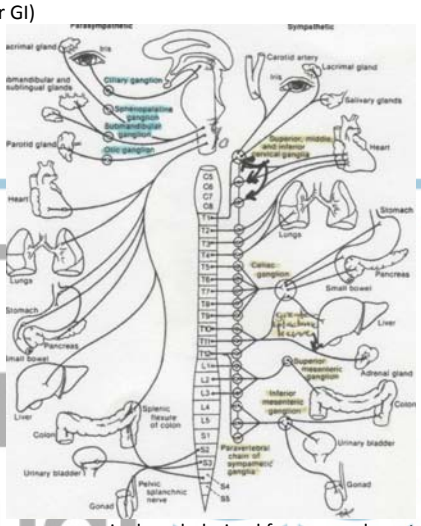
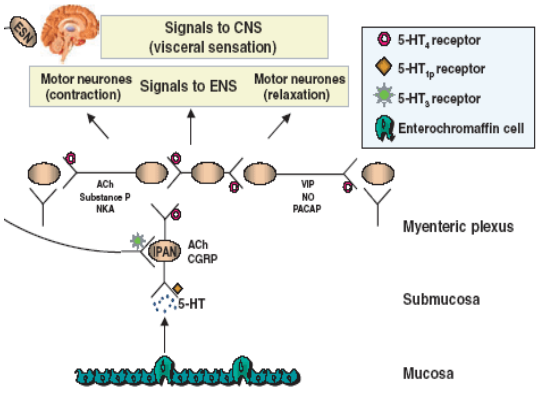
Innervation

- Afferent
  - Mechanical
  - Chemical
- Efferent
  - Extrinsic (Autonomic NS)
    - Para (+) Long ACh nerves beginning in PNS and ending in target organ – Short Ach nerves w/in target organ – Interact w/ Enteric NS
      - Vagus (upper GI)
      - Sacral (lower GI)
    - Sym (-) Short Ach nerves beginning in PNS and ending in three ganglia – Long NEpi nerves in ganglion and ending in target organ – Interact w/ Enteric NS
      - Celiac (upper GI)
      - SMP (mid GI)
      - IMP (lower GI)



  - Intrinsic (Enteric NS, 100 million neurons ~ spinal cord, derived from neural crest cells)
    - Plexi ("LOAI-CIMS")
      - Meissner's/Submucosal Plexi (controls secretions, near Mucosa b/t Circular Muscle and Submucosa)
        - NB another set of plexi b/t submucosa and circular muscle called Schabadasch's Plexi
      - Auerbach's/Myenteric Plexi (controls motility of smooth muscle, near Adventitia b/t Circular Muscle and Longitudinal Muscle)
      - NB Interstitial Cells of Cajal (ICC) intermediate cells b/t nerves and muscle, lie w/in muscle fiber, act as pacemakers modulate interaction b/t muscles and motors, +CD-117/c-kit
    - Neurotransmitters
      - +: 1° Ach, 2° SubP, GABA, Serotonin
        - 97% GI vs 2% Platelets (remove serotonin from circulation) vs 1% CNS (mood)
        - 5-HT: four families (1/2 in CNS, 3/4 in GI)
        - what it actually does in the GI tract is very complicated depending on balance of types of receptors it acts on
      - -: 1° VIP, NO, 2°Neuropeptide-Y, ATP, beta-NAD



Motility

- General
  - Tonic @ Sphincter (LES, ICV, IAS)
  - Phasic @ Lumen (Esophagus, Stomach, SI, LI)
    - Feeding State
      - Segmentation (no net movement forward just mixing)
      - Peristalsis (propels food forward)
    - Fasting State (MMC)
      - **Migratory Myoelectric Complex (MMC) aka InterDigestive Motor Cycle (IDMC)**
        - clears residual food and bacteria
        - can occur after vagotomy suggesting an intrinsic process mediated by motilin and inhibited by gastrin
        - antrum to ileum
        - occurs **Q90-120min** at a rate of **3cpm (stomach) vs 12cpm (proximal SI) vs 8cpm (distal SI)**
        - three phases: #1 quiescent (lasts ?min), #2 random irregular contractions (lasts ?min), #3 regular high amplitude contractions which migrates debris distally (lasts ?min)
- Swallowing (refer)
- Stomach (refer)
- SI (25ft = 760cm, 2,000,000cm^2, 5hrs transit)
- LI (5ft = 152cm, 900cm^2, 25hrs transit)

Gut Bacteria

- What is our microbiota?
  - Composed of 10^{14} (100 trillion) microbial cells and 10^{15} (1 quadrillion) viruses
  - Distinct b/t each person ("new fingerprint"?) even identical twins only share ~50% of the species
  - Stable throughout life in terms of type of bacteria
  - Can vary in metabolic activity and thus number w/ dietary changes, environmental changes, abx use, etc but even when disturbed (dysbiosis) the flora is able to restore itself and return to the exact state before
- How is our microbiota acquired?
  - Fetus is sterile in utero → at delivery the newborn begins to develop either skin-like profile if CS or vaginal-like profile if VD → as the infant begins to eat (especially with the introduction of solid food) the gut microbiota develops and diversifies into its adult state → thereafter the composition remains relatively stable
- What are the exact types of bacteria?
  - **Oropharynx/Stomach/Duodenum/Jejunum (10^3 CFU/mL, GPC aerobes, 200 species) → Ileum (10^8 CFU/mL, transition zone w/ mix b/t SI/colon) → Colon (10^{12} CFU/mL, GNC anaerobes, 1000 species)**
    - Predominant GP Aerobes Genera: *Staphylococcus*, *Streptococcus, Lactobacillus, Enterococcus*
    - Predominant GN Anaerobes Genera: *Bacteroides, Prevotella, Ruminococcus*
    - What creates this sharp gradient? (refer to etiology of SIBO)
    - Why minimize the amount of bacteria in the SI? prevent competition with food, prevent entry of bacteria across very permeable SI surface, et al
    - NB even w/in one part of the GI tract bacteria vary from mucosal surface (aerobes) to lumen (anaerobes) hence Bx mucosa and aspirate fluid for Cx
    - NB flora on the skin are distinctly different
- What does the microbiota do for humans?
  - GI Immune System Development
    - Hygeine Hypothesis: postulates that the lack of exposure to pathogenic and even non-pathogenic microbial products early in life might result in impaired immune system development and increased r/o atopy, autoimmune conditions, IBD, etc

        - This hypothesis has been confirmed when comparing germ-free GI tracts to conventionally colonized GI tracts → what was found was that germ-free GI tracts have less mucosal cell turnover, enzyme activity, lymphoid tissue, vascularity, wall thickness, motility, etc AND most importantly the GI tract is able to distinguish non-pathogenic from pathogenic bacteria
        - This homeostasis is important b/c the GI tract is exposed to the environment and must absorb nutrients from a foreign world w/o constantly generating an immune response except when a true pathogen exists
    - Protective Properties
        - Protect the host from pathogenic bacteria via the production of various substances such fatty acids, peroides, bacteriocins which are toxic to many bacterial pathogens
        - Additional ways our body protects ourselves from pathogenic bacteria: gastric acid, intestinal motility, mucus barrier, immune system
    - Metabolic Properties (not possessed by the host)
        - Transform 1° Bile Acids to 2° Bile Acids
        - Degrade Oxalate
        - Produce Biotin, Folate, Vitamin K
        - Convert undigestable/unabsorbed carbohydrates creating SCFAs which are subsequently used as an energy source by the colon
        - Ferment undigestable/unabsorbed carbohydrates creating H_2, CH_4, H_2S, CH_4S (last two give gas an unpleasant odor)
        - Bacterial azoreductase splits sulfasalazine into sulfapyridine and active mesalamine
        - Increase Fat Storage by suppressing epithelial derived fasting induced adipocyte factor (FIAF)
    - Carcinogenic Properties
        - Degrade Carcinogens
        - Create Carcinogens (tongue bacteria reduce nitrate (NO_3, used in the preservation of meats) to nitrite (NO_2) which subsequently react w/ other substances (eg. amines) forming carcinogenic N-nitroso compounds (eg. nitrosamines))
    - The Bad Side (occurs when there is a dysbiosis)
        - Acute Changes in Microbiota → C.diff colitis, Necrotizing Enterocolitis, Typhlitis, SIBO, etc
        - Chronic Changes in Microbiota → many chronic diseases eg. IBD, Celiac Dz, Atopic Dz, etc

