
 - Straight or curved
 - Designed for fine dissection in the eye and fine dissection of delicate tissues
- **Strabismus**
 - Straight or curved
 - Used for fine dissection of tissue with minimal force
- **Stevens Tenotomy**
 - Straight or curved
 - Designed for cutting or dissection of tendons and fine tissue dissection
- **Vannas**
 - Straight or curved
 - Typically used in micro-surgical applications
 - Small size and small blade designed for very fine cutting
- **Wire Scissors**
 - Straight or curved
 - Used for cutting wire suture and orthopedic wire
- **Lister Bandage Scissors**
 - Used for cutting bandage material
 - Flared blunt tip prevents tissue invasion and trauma



- **Spencer Suture Scissors**
 - Small and delicate
 - Straight or curved
 - Useful for suture removal
 - Have a hook tip lower blade to easily slip under a suture for easier suture cutting with subsequent removal
- **Littauer Suture Scissors**
 - Rugged and larger than Spencer, heavy duty suture scissors
 - Straight or curved
 - Useful for suture removal
 - Have a hook tip lower blade to easily slip under a suture for easier suture cutting with subsequent removal

Section 15.8: Needle Holders

- **Mayo Hager**
 - Holds a suture needle for wound closure
 - Ratchet mechanism
- **Olsen Hager**
 - Holds a suture needle for wound closure and contains scissor blades to allow easy suture cutting
 - Ratchet mechanism
- **Finochietto and Debaque Thoracic**
 - Have specialized angled tips to allow easier deep tissue suturing
 - Ratchet mechanism
- **Halsey**
 - Straight or curved
 - Used for delicate suturing and holding very small suture needles
 - Ratchet mechanism
- **Castroviejo**
 - Straight or curved
 - Used for delicate suturing and holding very small suture needles
 - Locking and non-locking
- **Mathieu**
 - Straight or curved
 - Used for delicate suturing and holding very small suture needles
 - Locking



Section 18.9: Self-Retaining Retractors

- **Balfour**
 - Used for abdominal retraction
- **Finochietto**
 - Used for rib retraction for thoracic access
- **DeBakey**
 - Used for rib retraction or for sternum retraction following sternotomy
- **Parker**
 - Nonflexible
 - Commonly used for abdominal retraction
- **Deaver**
 - Commonly used for abdominal retraction
- **Mayo Abdominal**
 - Commonly used for abdominal retraction
- **O’Sullivan, O’Connor and Wexler Abdominal Ring Retractors**
 - Used for abdominal retraction
- **Alm**
 - Useful for delicate soft tissue retraction
 - Small
 - Blunt rack jaws
- **Colibri**
 - Used for eyelid retraction (also known as eye speculum) and also used in rodent surgery for tissue retraction
- **Gelpi**
 - Useful for soft tissue retraction and holding open incisions for better visibility
 - Single prong tips (sharp)
 - Ratchet mechanism
- **Weitlaner**
 - Useful for bone and soft tissue retraction and holding open incisions for better visibility
 - Multiple pronged tips (sharp or blunt)
 - Ratchet mechanism



- **Finochietto Rib**
 - Self-retaining
 - Used for rib retraction for thoracic access

Section 15.10: Manual Retractors

- **Senn**
 - Used for tissue retraction
 - Double ended: one rounded and one pronged (sharp or blunt)
- **Army (Army-Navy)**
 - Used for tissue retraction
 - Double ended, rounded lip
- **Ochsner Ribbon**
 - Used for tissue retraction
 - Highly malleable to conform to desired configuration for tissue retraction
 - Primarily used for abdominal retraction
- **Langenbeck**
 - Used for tissue retraction
 - Distal blade tip slightly curved
 - Single-ended with a flat handle
- **Sauerbruch**
 - Used for tissue retraction
 - Long, slender blades with slightly curved tips
 - Single-ended with a hollow handle
- **Doyen**
 - Used for tissue retraction
 - Concave blade
 - Single-ended
- **Volkmann Rake**
 - Used for tissue retraction
 - 2-6 prong configurations (sharp or blunt)
 - Similar to Bernay retractors with a larger fenestrated handle for improved handling
 - Single-ended



- **Bernay Finger Rake**
 - Used for tissue retraction
 - 1-4 prong configurations
 - Sharp or blunt prongs
 - Single-ended
- **Love Nerve**
 - Used for neural tissue retraction and holding individual nerves or fibers
 - Straight or angled
 - Single-ended

Section 15.11: Suction Tubes

- **Yankauer**
 - Used for general suctioning fluids out of the surgical field and for removal of pharyngeal secretions
 - Tube fenestration for manual control of suction pressure
 - Flared and curved tip
- **Debakey**
 - Used for suctioning fluids out of the surgical field
 - Stopcock type valve allowing reliable “on-off” action
 - Flared and angled tip
- **Frazier**
 - Used for suctioning fluids out of small, delicate regions
 - Useful in cardiothoracic, neurological, and spinal surgical procedures
 - Fine fenestrated and angled tip
- **Poole**
 - Used for suctioning of fluids and debris out of the surgical wound and cavity sites
 - Tube has multiple holes at the end to reduce plugging with fat and omentum
 - Straight or angled tip



Section 15.12: Elevators

- **Periosteal**
 - Used for lifting full thickness periosteal tissue
 - Can be dual ended: one rounded and one (sharp or blunt) thin blade
- **Matson Rib Elevator & Stripper**
 - Used for rib elevation and stripping and retraction of the periosteum
 - Dual ended: one rib elevator and one periosteal elevator

Section 15.13: Tissue Cutting & Cautery

– Scalpel

- Handheld surgical knife
- Various sizes and cutting blades available
- Eliminates crush injury to tissue
- Useful for clean appositional cutting

– Harmonic Scalpel

- Used for simultaneous cutting and coagulation of tissue
- System consists of a generator, a foot-pedal and hand switch, a hand-held ultrasonic transducer and cutting instrument

– Cautery & Cautery Pen

- Handheld electric instrument used to control blood loss
- Various tip configuration available
- Battery (ex., Bovie cautery pen) or electric cable (with generator) operated
- Various temperatures (typically low & high) for coagulation or cutting tissues
- Varying degrees of thermal damage to surrounding tissues may occur depending on use and duration of contact

– CO₂ Laser

- Focused beam of light (various intensity levels deliver laser energy in continuous or pulsed wave modes) used for tissue ablation, cutting, cautery, and welding
- System consists of a laser generator, a foot-pedal or hand switch, aiming beam, articulating arm, and laser scalpel
- Minimal thermal damage to surrounding tissues

Section 15.14: Bone Instruments

– Bailey Rib Approximator

- Facilitates approximation of ribs for thoracic closure

– Bruns Bone Curettes

- Used for cutting or scraping bone
- Oval or hexagonal

– Spratt Bone Curettes

- Used for obtaining cancellous bone samples and bone debridement among other uses
- A single ended instrument with a round cup of various sizes on the end

- **Galt Cranial Trephine**
 - Used for cutting through skull bone
 - Has the form of a truncated cone with spiral teeth
 - It's conical form prevents entry into the cranial cavity following full thickness cutting of bone
- **Michele Trephine**
 - Used for bone biopsy
 - Available in various diameters
- **Lowman Bone Clamp**
 - Useful for holding long bones and bone plates
- **Sherman Bone Plate**
 - Used for fixation of bones and joints
 - Plate narrows in the spaces between the screw holes so that approximately the same strength is maintained at every point
- **Kern Bone Holding Forceps**
 - Used for grasping, holding and manipulating bone and bone fragments
 - Standard or ratchet mechanism to prevent slippage
- **Lebsche Sternum Knife and Stille-Liston Bone Cutting Forceps**
 - Used for cutting or splitting bone
- **Pilling-Ruskin, Beyer, and Zaufel-Jansen Rongeurs**
- **Finochietto Rib Spreaders**
 - Self-retaining
 - Used for rib retraction for thoracic access
- **Liston Bone Cutting Forceps**
 - Used for cutting lower density bone and cartilage
 - Durable bar spring-loaded
- **Gigli Wire**
 - Used for cutting (sawing) bone without crushing force
 - Smooth spiral milled stainless steel wire used as cutting blade
 - T- shaped handles are used to handle and control wire
- **Stryker Bone and Cast Saw**
 - Used for bone cutting
 - Oscillating precision tip saw blade
 - Electric cable or battery operated