Immune System

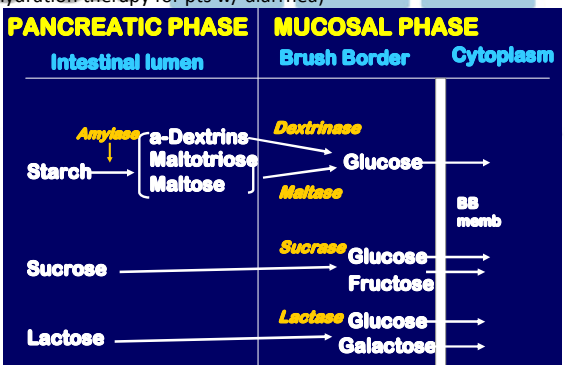
- **Gut Associated Lymphoid Tissue (GALT)**
    - MALT at Peyer's Patches in TI acting as normal physiologic immune tissue or acquired at sites that are experiencing inflammation
        - MALT kind of looks like a LN where lymphocytes are organized into different zones based on differentiation
        - stomach does not normally contain MALT but when there is a HP infection MALT develops
    - Tonsils & Waldeyer's Ring in Oropharynx
    - Appendix
    - Mesenteric LN
    - NB the rest of the GI tract is devoid of organized lymphoid tissue
- **Antigen Producing Cells** (dendritic cells, macrophages, epi cells) present Ag via MHC proteins encoded by HLA gene to effector sites (lymphocytes in lamina propria) which inducing them to produce a cell-mediated response (produce cytokines) / humoral response (produce IgA) which induce further immune cells to target the epithelium and "fight pathogens"
    - NB Ig bind Ag but do not activate complement AND induction of regulatory/suppressor T-cells = controlled local response w/o systemic reaction to commensal bacteria/dietary/self antigens (when this is not effective there is a los of tolerance to these antigens various conditions results i.e. IBD, Sprue, Autoimmune conditions)

Metabolism

- General
    - SI: energy source (Glucose and Glutamine)
        - Duodenum/Proximal Jejunum: absorbs everything **including uniquely iron**
        - Distal Jejunum: absorbs everything
        - Ileum: absorbs everything **including uniquely bile salts/vitB12/Zn/fat soluble vitamins**
    - LI: energy source (Glucose and SCFA)
        - Colon: does not normally absorb any nutrients except in salvage state, mainly only absorbs water/electrolytes
- Absorption
    - General
        - b/c polymers are potentially immunogenic that is why they are broken down and then reassembled in the body
        - <5% of nutrients escape absorption and are excreted in stool
        - SI ages very well absorbing stuff just like a young SI except for folate, B12, Ca, Cu, Zn hence supplementation, in addition the SI is more prone to ischemia, SIBO, NSAIDs, infections
    - **Water**
        - 10L/d reaches the SI (3/4 from secretions and ¼ from ingestion) w/ 9L/d absorbed via aquaporins by the SI (water permeability decreases as you move distally in the SI) such that 1L/d reaches cecum w/ 0.9L/d

absorbed by the colon such that 0.1L/d reaches stool (NB just a 1% increase in water in stool causes clinical diarrhea)

- **Electrolytes**
  - Generally **absorption-villus > secretion-crypt** but some electrolytes are poorly absorbed (magnesium, sulfate, phosphate)
  - Cholera and CF represent the extremes of disorder of secretion/absorption
  - B/c **absorption-villus > secretion-crypt** when there is a loss of villi there is a loss of absorption but intact secretion hence diarrhea
- **Other Essential Nutrients**
  - Carnitine, Choline, Cysteine, Glutamine, Taurine, Tyrosine
- **Carbs**
  - 4kcal/g, in general Americans consume twice the RDA (?, American avg 250g/d), preferred energy source for CNS, renal medulla, blood cells
  - Good: Natural state, high in fiber, many other vitamins/minerals, those that low glycemic index aka they cause a gradual delayed rise in serum glucose (eg. fruits, vegetable, whole grain breads)
  - Bad: Unnatural State, low in fiber, few other vitamins/minerals, high glycemic index aka they cause a big spike in serum glucose (eg. refined/processed like HFCS, white grain breads)
  - Available Polysaccharides aka Starch (amylose/glycogen = linear chains of glucose connected via α1,4 and amylopectin = branched chains of glucose connected via α1,4 and α1,6) are cleaved at α-1,4 via luminal amylase from 1° pancreas 2° salivary, creates maltose and alpha limit dextrins
    - NB Unavailable aka undigestable polysaccharides aka Fibers (cellulose/pectin/gums/alginates = linear chains of glucose connected via β1,4 and this bond cannot be cleaved my human amylase but can be fermented by bacterial enzymes into H_2/CO_2 (for every 10g of carbs you create 1L of gas) and SCFA which is absorbed aka "carbohydrate salvage" (NB this is also the case for lactose, lactuloase)
  - Oligosaccharides are broken down via brush border enz: Maltase (Maltose = Glu+Glu), Isomaltase (Alpha Limit Dextrins = branched Glu+Glu), Lactase (Lac=Glu+Gal), Sucrase (Suc=Glu+Fru), Trehalase (Tre=Glu+Glu), etc
    - NB some disaccharides are not absorbable (eg. raffinose and stacchyose from legumes, synthetic lactulose) or do not have enzymes (eg. fructans, cellulose, pectins from vegetables but are fermented by colonic bacteria)
  - D-Monosaccharides which are then absorbed by Na/Glu or Na/Gal Active CoTransporter (SGLT1, unsaturatable, dependent on Na) and Fructose Passive Transporter (GLUT5, saturatable, independent of Na, unlike glu/gal fructose is not as well absorbed and thus high levels in diet can lead to intolerance) on apical membrane, all sugars then pass thru Passive Transporter (GLUT2) on basal membrane which then enter into portal blood
    - NB no polymers of any length can be absorbed
    - NB for every glucose and Na this absorbed 1000 water molecules are absorbed (this is the rational for oral rehydration therapy for pts w/ diarrhea)



- **Protein**
  - Polypeptides are broken down via luminal enz from 1° pancreatic endopeptidase/exopeptidases secreted as proenzymes which are converted via trypsin, 2° gastric pepsin (secreted as pepsinogen which is converted to pepsin in an acid environment, broad range endopeptidase
  - Oligopeptides are broken down via various brush border peptidases
  - L-Amino Acids are then absorbed by various Na/AA Active CoTransporters which then enter portal blood
    - NB **bi/tripeptides can be absorbed** via a single H/Peptide Active CoTransporter which can then be broken down by various cytoplasmic peptidases into AA
    - NB plant proteins are less digestable than animal proteins (except collagen and keratin), high quality protein is that which contains the eight essential aa (animal > plant), <5% of protein is not absorbed, Hartnup Dz (disorder of renal/GI neutral aa transport)
  - 4kcal/g, in general Americans consume about the RDA (1g/kg/d, American avg 80g/d), there is no storage form if you eat too much you catabolize it, there are essential and non-essential AA