- **Bone Chisel**
 - Used for cutting bone
 - Single beveled blade
 - A mallet is typically used on the chisel to drive cutting
- **Osteotome**
 - Used for cutting or preparing bone
 - Double beveled blade
 - Wedge like design enables easier cutting while maintaining directional line
 - A mallet is typically used on the osteotome to drive cutting
- **Lambert Rongeur**
 - Used for breaking up bone fragments and removal and shaping of cortical bone
 - Has cupped jaws
- **Ruskin Rongeur**
 - Heavy duty
 - Dual action with spring-loaded handle with two chisel-like spoon-shaped blades
 - Used for standard bone fragment cutting and shaping
- **Kerrison Rongeur**
 - Typically used in spinal surgery
 - Used for removing bone by taking small 'bites' of bone at a time
 - Available in various sizes and angles
 - Upward traction must be used during placement and use to prevent trauma to soft tissue below the bone
- **Jacobs chuck & key**
 - Used for mounting a drill bit onto a drill
- **Steinmann pins**
 - Used for internal fixation of bone fractures
 - Slender and elongated metal rods used for securing fixation of bones and bone parts
- **Kirchner Wires**
 - Used for transfixion of fractured bones and obtaining traction in fractures
 - Steel wire

Section 15.15: Soft Tissue Biopsy Instruments

- **Tru-Cut Biopsy Needle**
 - Typically used for transcutaneous visceral tissue biopsies
 - Has a disposable needle with outer cannula and inner notched rod in which a tissue specimen is cut, contained, withdrawn, and then ejected
- **Tissue Biopsy Punch**
 - Used for collecting tissue samples
- **Tissue Biopsy Cup**
 - Used for collecting tissue samples
 - Cup-like punch
 - Typically spring action
- **Tissue Curettes**
 - Used for collecting tissue samples and scraping
 - Fenestrated or single cup configurations

Section 15.16: Basins & Bowls



- **Emesis Basin**
 - Used for collecting vomit
 - Kidney-shaped
- **Sponge Bowl**
 - Used for holding sponges and sterile fluids
 - Often used for holding damp sterile sponges
- **Irrigation, Soaking, or Organ Bowl**
 - Covered with lid to minimize/protect contents from contamination
 - Often used for holding irrigation solutions

Section 15.17: Miscellaneous Equipment & Instruments

- **Mayo Stand**
 - Small removable tray table typically placed near or over surgical subject and aseptically draped
 - Typically used aseptically as an intra-operative holding tray for instrument and select surgical items
 - May also be used strategically to isolate surgical field enabling anesthetic physical monitoring of surgical subject by anesthetist

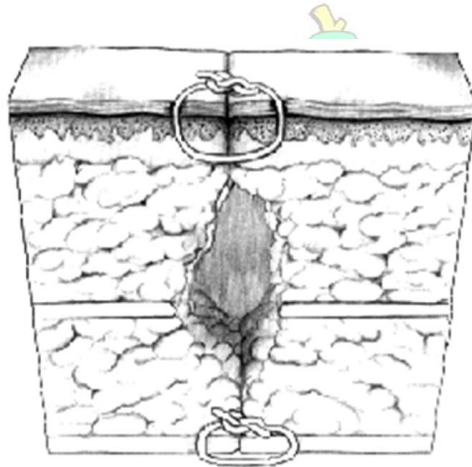
- **Surgical Trocar**
 - Typically used for tissue tunnel creation and for entry onto body cavities for subsequent passage of instruments/catheters/telemetry ECG leads
- **Surgical Staplers**
 - Multiple types
 - Stainless steel staples
 - Useful for dermal closure and other types of soft tissue
- **Stereotaxic Stand & Frames**
 - Used for exact head positioning and traction for subsequent surgical cranial manipulations
 - Specialized frame allows for exact centering of stereotaxic ear/jaw manipulator bars for head traction to accommodate subsequent and accurate determination of specific coordinates (i.e., lambda and bregma).



Section 16.1: Tissue Handling

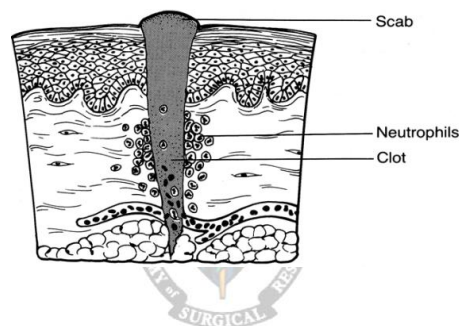
- The goal is to minimize tissue trauma, which leads to more rapid healing.
- Incisions heal side-to-side, not end-to-end. There is little advantage to making an incision too small.
- Gently handle tissues and do so as little as possible.
- Use minimal tension with tissue.
- Retractors should be placed to avoid excessive tension.
- Provide gentle retraction with proper instruments.
- Avoid impairing blood or lymph flow, which may change the local physiological state.
- Use instruments properly.
- DO NOT CRUSH TISSUES.
- Clamping tissue with hemostats/forceps causes crushing of the cells and is very traumatic, causing release of vasoconstrictors and clotting factors.
- Proper use of hemostats is for clamping vessels for ligation/hemostasis.
- Use proper technique.
 - Different surgical techniques induce different levels of damage.
 - Cutting with a sharp instrument is minimally traumatic, with little adjacent cell damage.
 - Cutting with scissors causes crush and tear trauma, is relatively traumatic, with adjacent cell damage.
 - Use blunt dissection between/along tissue planes.
- Keep tissues moist.
 - Dry tissue is dead tissue; keep it moist with irrigating solution, such as saline, LRS, Tis-U-Sol, etc.
 - Irrigate, rinse the incision surgery site.
 - Lavage, irrigate body cavities.
- Wounds with excessive debris should be thoroughly lavaged with an appropriate sterile fluid (isotonic saline, LRS, TisUSol, etc.).
 - “The solution to pollution is dilution”
- Nonessential material should be removed.
- Minimize tissue exposure time.
- Three “T’s” of tissue handling: time, trash, trauma
 - Keep time to a minimum.
 - Remove existing contamination and prevent addition of new contamination
 - Keep trauma to a minimum

- Hemostasis:
 - Bleeding should be stopped whenever possible.
 - Excessive bleeding may cause hematomas or increase dead space.
 - Hematomas prevent wound apposition and retard healing.
 - Blood is a natural food for microorganisms and a large clot can help protect them from the body's immune system.
 - Bleeding may be slowed or stopped by applying pressure, clamping, electro/thermocautery, ligatures, and with various hemostatic agents, depending on the rate/volume of hemorrhage.
 - Excessive pressure, like that applied using hemostats, may lead to tissue necrosis.
 - The 3 “P’s” of hemostasis”
 - Pressure – apply gentle, firm pressure
 - Patience – leave the gauze in place for an appropriate amount of time for the type of bleeding present
 - Perseverance – continue measures as necessary until bleeding is controlled
- Dead Space:
 - Dead space is an open area in closed tissue.
 - Filled with room air, it prevents tissue apposition, provides a space for blood and other fluid influx, and may harbor microorganisms. In many species, seromas may form.

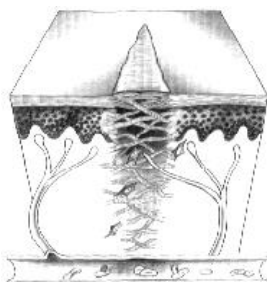


Section 16.2: Wound Healing

- Skin and fascia are the strongest tissues but regain tensile strength quite slowly.
- Stomach and small intestine are weak tissues, but heal quickly.
- Physiology of Wound Healing: Phases of Wound Healing
 - **Phase 1: Inflammatory Phase**
 - 0 - 5 Days, can be prolonged.
 - Inflammatory and “clean-up” process;
 - Epithelialization/migration (as early as 48 hours).
 - Clinically characterized by swelling, redness, and warmth/heat.
 - Course / Duration: peak within 24 hours, subsiding by day 3.
 - Inflammation results in pain/discomfort.
 - Inflammatory response causes an outpouring of tissue fluids, accumulation of cells and fibroblasts, and increased blood supply
 - Leukocytes produce enzymes to dissolve and remove damaged tissue debris
 - Closure material (suture) is the primary source of tensile strength

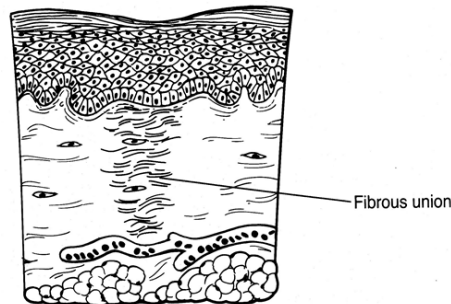


- **Phase 2: Migration/Proliferation Phase**
 - Fibroblasts begin forming collagen fibers in the wound
 - Beginning of the return of tensile strength
 - Fibroblasts migrate toward the wound site
 - Begin forming collagen fibers
 - Tensile strength rapidly increases
 - Lymphatics re-canalize
 - Blood vessels bud
 - Granulation tissue forms
 - Capillaries develop

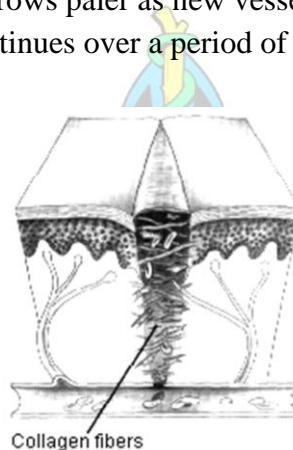


- **Phase 3: Maturation Phase**

- Begins ~ day 14 and continues for months.
- Collagen fibers become oriented along the “stress” line of the incision and form cross links; increases tensile strength.
- Normal stress can be withstood



- Tensile strength continues to improve for as long as one year.
- Skin regains 70 to 90% of its original strength.
- Collagen content remains constant but cross links with other fibers.
- Scar is formed which grows paler as new vessel construction tapers off.
- Wound contraction continues over a period of weeks or months.



Section 16.3: Types of Wound Healing

- First Intention: Wound edges brought together during closure at the time of surgery.
- Second Intention: Wound is left open and heals from the bottom (inside) up.
 - Slower than first intention and creates more granulation and scar tissue.
- Delayed Primary or Third Intention: Wound is initially not closed and remains open until a granulation bed formed, then the granulated tissue is closed using standard techniques.
 - Useful in infected wounds where the wound is left open until the infection is controlled.
 - Infected tissue should not be closed or it may dehisce (open up).
 - Infection is resolved naturally, or with topical and systemic treatments.

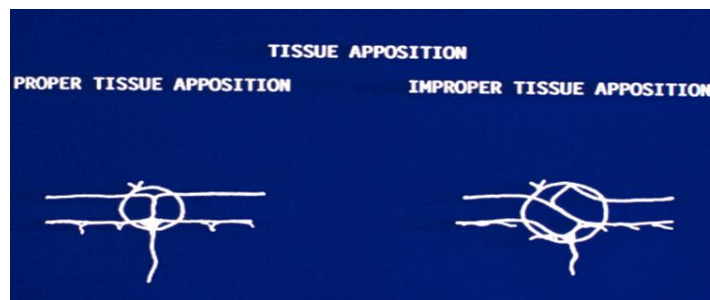
Section 16.4: Classification of Wounds

- Clean: standard aseptic surgical wound.
- Clean-contaminated: a clean wound that is contaminated by entry into a visceral organ resulting in minimal spillage of contents; a surgical site, which becomes contaminated at the time of surgery and is treated at that time.
- Contaminated: a wound that has become infiltrated with contaminants from lacerations, fractures, gross spillage from the GI tract, or a break in aseptic technique.
 - Within 6 hours of initial colonization a wound can be infected.
- Dirty-infected: is caused by perforated viscera, abscesses, or a prior clinical infection; indicates an on-going infection
- Ongoing infection at time of surgery may increase infection rates 4 times.
- Problems:
 - Infection.
 - The source of infection should always be determined.
 - Before closure of an infected wound the wound should be drained, debrided, and a small opening or drain left in.
 - Dehiscence
 - Failure of the incision line as a result of too much tension on tissue, improper suturing technique, or improper suture materials.

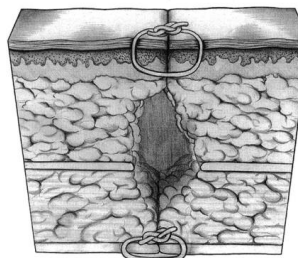


Section 16.5: Wound Closure

- Proper apposition restores alignment of the tissues.



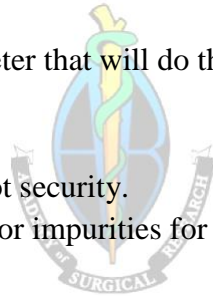
- Close/decrease dead space. Picture below shows improper closure



Section 16.6: Sutures

Section 16.6.1: The Ideal Suture Material

- All-purpose, composed of material which could be used in any surgical procedure (the only variables being size and tensile strength).
- Sterile.
- Nonelectrolyte, non-capillary, non-allergenic, and non-carcinogenic.
- Non-ferromagnetic, as is the case with stainless steel sutures.
- Easy to handle.
- Minimally reactive in tissue and not predisposed to bacterial growth.
- Capable of holding securely when knotted without fraying or cutting.
- Resistant to shrinking in tissues.
- Absorbed with minimal tissue reaction after serving its purpose.
- The Ideal Suture Material – Does not exist!
- Surgeon should select suture materials for:
 - High uniform tensile strength (quality).
 - Permitting use of finer sizes.
 - Suture should be the smallest diameter that will do the job.
 - Consistent uniform diameter.
 - Sterility.
 - Pliable for ease of handling and knot security.
 - Freedom from irritating substances or impurities for optimum tissue acceptance.
 - Predictable performance.



Section 16.6.2: Suture Size

- Generally stated as “ought”; i.e., 3-0, 5-0, etc.
- 2-0 is larger than 4-0, 0 is larger than 2-0, etc.
- Some suture and wire is larger than 0, then numbered 1 and higher.
- 2 is larger than 1, 6 is larger than 1, etc.
- From smallest to largest: 7-0, 3-0, 0, 1, 3, 7, etc.

Section 16.6.3: Monofilament Suture

- Is a single strand.
- Passes through tissue easily, won't harbor microorganisms.
- May be weakened by crushing (clamping in forceps or needle holders).
- Has more “memory.”
 - Continues to hold the shape as it lay in the package.

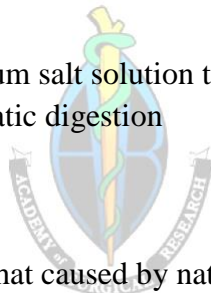
- Good for percutaneous sutures as the smooth surface is less prone to drawing microorganisms into the tissue.
 - Knots may slip over time due to the comparative slipperiness of the suture.

Section 16.6.4: Braided Suture

- Is a bundle of strands, typically braided like rope.
- Affords greater tensile strength, pliability, flexibility, and knot security.
- May harbor microorganisms and “wick” them down the suture.
- Should not be used for percutaneous sutures.

Section 16.6.5: Absorbable Suture

- Maintains strength temporarily but gradually loses tensile strength and is eventually mostly or completely absorbed.
- **Surgical Catgut Suture** (monofilament):
 - Plain: rapidly absorbed, tensile strength 7-10 days
 - **Chromic**
 - Tensile strength 10-14 days
 - Plain gut is treated with chromium salt solution to resist body enzymes
 - Absorbed by proteolytic enzymatic digestion
- **Synthetic Absorbable Sutures**
 - Broken down by hydrolysis
 - Results in less tissue reaction than that caused by natural absorbable suture
 - **Polyglactin 910: Vicryl®**, tensile strength 21 days, braided.
 - **Coated Vicryl Rapide®** - fastest-absorbing synthetic suture; causes less tissue reaction than chromic gut; indicated only for use in superficial soft tissue approximation on the skin; loses 50% of its tensile strength at 5 days; all of the original tensile strength is lost after 10-14 days.
 - **Polyglycolic acid: Dexon®**
 - **Poliglecaprone 25: Monocryl®**
 - Monofilament
 - Retains tensile strength for approximately two weeks.
 - **Polydioxanone: PDSII®**
 - Monofilament
 - Retains 50% of tensile strength at 4 weeks; 25% at 6 weeks
 - **Polyglyconate: Maxon®**
 - High initial tensile strength
 - Monofilament
 - Retains 81% of tensile strength at two weeks; 59% at 4 weeks; 30% at 6 weeks



Section 16.6.6: Non-Absorbable Suture

- Natural or synthetic, braided or monofilament
- While are non-absorbable, some, like silk, lose tensile strength over time
- **Silk**
 - Braided, superior handling and tying characteristics
 - Loses tensile strength if re-sterilized
 - Lowest tensile strength of the non-absorbable sutures
- **Monofilament Nylon:** Dermal on® Ethicon®
- **Braided Synthetic**
 - Polyester fibers
 - Uncoated (Merilee®) – high coefficient of friction when being passed through tissue
 - Coated (Ethicon®) – coated with polybutylene, eases passage through tissues
 - Nylon fibers
 - Neuron® - handles like silk, less reactive than silk
 - Surgeon®
- **Monofilament Polypropylene**
 - Prolene®– glides through tissue, does not adhere, ideal for external sutures
 - Merilee® - comes both as a braided and monofilament versions
- **Surgical Stainless Steel Wire**
 - Both monofilament and twisted multifilament
 - High in tensile strength, low in tissue reactivity, and hold a knot well
 - Used for abdominal closures, sternum closure, skin closure, and some orthopedic surgeries
 - Pose a hazard since it can easily tear through a glove or puncture surgeon's skin

Section 16.6.7: Needles

- Needles come in assorted sizes and shapes (quarter circle, 3/8 circle, half circle, 5/8 circle, or straight)
- **Cutting Needle:** Needle body is triangular and has a sharpened cutting edge on the inside. Primarily used for skin closure.
- **Reverse Cutting Needle:** Cutting edge on outer curve. Use for tough, difficult-to-penetrate tissues.
- **Taper Point Needle:** Needle body is round and tapers smoothly to a point. Used for soft, easily penetrated tissues.
- **Blunt Point Needle:** Taper body, for blunt dissection and suturing friable tissue.
- **Spatula Needle:** Needle is flat on top and bottom with a cutting edge along the front to one side. Primarily used for eye surgery.