        - NB 2/3 of nitrogen derived from protein breakdown is excreted into urine as 85% urea and 15% other therefore you can calculate protein catabolism by measuring Urinary Urea Nitrogen (UUN) g/d and 4 to account for the 15%, the goal is to maintain a nitrogen balance of 5g/d therefore you want Protein-Intake(g/d)/6.25 – UUN(g/d)+4 = >+5g/d
        - Low: low muscle mass, edema, hair loss
    - **Fat (b/c this is more complex than carbs/protein then it makes sense that when there is malabsorption/maldigestion fat absorption is the most affected)**
        - TG: Insoluble Fat Globs (via amphipathic bile salts from GB) → Soluble/Emulsified Fat Micelles (via luminal enz from 1° pancreas lipase, 2° lingual/gastric lipase, breaks down TG into two FFAs and monoglyceride, NB pancreatic colipase displaces bile salts so lipase can act) → FFAs and Monoglycerides are then absorbed via passive diffusion across membranes → fats then reesterify into TG and join other fats and ApoB forming chylomicrons which then enter into lymph
        - Phospholipids: similar to TG but is hydrolyzed by pancreatic phospholipase A2
        - Cholesterol/Vitamins: similar to TG but is hydrolyzed by pancreatic carboxylesterlipase and not absorbed passively rather it is an active process by a protein that is inhibited by ezetimibe
        - NB plant sterols are similarly absorbed but they are very atherogenic hence enterocytes actually export it back into the lumen by ABC transporters
        - 9kcal/g, in general Americans consume twice the RDA (?, American avg 100g/d), consists of TGL / sterols / phospholipids which serve as energy / precursor for steroids and PGL / structure of cells
        - Good (increased HDL and decrease LDL)
            - some unsaturated FAs like Mono (eg. nuts/avocados and olive/canola oil)
            - Poly (eg. fish)
            - Omega-3 (eg. fish)
        - Bad (increase LDL and decrease HDL)
            - all saturated FAs (eg. animal fat and some plant fat like coconut oil)
            - some unsaturated FAs like Trans (eg. hydrogenated liquid oils generated by scientist so that food can withstand the production process and can last longer on the shelf)
            - Omega-6/9 (eg. animal fat and palm/soybean/sunflower oil)
        - Other
            - **SCFA: Acetate/Butyrate/Proprionate**
                - products of dietary fiber fermentation, stimulate colonic blood flow, enhance colonic fluid and electrolyte absorption, trophic effects on colonic mucosa, butyrate may be preferred fuel for colonocytes
            - **Essential FAs: Linoleic and Linolenic Acid**
                - Essential FA Deficiency (EFAD) = scaly rash (main one), alopecia, capillary fragility, poor wound healing, increased susceptibility to infection, fatty liver, growth retardation

- **Hormones**
    - Stimuli: neural (site), chemical (taste/smell), nutrient (nutrient), mechanical (presence)
    - Hormones: endocrine, paracrine, autocrine, juxtracine (from neurons or inflammatory cells)
    - NB several different forms of a single hormone exist that vary in length, amidation, sulfation, etc
    - Two general classes of hormones: (1) gastrin/CCK and (2) all others
    - Systemic hormones (adrenal hormones, epinephrine, RAAS, thyroid) also have effects on the GI tract
    - High hormones in tumors, renal failure, general diarrhea
    - When there are a lot of nutrients in the distal SI then various hormones (Gastric Inhibitory Peptide, Neurotensin, Enteroglucagon, Peptide YY) are released which slow down SI motility to allow these nutrients to be absorbed

Gastrin	G Cells (Antrum) • + parasymp via GRP from Vagus during sham feeding • + protein but any food in the stomach causing distension • – acid • – fasting • – somatostatin	Receptor: CCK1 on Parietal Cells in gastric body • Gastric Acid Release • Gastric Mucosa Growth NB Hypergastrinemia • High Acid Level (ZES, G-cell hyperplasia, isolated retained antrum during an antrectomy) • Low Acid Level (atrophic gastritis, pernicious anemia, vagotomy, uremia, meds: PPIs/H2B)
Cholecystokinin (CCK)	I Cells (Duodenum) • + FFAs but not TGs (important b/c you can give TGs as an energy source in pancreatitis pts w/o stimulating the pancreas) • + protein/peptide/aa • + Ca/Mg/Zn • – acid • – trypsin unbound to food signifying no more food and thus no more need for CCK to stimulate enzyme release (trypsin does this by binding to "monitor peptide" or "luminal CCK releasing factor" – LCRF)	Receptor: CCK2 • Inhibit Gastric Emptying and Acid Secretion • Gallbladder Contraction and Sphincter of Oddi Relaxation • Pancreatic Enzyme Secretion (important to note that CCK does so indirectly by activating vagus nerve) • Creates sensation of satiety • Trophic Pancreas • Insulin Release

Secretin	S Cells (Duodenum) • + FFAs • + acid	• Inhibit Gastric HCl/Gastrin Secretion and Gastric Emptying • Increase Bile Production • Pancreatic Bicarb Secretion • Inhibits SI motility
Motilin	M Cells (Duodenum) • + fasting • + erythromycin • - eating	• secreted in a cyclic rhythmic pattern triggering the MMC
Somatostatin **Octreotide (Sandostatin)**	D Cells (Duodenum, Stomach, Pancreas) • + acid • + fat • – parasymp	• Inhibit Everything b/c all endocrine cells have receptors (stomact, gallbladder, pancreas, SI) therefore can be used for pancreatitis, dumping syndrome, short gut syndrome, diarrhea, high output fistula, any hormone releasing tumor • Inhibits gastrin and insulin • Inhibits intestinal absorption • Inhibits acid • Inhibits portal blood flow therefore can be used EV bleeds
Pancreatic Polypeptide (PP)	Ileum • (similar gastrin)	• inhibits pancreatic exocrine secretion

- General
  - Other
    - Generally you need 1200cal/d to maintain body weight
    - Energy
      - Resting Metabolic Rate (65%)
      - Thermic Effect of Physical Activity (25%)
      - Thermic Effect of Feeding (10%, this effect is much higher in pts who say they have a "high metabolism")
    - To lose 1lb of fat you need to burn 3500cal
    - How is energy measured? Indirect Calorimetry, Substrate Oxidation, Doubly Labeled Water
  - Assistance: RF outpt (Landry) vs RD inpt (Basement Johnson), forms at end of PN section, visit 2-3x/wk, there are automatic consults (eg. ICU, weight loss, TF at home, etc)
  - Assessment
    - Diet (vegetarian, food intolerances/allergies, etc)
    - Anthropometry
      - Weight
        - Cachectic / Under Weight (BMI <18) vs Ideal Weight vs Over Weight / Obese (BMI >25)
        - pts could be Ideal Body Weight (IBW) but have specific nutrient deficiencies
          - IBW: M (5ft = 106lbs and 6lbs for Q1") vs F (5ft = 100lbs and 5lbs for Q1")
        - pt could be under/over-weight based on BMI but be healthy
    - PEx
      - Always check nails, hair, muscle, mouth, skin
  - Labs
    - 3 Major Nutrients (protein, fat, carbs): albumin ($t_{1/2}$ = 21d), transferrin ($t_{1/2}$ = 9d), pre-albumin ($t_{1/2}$ = 3d, increase in RF and steroid/OCP use and decrease in liver dz or any illness), retinol binding protein ($t_{1/2}$ = 0.5d) for protein state, all made in liver, all are negative APRs, how do you assess fat/carb???
    - 7 Major Minerals/Electrolytes (refer below)
    - 4/9 Vitamins (refer below)
    - 10 Trace Elements (refer below)
  - Nutrition
    - EN vs PN, if you can use GI tract then use it b/c the barrier fxn of the mucosa is maintained by enteral food (specifically glutamate and SHFA which is the energy source for SI/LI mucosa) and if pt is not getting any enteral food then mucosa breaks down and bacterial invasion can occur aka translocation, also enteral nutrition prevents atrophy of GI organs, maintains IgA synthesis, prevents cholelithiasis, etc, NB remember that glutumate is the main "food" for GI mucosa
    - Supplements (nutrient, vitamins, elements, minerals)
    - Appetite Stimulants
      - **megestrol (Megace)** SEs: DVT-PE, cardiomyopathy, leukopenia, adrenal suppression
      - **dronabinol (Marinol)** SEs: dependency w/ withdrawal, seizure, depression, hallucination
      - **oxandrolone (Oxandrin)** SEs: many
- Specific Disease States
  - Short Bowel Syndrome (refer)
  - Pancreatitis: don't keep pts NPO rather use PN or consider intrajejunal feeds (recent studies show otherwise)
  - Liver Dz: malnourished esp low muscle mass, often hypermetabolic while also anorexic, decreased bile-salt production/excretion leads to intolerance to high-fat foods and fat soluble vitamin malabsorption, decreased absorption from mucosal edema, there is altered metabolism of protein w/ change in concentration of AA floating around in the body which is