Section 16.7: Suture Knot Tying & Suture Patterns

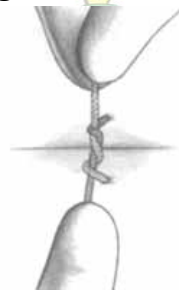
- Knots need to be tied flat
- Surgeon needs to avoid sawing on the suture as the throws are cinched down as this will weaken the strand.
- Sutures should not be tied too tightly since this may lead to tissue necrosis.
- Knots should be kept as small as possible to keep tissue reaction to a minimum
- Ends should be cut as short as possible (~3mm for most sutures; ~6mm for gut)

Section 16.7.1: Common Knots

- **Surgeon's Knot**

- An initial double throw followed by one or two single throws is generally sufficient
- Extra throws do not add appreciable strength to the knot and may, in fact, weaken it while adding extra bulk
- The exception is nylon monofilament sutures, where two successive double throws are useful to prevent slippage

Surgeon's Knot: First Throw



Surgeon's Knot: Second Throw



- **Square Knot**

- Easiest and most reliable two-handed tie for surgical gut, silk, and stainless steel
- Additional throws needed when used with other sutures
- If the strands are inadvertently incorrectly crossed, a granny knot will result, which has a tendency to slip when subjected to increased stress.

Section 16.8: Suture Patterns

Section 16.8.1: Interrupted Sutures

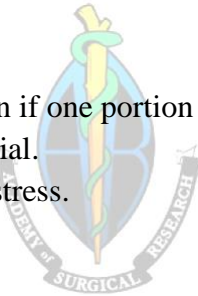
- **Ligatures**

- Used to occlude the lumen of a vessel/duct to either effect hemostasis or close off a structure to prevent leakage
- Free tie – a vessel, duct, or other structure is occluded using a clamp; a strand of suture material is passed around the structure, under the tip of the instrument; after the first throw, the instrument is removed and the surgeon tightens the knot; additional throws are added to square and secure the knot.

- **Simple Interrupted**



- Maintains strength and tissue position if one portion (knot) fails.
- Requires more time and suture material.
- Has minimal holding power against stress.

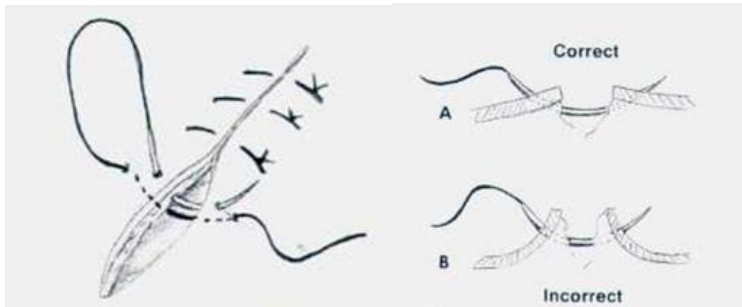


- **Horizontal Mattress**



- Tension suture.
- Useful in skin of dog, cow, and horse.
- Rapid and involves less suture material.
- Difficult to apply without excessive eversion.
- Should pass just below the dermis.
- Tightness should be such that the skin edges just meet.

- **Vertical Mattress**

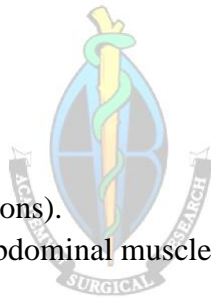


- Tension suture.
- Stronger than the horizontal mattress.
- Difficult to apply without excessive eversion.
- Time consuming and requires more suture material.

- **Cross-mattress (Cruciate Stitch)**



- Tension suture.
- Brings tissue into good apposition.
- Useful in suturing stumps (amputations).
- Also useful for rib apposition and abdominal muscle closure.

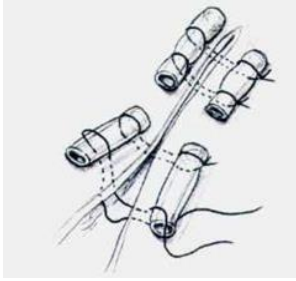


- **Gambee**



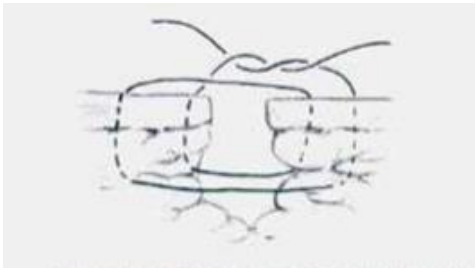
- Useful in intestinal anastomoses.
- Permits minimal leakage.
- May reduce fluid passage through the lumen underneath.

- **Quilted**



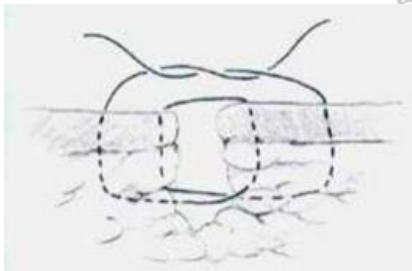
- Exteriorized skin suture through plastic tubing to resist excessive tension and stress.
- Useful for high-tension closures.

- **Far-Far - Near-Near**

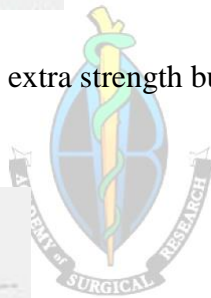


- Tension pattern.
- Overlapping suture pattern provides extra strength but requires extra suture material.

- **Near-Far - Far-Near**

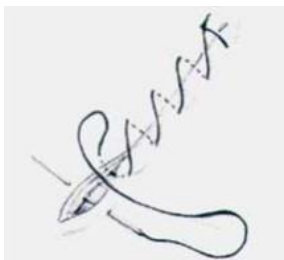


- Tension pattern.
- Overlapping suture pattern provides extra strength but requires extra suture material



Section 16.8.2: Continuous Suture

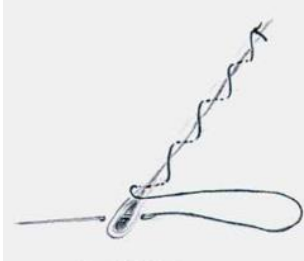
- **Simple Continuous**



- Usually used for lines no longer than 5 inches.
- Involves one diagonal pass and one perpendicular pass.

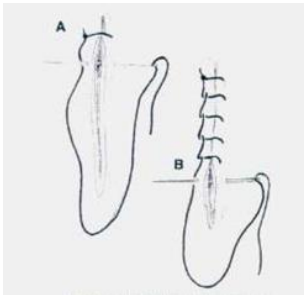
- Provide minimal tension holding but hold tissue together in good apposition.
- Creates a good seal.
- More prone to failure if any portion is broken.
 - Only two knots; if one knot fails, the line fails
 - One continuous strand; if the line breaks in one spot, the whole suture line fails
- Care must be taken to keep firm tension, but avoid tight tension to avoid tissue strangulation

- **Running Suture (Whip Stitch)**



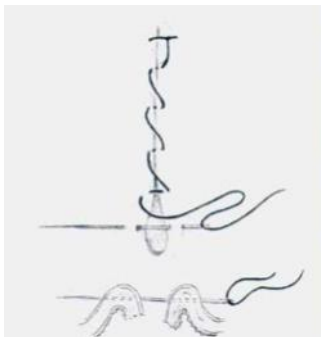
- Both deep and shallow passes can be used.
- Regularity more difficult.
- Slightly faster than a simple continuous pattern.
- Weaker than a simple continuous pattern.

- **Ford Interlocking**



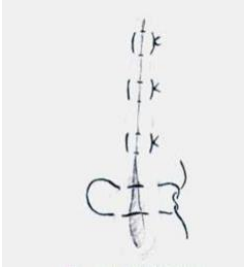
- More stable in the event of partial failure or breakage.
- Provides greater tissue stability.
- Uses more suture material.

- **Lembert**



- Closes hollow viscera.
- Provides inversion and creates a good fluid-tight seal.

- **Halsted**



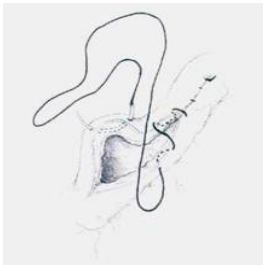
- Combination mattress and Lembert pattern.