postulated to be the cause of hepatic encephalopathy hence limiting protein in diet but malnutrition worsens hence don't protein restrict rather Tx HE w/ meds
    - Renal Dz: malnourished esp low muscle mass, altered metabolism of protein w/ change in concentration of AA, vitD deficiency, even though protein restriction delays progression of CKD the detrimental effect is much more detrimental, use low PO4 and low Mg diet
    - Pulm Dz: malnourished, hypermetabolic b/c of increased resp muscle use, don't overfeed b/c there will be increased CO2 esp w/ high carb diet
    - Onc Dz: malnourished b/c of hypermetabolic tumor and anorexic effects of tumor/chemo/radiation
    - Starvation: 0-1d (glucose from liver/muscle **glycogen**), 1-14d (muscle **protein** is broken down into AAs and then converted into glucose), >14d (fat **TG** is broken down into FFAs as organs begin to switch their metabolism and become capable of using FFAs instead of glucose for energy)
        - NB brain, RBC, renal medulla require glucose for energy
    - Malnutrition: gradual muscle/fat catabolism, Marasmus (malnourished child w/ prominent bones, thin skin, etc) vs Kwashiorkor (malnourished child who experiences a physiologic stress resulting in further changes in metabolism creating characteristic features classically protuberant belly b/c of weak muscles, hepatomegaly, intestinal distension and ascites) vs Nutritional Dwarfism, except the brain every system is affected: GI (SI mucosa atrophy, increase in bacteria, hypomotility w/ abdominal protuberance, etc), immune dysxn, poor wound healing, etc
    - **Refeeding Syndrome:** occurs when you begin to feed a pt who has been starving 2/2 rapid shift in fuel from fat (starvation state) to carbs (normal state) with increase in insulin which pushes K/PO4/Mg into cells in addition PO4 is consumed in making protein = hypoK/PO4/Mg with PO4 being the most important one b/c no ATP therefore all muscles (skeletal/cardiac) and brain cannot work resulting heart failure and seizures/delirium), in addition there is consumption of thiamine
        - S/S: Hypophosphatemia, RBC/WBC dysfunction, Bone Loss, Rhabdo, Cardiomyopathy, Respiratory Failure, Metabolic Acidosis, CNS dysfxn
        - Tx: refeeding slowly (10ckal/kg/d Day#1-3, 20ckal/kg/d Day#4-6, 30ckal/kg/d Day#8-10), replete K/Mg/PO4, give thiamine & VitB complex BEFORE you start feeding
- Enteral Nutrition (EN)
    - **PO**
        - Diet
            - Consistency: **Clear Liquid (eg. broth) - Full Liquid (eg. milk) - Pureed - Mechanical Soft w/ Ground Meat – Mechanical Soft w/ Chopped Meat – Full**
            - Calories: 1800cal/d
        - Supplements
            - Shakes: **Boost/Ensure** (general), **ProSure** (high protein), **Glucerna** (low calorie for diabetics), **Scandishake** (high calorie for cachectics)
            - Probiotics
            - Vitamins
        - Oral Rehydration Solutions

	Na	K	Cl	Citrate	Kcal/L	CHO (g/L)	mOsm
Equalyte	78	22	68	30	100	25	305
CeraLyte	70/90	20	98	30	165	40	235/260
Pedialyte	45	20	35	30	100	20	300
Rehydralyte	74	19	64	30	100	25	305
Gatorade	20	3	0	0	210	45	330
WHO	90	20	80	30	80	20	200

    - **Naso/Oro-Enteric: NGT or NDT aka DHT** or **Percutaneous: S/PEG/GJ/J** (Surgical/Percutaneous Endoscopic Gastrostomy/Gastrojejunostomy/Jejunosotmy)
        - **NGT**
            - Type: ? (firm) vs Silastic (flexible)
            - Duration: <1mo
            - Procedure: placed by RN at bedside, sit pt in sitting position, estimate insertion depth by measuring distance from tip of pt's nose to the earlobe and from earlobe to xyphoid process, choose most patent nostril by having pt blow through each nostril, anesthetize nostril with topical anesthetic spray, lubricate NGT and place into nostril and push posteriorly with pt neck slightly flexed, once NGT reaches oropharynx have pt swallow a sip of water, advance to determined length
            - Indication: gastric decompression prior to surgery or in trauma, in presence of recurrent vomiting and suspecting obstruction/ileus, occasionally can be used for nutrition, fluids, meds vs Diagnostic: lab analysis of gastric contents, determination of GI hemorrhage
            - Contraindications: facial/cribiform fx, esophageal pathology
            - Complications: aspiration pneumonia, sinusitis, esophageal injury w/ stricture, head/neck/chest injury from tube, inaccurate dosing of meds b/c some meds bind to wall of tubes, diarrhea from sorbitol (used to make solid meds liquid) and high osm feeds but remember other causes of diarrhea in ICU pts
        - **NDT/NJD aka DHT**
            - Duration: <1mo

- Procedure: placed by RNs (determine length of DHT needed similar to NGT but add 25cm b/c going into duodenum)
    - #1 "Over-the-Wire" Technique = generously lubricate scope and nares w/ lidocaine jelly, pass spaghetti scope thru nose into duodenum (remove as much as air possible in stomach b/c having wire in stomach results in loops and bends and prevents passage of DHT), feed wire thru scope, remove scope w/o moving wire, pass DHT, check KUB
        - NB this is a harder method: pass gastroscope into duodenum, feed wire, pull scope out leaving wire in place, feed the open end of the 6" curved purple tube thru the nose out of the mouth, take the wire and feed thru purple tube into nose, now the wire is thru the nose, then place the NJT over the wire into the duodenum
    - #2 "Drag-and-Pull" Technique = tie a loop of silk suture (actually use the needle a pierce thru the tip of the tube), place DHT into stomach via nose, use gastroscope w/ Resolution hemostasis clip and clamp suture and take tube into duodenum then open clamp and reclamp onto fold, come back adding lots of air to prevent pulling on the tube, check KUB
- Indication: do vs NGT to reduce r/o aspiration 2/2 suspected gastroparesis, gastric outlet obstruction, etc
- Contraindications: facial/cribiform fx, esophageal pathology

- **PEG**
    - Indication: enteral nutrition needed for >1mo (otherwise use NGT) and survival >6mo
    - Pre: coags/plts, assess if altered anatomy, no ab wall infection, no ascites, no gastric varices, no obesity, prophylactic abx, no VP shunt, no ab wall mesh, no gastric cancer, if gastroparesis/obstruction/aspiration then consider endoscopic PEG w/ jejunal extension (G for suction and J for food) or surgical PEJ
    - When you place a PEG always code for both dysphagia and malnutrition for Medicare to pay
    - Pull Guidewire Technique
        - Sterile Person: sterilely prep pt, give snare and PEG tube to nurse, find spot, mark w/ cover of needle, anesthetize (as you anesthetize and pull back the needle if you get a 2nd hit of air then you have passed thru the colon!!!), needle angled towards head thru ab (½ b/t midline and midclavicular and ½ b/t umbilicus and xiphoid), make 7mm incision, pass trocar, endoscopist grabs trocar w/ snare, feed wire thru needle and endoscopist grabs wire w/ snare, endoscopist pulls out scope with snare around wire, put betadine over wire outside of mouth, feed lubricated 20F Bard gastrostomy tube over wire thru mouth, it should pass thru stomach easily and once it passes thru skin you PULL the tube thru and then abut internal bumper to stomach wall w/ mild tension, remove wire, measure ab wall distance (~3cm), bacitracin ointment, add external bumper w/ little end pointing out, cut tube to shorten it then place valve
        - Scope Person: do full exam looking for varices, gastric outlet obstruction, et al then stay in stomach and keep inflated with air
    - Post
        - can use immediately for meds/water
        - inspect prior to starting TF
        - can begin TF as early as 6hrs afterwards
        - 24hrs late pull back 1/2cm b/c when placed you placed in tight to avoid bleeding but for the future you don't want it too tight b/c buried bumper can occur
        - Plastic Bumper lasts up to 1yr vs Balloon lasts up to 3mo
    - Complications
        - aspiration
        - Bleeding
        - Peristomal pain
        - if clogged then warm water or pancrease or Coke
        - if PEG pulled by accident then if PEG placed <4wks ago (fistula has not matured) then don't replace, at bedside rather repeat EGD and attempt to replace PEG thru original site but also call GS, NGT, abx, frequent PEx for peritonitis vs >4wks ago (fistula has matured) then bedside replacement (if in middle of the night tell ER doc to temporarily replace w/ similar size (F) foley and inflate balloon b/c tract closes in 6hrs!!!)
        - 5% skin infection even if Ancef is used but most cases are just maceration/irritation
        - gastric ulcer
        - leakage, make sure internal bumper has not popped out of stomach
        - damage to other organs
        - buried bumper syndrome b/c of too much tension or weight gain, Tx: just pull and do another PEG at a different site
        - gastrocolic fistula b/c colon pinched in b/t and is seen as diarrhea after feeds
        - neoplastic seeding to ab wall/skin
        - pneumoperitoneum, can be normal up to 5wks post placement
    - Replacement (need to determine length and French size)
        - TRY TO DO IN THE OFFICE NOT IN THE GI LAB BECAUSE YOU GET PAID MUCH MORE

        - If replacing plastic bumper with balloon then give some versed and fentanyl and don't forget to hold AC/AP
        - Kimberly Clark MIC Gastrostomy Tubes and MIC-KEY Low Profile Gastrostomy Tubes (18,20,22,24,26,28Fr, inflatable internal balloon)
        - US Endoscopy Replacement PEG Tubes (20F, not sure how they are placed)
        - Cook Replacement PEG Tubes (14,16,18,20,22,24F, inflatable internal balloon), Cook Passport Low Profile G-Tubes
        - Abbott Easy-Feed, Magna-Port, Flexiflo Gastrostomy/Jejunostomy Tubes
        - Other: J-tubes that you pass thru a PEG, et al
    - Removal: duration is indefinite
        - if flexible internal bumper (most, placed by GI, no sutures) cover w/ towels, distract pt, use other hand to prevent tenting of abdomen, very quickly pull on it pointing away from you while turning head b/c splatter will occur, dress w/ 4x4
        - if internal balloon (third port) deflate balloon and pull it out
        - if stiff internal bumper (few, placed by surgery, sutures) then endoscopic removal is needed
- **Tube Formulas** (assume 1-1.5kcal/L and 35-40g of protein/L protein, unless specified differently below)
    - **Types**
        - **Standard: Osmolite** (genera, lactose free, isotonic)
        - **Jevity** (good for D/C b/c contains fiber)
        - **Vivonex/Perative/Optimental** (elemental, good for pancreatitis)
        - **Nepro/NovasourceRenal** (good RF pts b/c has low K, PO4, Mg, fluid, protein)
        - **TwoCal** (high calorie and good for pts who are volume restriction)
        - **Vital/Peptamen** (amino acid based protein)
        - **Promote/TwoCal/EnsurePlus/Isocal/Osmolite NH** (high protein)
        - **AlitraQ/Impact** (glutamine rich and thus is used to promote good mucosal health)
        - **NutriHep/HepaticAid** (branched chain aa rich and thus is good in HE pts in which the BCAAs inhibit uptake of bad aromatic aa into CNS and in trauma pts in which BCAAs can be used as a fuel source in skeletal muscle)
        - **Crucial/Immun-AID/Impact/Oxepa** (lipids low in polyunsaturated FAs and high in omega-3s, AAs high in arginine/glutamine, high in nucleotides, etc which normally serve as precursors for inflammatory mediators and thus is good for limiting inflammatory mediated tissue injury)
        - **Pulmocare** (lipid rich and is good for respiratory failure b/c has CO_2 production than carb metabolism)
    - General
        - Start at 20cc/hr then increase by 10cc/hr Q8hr until goal of 60cc/hr, NGT (give bolus (fast, Q4-6hrs) vs intermittent (slow over 30min, Q4-6hrs)) vs DHT (continuous)
        - HOB elevated to 45° during and for 2hrs after feeds
        - check residuals Q4-6hr and stop if >100cc/distension
        - irrigate w/ 40cc of warm water q4hrs and chase meds w/ warm water flush (use a small syringe to create a lot pressure) to prevent occlusion but if it occurs then order "Clog Zapper", Pancreatic Enzyme aka "Viokase", Coke-Cola (don't use b/c it has sugar which creates a sticky surface), flexible wire
        - NB for DHT give continual feeds, no need to check residuals, DHT lumen is smaller than NGT hence clogging is more common
        - If diarrhea you can add loperamide into formula!!!
    - Top Things to Remember
        - Isotonic better tolerated than Hypertonic
        - Provide adequate free water (1mL per calorie)
        - Continuous is better than intermittent
        - Start slow and increase gradually
        - Always keep HOB elevated to 30 degrees
        - Keep tube flushed especially prior to and after giving drugs

- Total Parenteral Nutrition (TPN)
    - General
        - Indications: profound N/V, mesenteric ischemia, bowel obstruction, ileus, pancreatitis, diarrhea or high volume fistulas such that enteral feeds cannot be started w/in 7d
        - NB Dextrose Solutions (D5W is isosmolar but only provides 170kcal/L therefore to provide ~2000kcal/L you need D50W which is hyperosmolar and thus can only be given via a central line but no one does this b/c typically you want only 70% of your calories from carbs)
        - NB Peripheral Parenteral Nutrition (PPN) is actually available but often not done, you can actually get about 2/3 of energy requirements thru this route
    - Approach
        - General
            - print out the "Parenteral Nutrition Custom & Support Formulas" sheets from the "order set" section in the EMR

- RD consult for recommendation or take charge, strict W and I&O, SSI, infusion pump, labs (CBC, CMP, PO4, Mg = Qd x3d then QMWF and TGL & PreAlb = Qd x3d then QM), CXR to confirm placement of catheter, do not use catheter for anything else aside from TPN, warm up TPN to prevent hypothermia
- New bags are hung at 2200

- **calculate IBW** (M/F: 50/45kg + 2.3kg for every 1in over 5ft)
- **calculate protein requirements** (1.0/1.1/1.3/1.7xIBW = g/d = nl/mild/mod/severe dz)
- **calculate calorie requirements** (25/30/35/40xIBW = kcal/d for nl – bedrest / mild – non active person /mod – active person / severe dz – heavy exercise)
    - advanced equations for determining calorie requirements based on weight/age/height are rarely used (Penn-State, Ireton-Jones, Harris-Benedict)
    - if severely malnourished calculate calorie requirements based on current weight not IBW and then slowly increase to requirements for IBW
    - you should obtain energy from 80%-carbs (4kcal/g) / 20%-lipids (9kcal/g) not from protein which should be used to maintain enzyme/structural protein stores and not used for energy
- **Pick the standard 3-in-1 pre-mix and the determine the volume based on calorie requirements, next based on this volume determine if protein requirements are met and if not than increase volume until it does, in the end it is not an exact science rather just get in the ball park**
    - 3-in-1 means that protein, fat, carbs are mixed together into one bag, 2-in-1 is just protein and carbs, fat is given 3x/wk in a separate bag
    - determine if continuous (most common) or intermittent (same say good b/c it gives the liver a break)
    - generally start w/ 1L for a few days to avoid refeeding syndrome and the increase to volume appropriate for calorie requirements
    - you can create your own formula BUT it is much more expensive therefore just use a pre-mixed formula
- **adjust electrolytes and vitamins**
    - Na (1.5mEq/kg/d w/ X% being NaCL and X% being NaPO4 determined by the need for 40mMol/d of PO4 where 1mEq of Na = 0.75mMol of Phos, if pt is acidemic then add some NaAcetate)
        - Eg. 70kg pt, 105mEq Na total w/ 52mEq from NaCl and 53mEq or 70mmol from NaPO4
    - K (1.5mmEq/kg/d w/ X% being KCL and X% being KPO4 determined by the need for 40mMol/d of PO4 where 1mEq of K = 0.7mMol of Phos, if pt is acidemic then add some KAcetate) eg. similar to above
    - CaGluconate (5-30 mEq/d)
    - MgSulfate (8-40 mEq/d)
    - Insulin (start w/ 10U (or ¾ of their prior day insulin requirements) in a bag and then adjust each day by adding ½ of prior day SSI requirements)
    - MTE-5 1mL/d (Chromium 10mcg/d, Copper 1mg/d, Manganese 0.5mg/d, Selenium 60mcg/d, Zinc 5mg/d)
    - MVI-12 10mL/d (multiple things INCLUDING VitK so hold if getting coumadin)
    - Famotidine (rarely added anymore)
    - Heparin (rarely added anymore)
    - Folate (0.5-3mg/d), VitC (100-200mg/d), Thiamine (25-100mg/d), Zinc
- **Assess for Complications**
    - Central Line Complications = infection, embolism, pneumothorax, thrombosis, etc
    - Refeeding Syndrome (refer above)
    - Excess Protein = azotemia (increasing BUN), hyperammonemia, hyperchloremic metabolic acidosis
    - Excess Fat = fat embolism resulting in ARDS, steatosis, immune dysfunction, pancreatitis 2/2 hypertriglyceridemia (stop TPN if >400), hemolytic anemia, thrombocytopenia, coagulopathy (NB if not enough you will get essential FA deficiency, SEs: scaly/dry skin, hair loss, hepatomegaly w/ abnl LFTs)
    - Excess Carbs = diabetes
    - Altered Electrolytes/Fluid = hyper/hypo fluid/electrolytes esp microprecipitates of calcium/phosphorus or thrombi which can embolize
    - Hepatobiliary Problems (the key is to always rule out secondary causes)
        - **First Few Weeks: Abnormal LFTs**
            - Mech: AT peaks at 1-2wks and AP peaks at 2-3wks of initiation of TPN (mechanism is unclear), if AT/AP are significant or don't begin to resolve or hyperbilirubinemia then investigate (always rule out other causes esp line sepsis such that TPN is always a DOE) otherwise don't do anything
        - **Several Weeks: GB/CBD Cholestasis leading Sludge/Cholelithiasis & Acalculus Cholecystitis**
            - Mech: 2/2 biliary stasis from lack of CCK stimulation for GB emptying (risk increases w/ duration of TPN such that 50% have something at 5wks) NB some think that manganese toxicity is a cause
            - Px: CCK 50ng/kg IV over 10min Qd
            - Tx: URSO, cyclic TPN and give 1d/wk of no TPN, try to give some enteral feeds to promote biliary flow, prophylactic cholecystectomy, ? lower copper levels
        - **Few Months: Steatohepatitis**
            - Mech: 2/2 excess calorie intake esp w/ high [glucose and fat] and low [protein] leads to hyperinsulinemia which leads to hepatic lipogenesis