- **Connell**



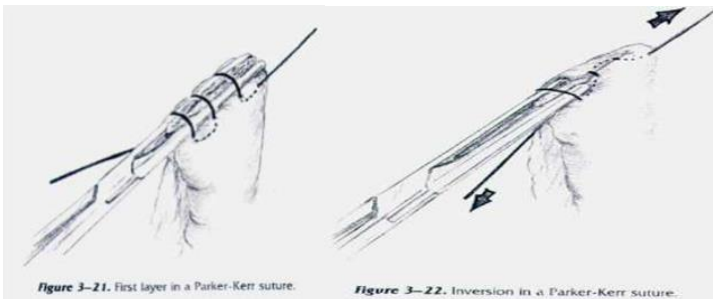
- Begun with a single inverting vertical mattress suture.
- Continues for the length of the incision.

- **Cushing**



- Modified Connell where the needle and suture do not enter the lumen.
- Provides a better fluid-tight seal than the Connell pattern.

- **Parker-Kerr**



- A single layer of Cushing covered by a single layer of Lembert.
- Used for infected uterine stumps and some bowel closures.
- Provides complete clamping to prevent leakage during suturing.
- Rochester-Carmalt forceps are used to clamp the lumen shut and then slowly withdrawn while placed suture is tightened to prevent spillage of contents.

- **Guard**



- Modified Cushing.
- Closes incisions of the rumen, intestine, and uterus.
- Needle does not enter the lumen.
- Starts slightly higher than start of incision.
- Inverting pattern.

- **Continuing Everting Mattress**



- Provides increased strength.
- Rapid placement.

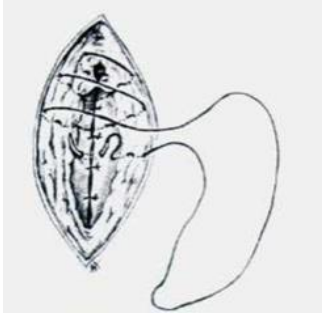


- **Subcuticular**



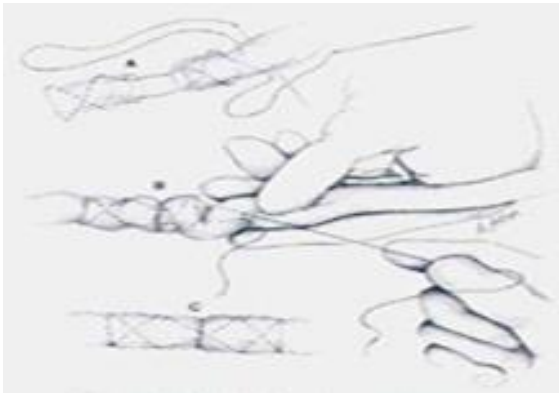
- Does not penetrate the surface of the skin.
- Rapid and uses little suture material.
- Used to close the uppermost layer of the skin incision.
- Requires no suture removal.

- **Subcutaneous**



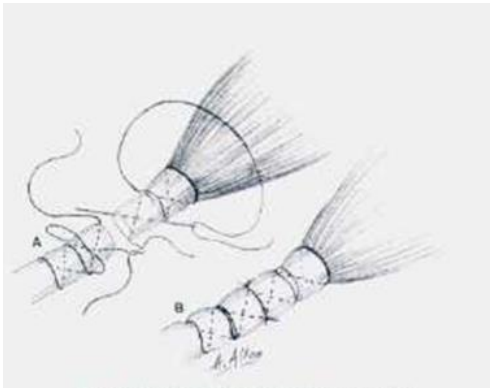
- May use simple interrupted, simple continuous or horizontal mattress.
- Simple continuous is fast and eliminates dead space.

- **Bunnell**



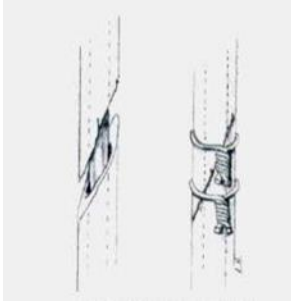
- Used for apposing tendons.
- Requires a high degree of closure strength.
- Uses a double-armed non-absorbable suture.

- **Modified Bunnell**



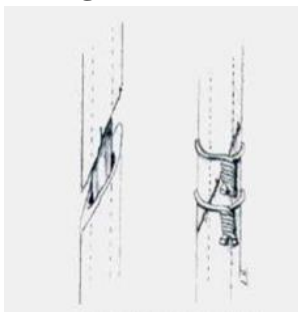
- Used for apposing tendons.
- Requires a high degree of closure strength.
- Uses non-absorbable suture.
- Uses a single-armed suture.

- **Cerclage Wiring**



- Used for fracture repair.
- Wire/pin placed in the bone center to hold it together.
- Wire winds about the bone under the periosteum.

- **Hemicerclage**



- Wire goes through holes drilled in the bone.

Section 16.8.3: Suture Patterns for Specific Tissues

- **Skin:** Simple Interrupted Horizontal Mattress, Vertical Mattress, Continuous Apposing or Everting.
- **Subcutaneous Tissue:** Simple Continuous.
- **Fascia:** Simple Continuous (primary), Simple Interrupted, Vertical Mattress, Far-Near, Near-Far
- **Peritoneum:** Simple Continuous (two layers), and Simple Interrupted.
 - Very thin and fragile in horse, close muscle instead.
- **Vessels:** Simple Interrupted and Simple Continuous.
- **Viscera:** Direct Appositional Cushing Suture.
- **Muscle:** Simple Continuous, Simple Interrupted and Horizontal Mattress.
- **Tendons:** Bunnell.
- **Bone:** Hemicerclage and Cerclage.

PART 17: ENDOSCOPIC PROCEDURES

Section 17.1: General

- Endoscopy: “To look inside.”
 - Used for the interior of hollow viscera (bronchi and intestinal tract).
 - Applied to laparoscopy, arthroscopy, and thoroscopy.
- Also known as Minimally Invasive Surgery (MIS).
 - Surgical techniques designed to minimize the anatomic approach to the target surgical site.
- Requires extensive equipment, training, and practice.
 - Requires training not only for the operating personnel but also for the preoperative and especially anesthesiology personnel.
 - People must know their jobs and perform them properly without supervision.
- Requires multiple preparations, steps, and procedures.
 - Packs should be easily available if the need arises to transform to an open procedure.
 - Room layout must be planned beforehand and orientated towards a smooth operating flow and lack of obstruction.
 - Surgeon(s) and camera operator needs easy viewing of the monitor.

Section 17.2: Endoscopic Equipment

- Video-imaging equipment.
- Endoscopes can be either flexible or rigid.
 - Flexible endoscopes are usually used for examination of the GI and respiratory systems.
 - Rigid endoscopes (telescopes) are more commonly used.
 - Provide the most light.
 - Provide the largest viewing field.
 - Greatest resolution and clarity.
- Larger scopes provide a greater degree of light and better field of view.
- 10 mm laparoscopes are preferred for most procedures.
- Laparoscopes < 5 mm are ideal for diagnostic laparoscopy and thoracoscopy.
- Operating endoscopes are rigid scopes with channels for inserting instruments such as biopsy collectors.
- Viewing fields may be straight (0 degrees) or at angles.
- Field of Vision: the borders of the field of view.
 - The closer the tip of the endoscope is to the target tissue the greater the magnification.
- Camera operator may need to adjust the focus.
- Endoscope must be attached to a camera, camera control unit, and monitor.
- Some older endoscope types can also be manually looked through with the eye like a telescope but this is poorly suited for much beyond biopsies.
- Endoscopic surgical instruments are used and look identical to standard instruments at the working end.
- The instruments are connected to a shaft, which is passed through the trocar or port.

– **Lights**

- Older systems use tungsten bulbs.
- Newer systems use mercury, xenon, or halogen bulbs and are significantly brighter.
- Brightness needs to be adjustable to prevent washing out the image.
- Light is transmitted by a fiber optic cable.
- This cable bundle should be clean at both ends and replaced when enough (commonly 20%) of the cable breaks and fails.

– **Camera**

- Use either one or three chips to convert the camera's image into an electronic signal to be sent to the monitor.
- Single-chip offers 450 lines of resolution.
- Three-chip uses a separate chip for red, green, and blue and offers 600 - 700 lines of resolution.
- Better systems avoid "whiteout" from glare reflected off light colored tissues.
- Camera Control Unit: Allows adjustment of the camera images and transmits signal to the monitor.
- Can adjust focus, sharpness, etc.

– **Monitors**

- Offer between 400 and 700 lines of resolution.
- Should be optimized for the camera chips used.
- Must be medical grade and properly grounded.
- May be ported to VHS systems for recording.