- Tx: decrease calories by decreasing glucose to 4mg/kg/min and lipids to 1g/kg/d, try to give some enteral feedings even if small volume, cyclic TPN and give 1d/wk of no TPN, supplementation (carnitine 40mg IV QD, choline 2g IV QD, lecithin 20g PO BID, essential FAs, L-glutamine, taurine)

o **Several Months-Years: Cirrhosis**
- Mech: unclear
- 20% of long term >6mo TPN users die from cirrhosis

- Other: SIBO, loss of gut barrier w/ sepsis, metabolic bone dz 2/2 aluminum toxicity, et al

	Types	RDA	Low	High	Lab	Tx
3 Major Nutrients	Carbs					
	Fats					
	Proteins					
7 Major Minerals (need >100mg/d)	Na	0.5-5.0g/60-150mEq	(refer)	(refer)	(refer)	(refer)
	K	2-5g/60-100mEq				
	Cl					
	HCO3					
	Mg	300-400/8-24mEq				
	Ca	800-1200/5-15mEq				
	PO_4	800-1200/12-24mEq				
4 Fat Soluble Vitamins (hormones) • Cannot be synthesized except D/K	A (Retinol) NB precursor is caretonoid	0.8-1mg Diet: liver, veggies/fruits Abs: jejunum Storage: liver stellate cells	• CNS: Night Blindness 2/2 Conjuctival Xerosis, Keratomalacia, Bitot Spots (focal areas on cornea with foamy appearance) • Skin/Hair: Dry Skin, Follicular Hyperkeratosis • Immune System: Increased Infection	Classically seen in Eskimos who eat lots of fish/seal liver • Acute (Psuedotumor Cerebri, Bone Pain, Hepatocellular Damage) • Chronic (Cirrhosis, Bone Fx, Dry Skin)	Plasma Retinol	If symptomatic then 100k U Qd x3d then 50k U QD x14d then asymptomatic Tx w/ 25k U 2-3x If asymptomatic 10-100k U PO QOD-QD
	D (Ergocalciferol)		Rickets/Osteomalacia	Hypercalcemia Hyperphosphatemia	Serum 25-OH-VitD	Refer
	E (Tocopherol)	8-10mg Diet: vegetable oils	• Mech: most important fat soluble antioxidant therefore intracellular • NB often seen in premature infants • Heme: Hemolysis • CNS: Ophthalmoplegia, Peripheral Neuropathy, Posterior Column Spinal Cord Damage • CV: atherosclerotic dz???	Antagonize other fat soluble vitamins ADK, impaired immune fxn, increased r/o hemorrhagic CVAs, Necrotizing Enterocolitis in Infants, Promotes GI tumor growth, exacerbates autoimmune conditions	Serum Tocophenol	400 U PO Qd
	K (Phylloquinone)	65-80mcg Diet: green leafy vegetables and colonic bacteria	• Mech: catalyzes carboxylation of glutamate AAs on blood clotting proteins • Seen in pts who are NPO and on abx or pts on TPN • Coagulopathy	IV (dyspnea, flushing, hypoTN) Pregnant (infant w/ hemolytic anemia resulting in high bili and kernicterus)	Serum PT	5mg PO Qd 10mg SC Qwk
9 Water Soluble Vitamin (no B4/8/10/11)	B1 (Thiamine) Found in almost all animal/vegetable	1mg	• Mech: cofactor (TPP) for many enzyme reactions in energy metabolism • Seen in alcoholics, pts on	NONE	serum thiamine to dx and then use RBC Transketolase	Thiamine before Glucose

(coenzymes) • Cannot be synthesized except B7 • All can become deficient quickly in the order of weeks except VitB12 which is stored in liver and becomes clinically apparent after several years!!! • In general the VitB# result in dermatitis, glossitis, diarrhea	products but abundant in few (yeast, legumes, pork) importantly when plants are refined like white rice, white flour, etc thiamine is lost		HD, TPN, bariatric surgery, Asians eating white rice, etc (pt's that get glucose b/c thiamine precipitates Sx) (1) **Wet Beriberi** (HO-CHF, D-CM w/ profound 3rd spacing, severe lactic acidosis) (2) **Dry Beriberi** (Peripheral Poly Neuropathy) (3) **GI Beriberi** (delayed gastric emptying and constipation from dilated colon) (4) **Neuropsych Beriberi** (Wernicke's Encephalopathy (hallucinations, confusion) and Ophthalmoplegia (nystagmus, 6th CN palsy), Korsakoff's Pyschosis (short term retro-/ante-grade amnesia w/ confabulation and hallucinations, once you reach this state it is no longer reversible) • Other: Lactic Acidosis		Activity (give TTP and measure increase of enzyme, <25% good stores, >25% poor stores) to monitor Tx	
	B2 (Riboflavin) Found in meat/dairy products and also broccoli	3.6mg	• Mech: cofactor (FADH2) for many enzyme reactions esp in energy metabolism • Deficiency: uncommon but can be seen in pts who take TCAs, phenothiazines, etc • S/S of Deficiency: cheliosis, glossitis, stomatitis, seborrheic dermatitis, anemia	NONE	RBC Glutathione Reductase Activity	
	B3 (Niacin) Found in grains, meat, fish, legumes or endogenous production from tryptophan	30mg	• Source: made from tryptophan • Mech: cofactor (NADH) for many enzyme reactions • Causes: Hartnup Dz (AR mutation of renal tubular transportation of neutral AAs), Carcinoid Syndrome where tryptophan is diverted to other pathways, nutritional deficiency esp in people who eat mainly corn • S/S: Pellagra w/ the "4 D's" (symmetric pigmented Dermatitis in sun exposed	NONE (but some flushing, burning of hands/feet, liver injury, hyperglycemia, hyperuricemia)	Urinary N-Methyl Nicotinamide and 2-Pyridone	

			areas, Diarrhea, Dementia Death, anxiety, insomnia, etc, Stomatitis, Glossitis, Vaginitis, Vertigo, Dysesthesia)			
	B5 (Pantothenic Acid)	10mg	• Source: all foods • Causes: • Mech: cofactor (Coenzyme A) for many enzyme reactions • S/S: Adrenal Insufficiency, Alopecia, Fatigue, Weakness, Paresthesia Foot, TTP	NONE (but some GI upset)	Urinary/Whole-Blood Pantothenic Acid	
	B6 (Pyridoxine)	2mg	• Source: all foods • Causes: INH, estrogens, penicillamine, etc which bind this vitamin in the GI tract prohibiting absorption • Mech: cofactor (Pyridoxal Phosphate) for many enzyme reactions • S/S (isolated is uncommon usually occurs with oyher VitB deficiencies): Serborrheic Dermatitis, Stomatitis, Angular Chelosis, Cheilosis Glossitis, Peripheral Neuritis, Seizures, Sideroblastic Anemia, Depression	Peripheral Neuropathy Photosensitivity *** pyridoxine toxicity is the only clinically significant common VitB toxicity ***	Plasma/RBC Pyridoxal Phosphate	
	B7 (Biotin)	60mcg	• Source: all foods and enteric bacteria produce it • Causes: chronic TPN, eating large quantities of raw egg white which contains avidin which binds biotin in GI tract • Mech: cofactor (?) for many enzyme reactions • S/S: Hair Loss, Sebhorrheic Dermatitis, Enteritis, Alopecia, AMS, Seizures, Myalgia, Hyperesthesia, Lactic Acidosis	NONE	Plasma/Urine Biotin	
	B9 (Folic Acid)	400mcg	Refer	NONE	Refer	Refer
	B12 (Cobalamin)	5mcg	Refer	NONE	Refer	Refer
	C (Ascorbic Acid) Source: Fruits & Vegetables	40mg	• Source: fruits and vegetables • Causes: nutritional deficiency • Mech: most important water soluble antioxidant therefore extracellular effect, hydroxylatoion of proline/lysine for collagen synthesis, facilitates iron absorption, cofactor for dopamine synthesis • S/S: Scurvy (Petechia, Purpura, Gingival Inflammation/Bleeding, Weakness, Depression,	GI Upset Oxalate Kidney Stones Iron Overload Infertility Xerostomia	Plasma/Leukocyte Ascorbic Acid	

			Impaired Wound Healing, Coiled Hair, Perifollicular Hemorrhage, Impaired Bone Growth, Joint Effusions, IDA, Lethargy)			
10 Trace Elements (need <100mg/d) (enzyme cofactors) (serum/urine levels are notoriously inaccurate in deficient states hence Tx based on a clinical diagnosis or some argue doing hair analysis) NB other elements that are needed include silicon, vanadium, nickel, tin, cadmium, arsenic, alum, boron	Chromium	10-15mcg Fxn: glucose/lipid metabolism	(Seen in pts on long term TPN) Glucose Intolerance Peripheral Neuropathy Ataxia	GI Upset	Serum Chromium	
	Copper	0.5-1.5mg Function: cofactor for a variety of enzymes	Etiology: diet (seen in infants fed exclusively on cow's milk and in adults on chronic TPN), RYGB, Diarrhea, Menke's Dz & Occipital Horn Syndrome aka X-linked Cutis Laxa (inherited inability to absorb) Heme: IDA MS: OP, fibrosis of epiphysis CNS: AMS, Ataxia, Spastic (similar to VitB12)	Wilson's (refer)		
	Iron	1-2mg	IDA (refer)	Hemochromatosis (refer)		
	Iodine	70-140mcg	Goiter w/ Hypothyroidism Fetal Demise in Pregnant Women	Hyperthyroidism (refer)	Urine Iodine TSH	
	Manganese	0.1-0.2mg Fxn: cofactor for many enzymes	S/S (very rare) Hypocholesterolemia Dementia Dermatitis Weight Loss Hair/Nail Changes Impaired Vit-K Dependent Enz	Often seen in pts on chronic TPN S/S: Cholestasis and Parkinsonism	Toxicity Dx w/ MRI Head	
	Selenium	50-100mcg	Mech: most important element for antioxidant enzymes Seen in pts on long term TPN S/S: Cardiomyopathy (Keshan's Dz), Arthritis (Kashin-Beck's Dz), Increased Cancer Risk?, Albinism, Myalagia/Myopathy, RBC Macrocytosis	GI Sx AMS Peripheral Neuropathy Hair/Nail Loss	Serum Selenium, RBC Glutathione Peroxidase Activity	
	Zinc Mech: enzyme and structural protein cofactor Source: meat, shellfish, cereals, legumes Absorption: ileum (only 20% efficient)	12-15mg	Etiology: Diarrhea of any cause!!!, Acrodermatitis Enteropathica (AR mutation in zinc absorption), Chelators (Penicillamine, Oxalate) Derm: perioral/perianal & hands/feet rashes, alopecia, poor wound healing CNS: personality changes, lethargy, irritability, delayed sexual maturation MS: growth retardation GI: dys/hypogeusia, anorexia	N/V, Hyperpnea, Copper Deficiency	Plasma/RBC/Hair Zinc Levels	
	Fluoride	4mg	Dental Caries	Dental Fluorosis aka Mottling,	No Test	

				Tendon/Ligament Calcification, Brittle Bones		
	Molybdenum	15mcg	(seen in pts chronically on TPN) AMS Hypouricemia	Hyperuricemia w/ Gout	No Test	

Obesity

Epidemiology

- Increasing rate from 10% in 1970s to 30% in 2000s, in Texas ¼ people are obese w/ 6 of 25 "Fattest Cities" #2,3,4,6,8 (Houston, Dallas, San Antonio, FW, Arlington)
- Increasing in children
- Only behind smoking as the most preventable cause of death

Definition

- WHO defines obesity based on BMI (BMI = kg/m^2)
  - Overweight 25-29.9
  - Obese Class I 30-34.9
  - Obese Class II 35-39.9
  - Obese Class III ≥40
- BMI sometimes inaccurate b/c muscular pts are healthy but have high BMI and vice versa
- Pattern of fat distribution is prognostic where central adiposity (waist size >40in in men and >35in in women) has increased cardiovascular risk

General

- CNS
  - Hypothalamus
    - **Lateral** lesions causes hypophagia and starvation (orexigenic)
    - **Medial** lesions cause hyperphagia and obesity (anorexigenic)
- Peripheral Mediators
  - Stimulate Feeding: ghrelin (gastric fundus → CNS, it suppressed after RYGB)
  - Inhibit Feeding aka Satiety: leptin (adipose → CNS), neuropeptide Y (SI → CNS), vagus, 5-HT_{2C}, insulin, corticotropin releasing factor, estrogen, CCK, amylin, GLP-1, bombesin, exercise, gastrin releasing peptide, apolipoprotein A-IV, pancreatic polypeptide, peptide YY

Mech

- Excessive Food Intake (95%) likely 2/2 defective signaling/regulation of peptides (leptin, leptin receptor, pro-opiomelenocortin, prohormone convertase 1, STM1, melanocotin-4 receptor, etc)
- Other (5%): Defective Thermogenesis (less brown fat and lower basal metabolic rate), Endocrinopathy (Cushing's, PCOD, HypoTH, Hypogonadism, Prader-Willi, Laurence-Moon-Biedl Syndrome), Meds (steroids, antidepressants, antipsychotics, anticonvulsants, antidiabetics), Adipocyte Abnormalities

Obesity Complications (Metabolic Syndrome = constellation of Dz 2/2 obesity)

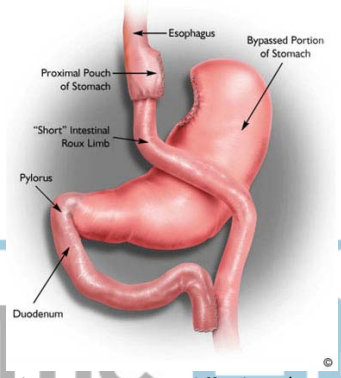
- CV: Vascular Disease, Venous Stasis
- Endo: Diabetes, DL
- Onc: Gastrointestinal (EVERY ORGAN), Breast, Endometrial, Cervix, Kidney, Prostate
- GI: Gallstone, Fatty Liver Disease, GERD
- MS: Osteoarthritis, Gout
- Pulm: OSA
- Ophtho: Cataracts
- Psych: Depression