– **Insufflator**

- Abdominal cavities are commonly filled with an inert gas (carbon dioxide or nitrogen) to prevent collapse of the cavity and difficulty with surgery.
- Insufflator provides constant pressure in the cavity.
- May be electronic or mechanical.

– **Electrosurgery**

- Used for hemostasis and cutting.
- Ultrasonic or laser devices may also be used.

– **Irrigation and Suction**

- Used to keep the surgical field clean and allow easy vision.
- Commonly combined into one device.

– **Insufflation needles**

- Used to create a sealed breach into the abdominal cavity to administer gas.
- May be disposable or reusable.

– **Trocars**

- An obturator enclosed in a sleeve used to create "ports" for the entry of instruments and materials into the body cavity.

- **Ports**
 - A device that holds an incision open to allow passage of endoscopic instruments into a body cavity.
 - Ports may be placed by an open technique rather than using trocars.
 - More time consuming.
 - Useful when adhesions may be present or when trying to avoid organs such as the rumen.
- **Reducers**
 - Act as additional gaskets inside or on top of the trocar for the maintenance of pneumoperitoneum.

Section 17.3: Anesthesia for Endoscopy & Endosurgery

- Differs from standard anesthesia due to the increased cavity pressure caused by insufflation.
- Thoracic procedures usually do not use as the collapse of one lung and the rib cage allow an open surgical site.
- Insufflation increases the abdominal pressure and pushes the diaphragm into the chest cavity.
 - Increased intraabdominal pressure (IAP) increases intrathoracic pressure and thus requires mechanical ventilation at higher pressures than normal.
 - PaCO₂
 - Arterial carbon dioxide increases when the insufflation gas is CO₂ by transperitoneal absorption.
 - If PaCO₂ goes up, PaO₂ goes down to compensate resulting in less O₂ being free in blood.
 - Increases heart rate.
 - Increases mean arterial pressure (MAP)
 - Increases vascular resistance
 - Decreases cardiac output
 - Decreases arterial and visceral blood flow
 - Positioning in Trendelenberg (head down) or Fowler (head up) also shifts pressures in the abdomen and chest
 - For some procedures, an increased working space is needed in the chest and inert gasses are introduced to expand the cavity.
 - This can be dangerous as it limits lung capacity.
 - Requires relatively little increases (5 mmHg) to clear space.
 - EtCO₂, MAP, heart rate, and cardiac output will increase.
 - Requires single lung ventilation.
 - Single lung respiration requires specialized endotracheal tubes.
 - The inferior lung receives 60% of the cardiac output.
 - Hypoxic pulmonary vasoconstriction (HPV) diverts blood flow from an atelectatic lung.
 - Inhalation anesthetics inhibit HPV, injectable barbiturates commonly do not.
 - Due to a constant and maintained pressure, liquids or inert gasses may be infused between tissues to dissect them apart.

Section 18.1: Intervention Plan Considerations

- **Basic Life Support & Resuscitation (ABC)**
 - Airway
 - Breathing
 - Circulation
- **Airway Patency**
 - Intubate (if not already intubated)
- **Administer oxygen and assist respirations if needed**
- **Vascular Access**
 - Place percutaneous catheter
 - Post-operatively, best practice is to leave the iv catheter in place until animal has recovered, or in the case of NHP's, recovery has progressed
- **Therapeutic Interventions**
 - Fluid Therapy
 - Drug Therapy
- **Crash Cart Supplies**
 - Stethoscope
 - Endotracheal tubes
 - Gauze
 - Syringe to inflate endotracheal tube cuff
 - Laryngoscope and blades
 - Syringes and needles
 - Emergency drugs and dosages (best is a chart with body weights and dose volumes)
 - Ambu bag
 - Hair clippers
 - Adhesive tape
 - IV catheters
 - IV catheter flushing solutions
 - Isotonic crystalloids
 - Synthetic colloids
 - Bandaging materials
- **Cardiopulmonary Resuscitation Drugs**
 - Atropine for bradycardia, atrioventricular (AV) block, asystole
 - Dobutamine for myocardial failure
 - Dopamine for low cardiac output
 - Epinephrine for V-fibrillation, asystole, pulseless electrical activity



- Lidocaine for ventricular arrhythmias
- Magnesium chloride for V-fibrillation, V-tachycardia
- Naloxone for pulseless electrical activity
- Sodium bicarbonate for cardiac arrest

– **Emergency Equipment**

- Defibrillator
- ECG machine
- Suction unit w/various tips
- Indirect blood pressure unit
- Pulse oximeter
- Capnograph
- Blood gas analyzer

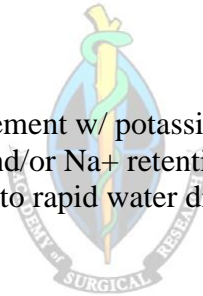
– **Emergency Vascular Access**

- Administration of drugs, fluids, and blood products
 - **Intravenous (IV)**
 - Rapid onset of action
 - Shortest duration
 - Maintain/restore fluid & electrolyte balance
 - **Intracardiac (IC)**
 - Drugs injected through chest wall directly into heart chamber
 - Immediate access to bloodstream
 - Quick delivery to all tissues in body
 - Used in cardiopulmonary resuscitation and for euthanasia.
 - **Intraosseous (IO)**
 - Drug injected directly into the bone marrow cavity.
 - 15 to 18 g bone marrow needle (large animals).
 - Rapid delivery to central circulation via intramedullary vessels.
 - Small animals, neonates, or animals w/poor vascular access:
 - Tibia
 - Femur
 - Humerus
 - Iliac wing or ischium
 - ♦ Requires technical expertise to execute successfully.
 - ♦ Careful attention to sterile technique is required to avoid osteomyelitis.
 - **Intratracheal (IT)**
 - Rapid absorption
 - Dosage usually 2x IV dosage
 - Emergency drugs that can be administered IT
 - Atropine
 - Lidocaine
 - Epinephrine

Section 18.2: Fluid Therapy

Section 18.2.1: Crystalloid Solutions

- Sodium (Na^+) is the main osmotic active electrolyte.
- They may contain other electrolytes or buffers
 - Chloride (Cl^-)
 - Potassium (K^+)
 - Calcium (Ca^{++})
 - Lactate
- Decrease colloidal oncotic pressure (except when used w/colloids).
- Classified by tonicity: Isotonic, Hypotonic, Hypertonic
 - **Isotonic Crystalloid Solutions**
 - Osmolality similar to normal serum (300 mOsm/L)
 - Replacement fluids—dehydration
 - Provides rapid volume expansion
 - Lactated Ringers Solution (LRS)
 - 0.9% Saline (Physiologic Saline)
 - Normasol-R
 - **Hypotonic Crystalloid Solutions**
 - Good maintenance fluid - supplement w/ potassium chloride (KCl)
 - Congestive heart failure, liver and/or Na^+ retention diseases or models
 - Contraindicated in SHOCK due to rapid water distribution.
 - 2.5% Dextrose
 - 0.45% Saline
 - **Hypertonic Crystalloid Solutions**
 - High osmolality
 - Rapid volume expansion
 - Used in combination w/colloids
 - Treatment of hemorrhagic & endotoxic shock
 - 7% Saline
 - Possible Complications
 - Hyponatremia
 - Hyperosmolality
 - Increased bleeding
 - Thrombosis/Thromboembolism
 - Tissue irritation or sloughing
 - Electrolyte imbalances
 - Administration rate too fast:
 - ♦ Bronchoconstriction
 - ♦ Bradycardia



Section 18.2.2: Colloid Solutions

- Resuscitative utility
- Rapid plasma volume expansion w/low volume administration as compared w/crystalloids
- Increases oncotic pressure (used to restore oncotic pressure)
 - Large-molecular-weight substances restricted to plasma compartment because of size
 - Osmoles hold fluid in vascular space
 - Macromolecules are negatively charged—attract H₂O from interstitial space
 - Examples:
 - Albumin
 - Plasma
 - Synthetic Colloids
 - ♦ Hetastarch
 - ♦ Oxypolygelatin
- Can be use as “Maintenance” w/crystalloids
- Go to therapy for hypovolemic or septic shock
- Possible Complications
 - Related to clotting deficiencies or allergic reactions

Section 18.2.3: Dextrose Solution (Specialty Solution)

- Useful for replacement of fluids due to insensible losses and congestive heart failure
- Examples:**
- 2.5% to 50% Dextrose in H₂O
 - 5% Dextrose in LRS
 - 2.5% Dextrose in 0.45% or 0.9% Saline
- Nutritive fluid therapy used in combination w/crystalloids
 - Possible Complications:
 - Contraindicated in cases of shock.
 - Does not provide adequate intravascular expansion due to rapid metabolism to CO₂ and H₂O.
 - Not to be administered SC as electrolyte redistribution in injected tissue will result in tissue necrosis.



Section 18.3: Perioperative Emergencies

Section 18.3.1: Shock

- Condition of decreased tissue perfusion and oxygen delivery to vital organs
 - Untreated—rapidly fatal
- Imbalance between tissue oxygen demand and oxygen delivery leads to:
 - Tissue injury
 - Organ failure
 - Death

- **Treatment**

- Restore oxygen delivery
- Treat underlying causes of shock
- Fluid therapy
 - Prevent circulatory collapse
 - Restore effective vascular volume and blood pressure
 - Shock doses of crystalloid solutions
 - 90 mL/kg/hr (large animals)
 - 45-60 mL/kg/hr (small animals)

- **Systemic Reaction to Shock**

- **Hyperdynamic/Compensatory Shock**

- Impaired perfusion triggers natural compensatory mechanisms that maintain blood pressure and increase cardiac output
- Vasoconstriction
- Tachycardia
- Increase cardiac contractility
- Once blood loss exceeds 40% of blood volume, compensatory organ mechanisms fail over time, and shock becomes irreversible.

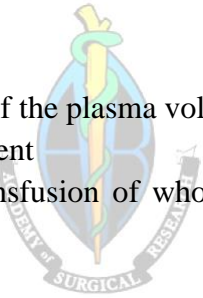
- **Hypodynamic/Uncompensated Shock**

- Blood flow preferentially distributed to vital organs (brain/heart) at expense of other tissues
- Shunting of blood exacerbates the O₂ deficit and fluid imbalance in other tissues
- Leads to organ failure
- Clinical signs (associated w/circulatory failure):
 - Hypotension
 - Tachycardia
 - Weak pulse
 - Prolonged capillary refill time (CRT)
 - Pale mucous membranes
 - Hypothermia
 - Overt weakness
 - Depression
 - Loss of consciousness

Section 18.3.2: Types of shock

- **Hypovolemic Shock**

- Most common
- Hypovolemia = Decrease volume of circulating blood
- Perfusion failure results from decreased volume of blood
- **Symptoms**
 - Pallor
 - Cyanosis
 - Disorientation
 - Tachycardia
 - Cold extremities
 - Cardiac dysrhythmias
 - Tachypnea
 - Hypotension
 - Oliguria
 - Disseminated intravascular coagulation (DIC)
 - Progressive metabolic acidosis
- **Treatment**
 - Colloid solutions for expansion of the plasma volume
 - Hypertonic saline in early treatment
 - Massive blood loss requires transfusion of whole blood/packed RBCs to replace O₂ transport capacity



- **Distributive Shock**

- Includes infectious, anaphylactic, endocrine, and neurogenic causes
- Maldistribution of blood flow associated with pathologic vasodilation
- Pooling of blood in capillaries/veins
- Results in decrease in effective blood volume due to:
 - Trauma
 - Heatstroke
 - Anaphylaxis

- **Cardiogenic Shock**

- Inadequate circulation of blood due to primary failure of the ventricles of the heart to function effectively
- Occurs from heart failure from many primary heart diseases
- **Treatment**
 - Oxygen therapy
 - Fluid therapy
 - Drugs

- Epinephrine
- Norepinephrine
- Dobutamine

- **Obstructive Shock**

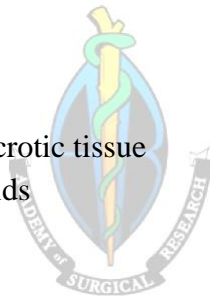
- A form of shock associated with physical obstruction of the great vessels or the heart itself
- Can occur due to vessels becoming blocked from instruments during surgery, or from tumors/abscesses.

- **Septic Shock**

- Occurs when overwhelming infection leads to sepsis which causes a decrease in tissue perfusion and oxygen delivery if not controlled with antibiotic therapy
 - Precipitates state of shock by inducing
 - Vasodilation
 - Vascular permeability
 - Poor cardiac function
 - Activation of coagulation

- **Treatment**

- Aggressive fluid resuscitation
- Antibiotic therapy
- Surgical excision of infected/necrotic tissue
- Supportive care +/- corticosteroids



- **Anaphylactic Shock**

- Immediate hypersensitivity response
- Respiratory arrest
- Cardiovascular collapse
- Death

- **Signs**

- Brick red mucous membranes
- CRT of 1 sec or greater
- Labored breathing/wheezing
- Tachycardia

- **Anaphylactic Shock Treatment**

- Antihistamine
- IV fluid therapy
- O₂ therapy
- Corticosteroids
- Epinephrine (in severe cases)
- Life support

Section 18.3.3: Respiratory Distress

- Marked by labored, exaggerated respiratory effort with insufficient ventilation and oxygenation
- Limited amount of air being moved with respirations

- **Evaluation**
 - Observe respiratory pattern
 - Observe the mucous membranes color
 - Auscultate the lungs

- **Signs**
 - Dyspnea
 - Tachypnea
 - Orthopnea
 - Hyperventilation
 - Hypoventilation
 - Apnea

- **Oxygen Supplementation By**
 - Face mask
 - Flow-by technique
 - Nasal cannula
 - Oxygen cage
 - Intubation with manual or mechanical ventilation

- **Treatment**
 - CPR
 - Manual or mechanical ventilation
 - Respiratory stimulants
 - Doxapram HCl
 - Stimulates respiratory centers in medulla
 - Jen Chung acupuncture to stimulate breathing when other methods fail, or until other methods become available (use a needle to stick the base of the nose at junction of upper lip).



Section 18.3.4: Cardiac Arrest

- Cessation of Heart Beat
- Pulseless electrical activity (PEA), formerly known as electrical mechanical dissociation (EMD), is present initially on the ECG

- **Signs of Cardiac Arrest**
 - Non-auscultable heart beat or weak heart beat sounds
 - Weak, thready or non-palpable pulse

- Dyspnea or frank apnea
- Lack of surgical bleeding and/or lack of or severely low BP
- Cyanosis
- No muscle tone
- Dilated pupils (later)
- **Common causes during surgery (not limited to)**
 - Anesthesia overdose
 - Hypovolemia
 - Acute cardiogenic shock
 - Severe acidosis
 - Hypoxemia

Section 18.3.5: Other Types of Cardiac Emergencies

- **Asystole**
 - No cardiac electrical activity.
 - No cardiac output or blood flow.
- **Ventricular Fibrillation**
 - Uncoordinated contraction of ventricular cardiac muscles.
 - Successful treatment requires early diagnosis/intervention.
 - Brain most susceptible to hypoxia and ischemia.
 - Serious injury after 4 or 5 minutes.
 - MUST develop effective blood flow and reestablish heart beat.
- **Cardiopulmonary Cerebrovascular Resuscitation (CPCR)**
 - Commonly referred to as CPR – cardiopulmonary resuscitation
 - Extra “C” emphasizes importance of maintaining perfusion and oxygen delivery to CNS during/after an arrest
 - Most important goal = early restoration of brain perfusion!
 - Initiate the “ABCDE” plan:
 - A = Airway (assure airway is patent; intubate if possible)
 - B = Breathing (supply oxygen therapy)
 - C = Cardiac massage (external or internal)
 - D = Drugs
 - E = Electrical manipulation (defibrillation)
 - External thoracic massage provides cardiac output by one or a combination of two methods
 - Thoracic Pump Theory
 - Blood moves out of thoracic cavity during the compression half of the CPR cycle because of a buildup of internal thoracic pressure.
 - Cardiac pump theory

- Explains blood flow in smaller animals or animals with a narrow side-to-side thoracic width.
- Refers to mechanical compression of myocardium by thoracic wall during CPR
- Abdominal compressions may be interposed with chest compressions to increase blood return from lower half of the body to the heart.
- Positioning of animal during compressions dependent on:
 - Animal's size and shape of chest (barrel vs. deep/narrow).
 - Animals < 15 lb (7 kg) = lateral recumbency
 - Animals > 15 lb (7 kg) = lateral or dorsal recumbency
 - Dorsal recumbency = deep chested breeds
- Compressions should be given at a rate of 120/minute for animals less than 7 kg and 80 to 100/minute for animals greater than 7 kg.
- Open thoracic or internal CPR more effective at perfusing the heart and brain during the critical beginning minutes of CPR.
 - Higher BP and cardiac output is possible with internal CPR.
- **Heart Defibrillation**
 - Administer shock of 3-5 joules (watts/s)
 - Ventricular fibrillation least common form of cardiac arrest

Section 18.4: Drug Therapy

- **Epinephrine** (also known as adrenalin)
 - Early administration is crucial!
- **Vasopressors** (isoproterenol, phenylephrine)
 - Augments coronary blood flow by constricting vessels, increasing systemic vascular resistance and increasing diastolic perfusion pressure.
- **Lidocaine**
 - Used after resuscitation if ventricular dysrhythmias are compromising cardiac output.
- **Atropine or Glycopyrrolate**
 - Reflex bradycardia may have contributed to initial cardiac arrest.
 - Bradycardia often occurs after heartbeat is re-established.



Section 18.5: Anesthetic Emergencies

- **General Causes**
 - Adverse drug reactions
 - Equipment malfunctions
 - Anesthetic overdose
 - Surgical complications
 - Preexisting medical problems
 - Human error

– **Interventions**

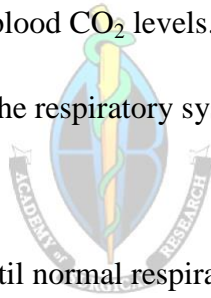
- Reduce/turn off anesthesia
- Provide oxygen therapy
- Verify equipment is working properly; replace if needed

– **May require**

- Manual respirations (bagging or ventilator)
- IV therapy
- Thermotherapy
- Reversal agents +/- other drug therapy

– **Resuscitation**

- Cardiopulmonary arrest most often follows uncorrected excessive anesthetic depth--can happen at any time during anesthesia.
 - Requires prompt initiation of CPR.
- **Causes**
 - Hypoventilation from decreases in blood CO₂ levels.
 - Excessive anesthetic depth.
 - Induction with drugs that suppress the respiratory system.
- **Treatment**
 - Adjust anesthesia accordingly.
 - Bag animal 2 to 10 times/minute until normal respirations resume.
 - Use low end of range in cases of apnea to hypoventilate to allow normalization of CO₂ levels.



– **Hypotension**

- **Causes**
 - Blood loss
 - Shock
 - Cardiac arrhythmias
 - Excessive anesthetic depth
 - Adverse effects of drugs
- **Direct Evaluation**
 - Doppler, oscillometric, or direct monitoring
 - Pale mucous membranes, increased CRT, weak pulses
- **Treatment**
 - Decrease anesthetic
 - IV fluid therapy
 - Oxygen therapy

- Thermotherapy
- Drug therapy
 - Sympathomimetic agents
 - Dopamine or Dobutamine
- **Hypoxia**
 - Deficiency of oxygen at the tissue level caused by reduction in perfusion or a reduction in oxygen content of the blood.
 - **Hypoxia without cyanosis**
 - 5 g/dl of deoxygenated hemoglobin must be present in the circulation before cyanosis can be detected.
 - **Most species:** oxygen saturation may fall below 50% before any evidence of cyanosis detected; below 90% indicates hypoxia, and below 80% can lead to organ failure.
 - **Causes**
 - Lung disease
 - Decreased cardiac output
 - Severe anemia
 - Other
 - **If Prolonged leads To:**
 - Vascular paralysis
 - Systemic vasodilation
 - Cardiovascular collapse
 - ♦ Irreversible and rapidly fatal!
 - **Treatment**
 - Depends on underlying cause
 - ♦ Oxygen therapy
 - ♦ Mechanical ventilation
 - ♦ Respiratory stimulants



Section 18.6: Acid-Base Imbalances

- Defined by pH—result of processes in body tending toward acidosis or alkalosis.
- Normal values 7.36-7.41
 - pH < 7.35 acidosis
 - pH > 7.42: alkalosis

Section 18.6.1: Mechanisms That Regulate pH

- Maintained by 3 systems
- **Chemical buffers**
 - Bicarbonate (carbonate acid)
 - Phosphate (RBCs, kidneys)
 - Hgb
- **Respiratory**
 - Breathing and alteration of CO₂, lungs regulate concentration of carbonic acid
- **Kidney**
 - Elimination of excess acid or bases
 - Carbonic acid- CO₂ equilibrium

Section 18.6.2: Respiratory Acidosis

- **Occurs when CO₂ production > CO₂ excretion**
 - Blood gas analysis will show an increase in CO₂ levels
 - This increase in CO₂ causes gain in acids—pH decreases
 - **Causes**
 - Anything that depresses/impairs excretion of CO₂
 - Deep anesthesia
 - Pulmonary disease
 - Respiratory obstruction
 - Increase CO₂ production with malignant hyperthermia
 - **Other Signs**
 - Increased cardiac output (hypertension)
 - Vasodilation
 - Ventricular arrhythmias
- **Natural compensation by the body with time through kidneys**
- **Respiratory Acidosis Treatment**
 - Need to lower carbon dioxide levels in the blood
 - Ventilate animal with a higher minute volume (increase tidal volume and/or respiration rate) than what was occurring previously (either spontaneously or manually).

Section 18.6.3: Respiratory Alkalosis

- **Occurs when CO_2 excretion > CO_2 production**
 - Blood gas analysis will show a decrease in CO_2 levels
 - This decrease in CO_2 causes an excess loss of H^+ and gain in bases
- **Causes**
 - Anything that stimulates spontaneous hyperventilation and removal of CO_2
 - Excessive controlled ventilation
 - Pain and excitement
- **Other signs**
 - Tachycardia
 - Electrocardiographic changes
- Natural compensation by the body with time through the kidneys.
- Respiratory alkalosis treatment
 - Decreased minute volume if patient is being mechanically ventilated
 - If animal is breathing spontaneously and hyperventilating, assess and treat the cause (e.g., light anesthesia)

Section 18.6.4: Metabolic Acidosis

- Blood gas analysis shows low adjusted base excess (ABE) or low bicarbonate (HCO_3^-)
 - This causes loss of HCO_3^- which means H^+ gain
- **Causes**
 - Lactic acid gain (commonly caused by decreased tissue perfusion)
 - Renal failure
 - Body secretions rich in HCO_3^- lost and not reabsorbed
 - Diarrhea
 - Natural compensated by a rapid response of respiratory system
 - Hyperventilating
- **Treatment**
 - Mild imbalance
 - Alkalinizing IV solution (containing lactate, gluconate, acetate)
 - More severe imbalances – administer sodium bicarbonate
 - Administer slowly IV (give over 15 - 30 minutes)
 - Deaths have occurred during fast administration in dehydrated animals.

Section 18.6.5: Metabolic Alkalosis

- Blood gas analysis shows high adjusted base excess or high bicarbonate (HCO_3^-)
- **Causes**
 - Vomiting (loss of H^+)
 - Hypochloremia (increased renal absorption of HCO_3^-)
- **Natural compensation through the respiratory system by hypoventilation**
 - Results in mild respiratory acidosis
- **Treatment**
 - Replace the lacking element
 - K^+ may be necessary if hypokalemic
 - Cl^- may be necessary if vomiting

Section 18.7: Allergic Reactions

- Allergic or anaphylactic reactions mediated by immune system.
 - Reactions involving anesthetics uncommon - could occur after sensitization to a drug.
- More common:
 - Repeated exposure to allergen e.g. allergies to eggs could lead to a reaction to the egg proteins in propofol.
- Anaphylactic reactions to Thiopental have been reported.
- Allergic reaction in dogs to IV injections of the contrast agent diatrizoic acid has been reported.
- **Signs:**
 - Tachypnea
 - Bronchoconstriction
 - Mucoïd diarrhea
- **Treatment:**
 - IV fluid therapy
 - Antihistamines
 - Corticosteroids
 - Epinephrine

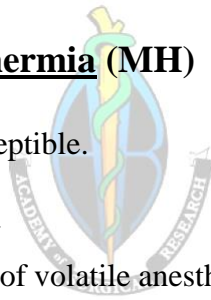
Section 18.8: Miscellaneous Emergencies

Section 18.8.1: Reperfusion Injury

- Cellular injury that develops as blood flow returns to an area or tissue previously deprived of perfusion.
- Upon reestablishment of oxygenation/perfusion, altered enzyme systems generate harmful molecules (oxygen free radicals).
- WBCs release inflammatory mediators in response to damaged cellular membranes.
 - This results in inflammation and vessel injury.
 - Thrombosis and edema follows.
- Effects collectively called “reperfusion injury”.
- Results in systemic disorders such as:
 - Disseminated Intravascular Coagulopathy (DIC)
 - Systemic Inflammatory Response Syndrome (SIRS)
 - Multi-organ dysfunction
- All vital organ systems can be affected by reperfusion injury and inflammation following resuscitation from shock or cardiopulmonary arrest.

Section 18.8.2: Malignant Hyperthermia (MH)

- Swine (Yorkshire) are particularly susceptible.
 - There is a genetic pre-disposition
- Can lead to Pharmacogenetic myopathy
- Halothane most potent triggering agent of volatile anesthetics but others can also trigger it
- Causes a rapid increase in body temperature.
- If not treated quickly, death can result
- MH treatment:
 - Prophylactic Dantrolene before anesthesia.
 - Depresses the intrinsic mechanisms of excitation - contraction coupling in skeletal muscles
 - Replace potassium loss due to muscle tremors



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