Tx

BMI	**Normal** **<25**	**Overweight** **25-30**	**Class I** **30-35**	**Class II** **35-40**	**Class III** **>40**
Diet & Exercise	If +RFs	Yes	Yes	Yes	Yes
Pharmacotherapy		If Obesity Complications	Yes	Yes	Yes
Bariatric Surgery				If Obesity Complications	Yes

- NB liposuction improves appearance and physical function but does NOT change the metabolic complications associated with obesity as Tx below do!!!
- Diet & Exercise
    - doesn't matter what you do (low fat diet (Pritikin, Ornish, etc), low carb diet (Atkins, South Beach), etc) as long as the diet is a low calorie diet (no less than 800cal/d b/c anymore does not give you more weight loss), therefore eat whatever kind of food you want just limit calories and make sure diet is balanced but in general shoot for <30% fat (~30gm/1000kcal/d)
        - Overweight: 1000-1200 kcal/d (women-men)
        - Obese: 800-1000 kcal/d (women-men)
    - Best Diet Plans: Weight Watchers & Sugar Busters
    - Increase fiber in diet to feel full but it isn't absorbed
    - 3500 cal = 1 pound (therefore 500cal/d/wk = 1lbs weight loss/wk)
    - Walk 40 miles = 1 pound (therefore 5.7miles/d/wk = 1lbs weight loss/wk)
    - Don't forget to supplement with MVI and minerals
    - You can't do just diet or just exercise
- Psychotherapy
    - Address depression
- Pharmacologic
    - effects only last for a month they should only be used for short-term (eg. pt needs to lose weight b/f surgery but can't b/c they have a broken leg)
    - Anorexiants: phentermine (Adipex-P, Ionamin)
        - Mechanism: NorEpi/Serotonin/Dopamine Reuptake Inhibitor (Schedule IV Drug) which increase satiation and decreases satiety (~5% weight reduction after 24wks of Tx)
        - SEs: HTN/tachycardia, adrenergic effects, dry mouth, HA, insomnia, constipation
        - Contraindications: bad heart/stroke dz or RFs, pregnancy/lactation, h/o psych disease, drug interactions
        - NB sibutramine (Meridia) was removed from the market b/c of increased CV events
    - Malabsorption Agents: orlistat (Xenical-Rx or Alli-OTC)
        - Mechanism: inhibitor of pancreatic/intestinal lipase thus increasing fecal fat loss
        - SEs: fatty like diarrhea w/ flatulence, fecal incontinence, fat soluble vit deficiency
        - NB new evidence of liver injury!!!
    - Diethylproprion (Tenuate, Dospan), phendimetrazine (Bontril)
    - Other
        - OTC: Ephedrine/Caffeine, Chinese Herbs, Chromium, Chitosan, Green Tea Extract
        - Off Label Use Meds: bupropion/fluoxetine (Depression), topiramate/zonisamide (AED), metformin (T2DM)
    - NB Olestra was a complex carbohydrate that had oily characteristics, developed in the 1990s, never liked b/c the melting point is 97 degrees therefore in the body it is in a melting state and people defecate very oily stool
    - NB Ephedra, Bitter Orange, Country Mallow have recently been banned
- Bariatric Surgery
    - Other Criteria Aside From Above: (1) show that s/he has faithful tried diet and exercise but w/o avail, (2) low operative risk, (3) no psych dz, (4) non-pregnant adult
    - In general it is covered by insurance if criteria above are met
    - Diabetes resolves in 75%, DL improves in 70%, HTN resolves in 60%, OSA resolves in 85%
    - Going to high volume center is important
    - Mechanism: restrictive ± malabsorption
    - All surgeries can now be done laparoscopically
    - Endoscopy
        - Pre-Op Endoscopy is important to Tx any prior dz (esp GERD) that may be present and to help guide surgery
        - Avoid endoscopy early post-op as air insufflations may damage anastomosis
        - Consider fluoro imaging prior to endoscopy to help map anatomy and to look for leaks/strictures
        - Always document the length of pouch, anastomotic size, etc
    - Endoscopic Approaches (Christopher Thompson, MD at Harvard)
        - Intragastric Balloon (a balloon is inflated in the stomach and has a restrictive effect)
        - Gastroplasty w/ EndoCinch or TOGA (part of the stomach is stapled or sutured together on the inside creating a restrictive effect)
        - Duodenojejunal Bypass Liner (EndoBarrier) (a sleeve is fixed in the duodenum and extends into the jejunum interfering with mucosa absorption creating a malabsorptive effect)
    - Types

- **Jejuno-Ileal Bypass (1960s):** rarely done b/c profound malnutrition, hyperoxaluria w/ kidney stones, gallstones, arthritis/dermatitis 2/2 SIBO, progressive liver dz w/ cirrhosis 2/2 SIBO
- **Roux-en-Y Gastric Bypass (RYGB) (1970s)** (0.5% 30d Mortality, 40kg weight loss): introduced in the 1970s, Stomach is divided creating a small gastric pouch (15-30mL restrictive), jejunum is then cut 30-70ccm from LOT and proximal end is anastomosed (side-to-side) to side of jejunum at a distance determined by BMI anywhere b/t 75-150cm from where jejunum was cut, the distal end is anastomosed (end-to-end) to gastric pouch (malabsorption) also creating a blind jejunal pouch
    - Efferent Limb aka Roux Limb (esophagus, gastric pouch, distal jejunum) "esophagus = effect"
    - Afferent Limb (remaining stomach, duodenum, proximal jejunum, biliary/pancreatic tree) " the stuff (aka enzymes, bile, etc) that affects food digestion"
        - NB getting into the afferent limb is very challenging and usually requires an enteroscope
    - Common Limb (JJ anastomosis to ICV)

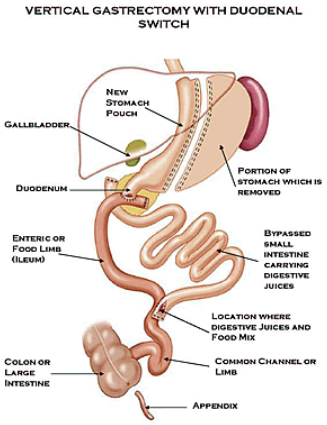


    - NB surgical revisions are very difficulty w/ 2% mortality and 50% morbidity
    - Complications
        - **General**
            - Gastrograffin UGI Series to assess overall anatomy
            - Enteroscopy to assess the JJ anastomosis and bypassed stomach
        - **Acute Post-Op Complications**
            - Peritonitis 2/2 leak, strangulation (internal hernia or intussusception), pancreatitis
            - Tachycardia/Hypotension 2/2 peritonitis causes above but also PE, bleeding, MI, PTX, gluteal myonecrosis (rare but serious complication)
            - D = steatorrhea from intentional/inadvertent short common channel, infection (C. diff), gastric dumping syndrome, celiac dz, lactose intolerance, SIBO, niacin induced colitis, thiamine induced megacolon, pancreatic insufficiency 2/2 loss of pancreatic stimulation 2/2 absence of food in duodenum, postvagotomy diarrhea
            - N/V = efferent limb obstruction (internal hernia, intussusception) vs dry heaves = afferent limb obstruction
                - NB vomitus should never be bilious but if it is then consider incorrect surgery or gastrogastric fistula
        - **AMS**
            - **D-Lactic Acidosis**
            - **Wernicke's Encephalopathy**
            - **OTC Deficiency** (new concept, seen in female pts who have the Urea Cycle Defect (OCT deficiency) resulting in the accumulation of orotic acid and ammonia, precipitated after RYGB b/c of the hyperinsulinemia and zinc deficiency down regulates OTC activity unmasking Sx (AMS, irritability, protein avoidance, vomiting, ataxia, seizure), very high mortality, steatosis on liver Bx, Tx: lower ammonia, protein free diet/TPN, scavenge nitrogen w/ sodium benzoate and sodium phenyl acetate and replace zinc and carnitine, discovered by Dr. Fenves)
        - **Dietary Noncompliance**
            - Post-GI Diet: Clear Liquids → Full Liquids →Puree → Regular (Q2wks)
            - Non-compliant w/ low volume/quantity diet → acute Sx of N/V/pain → chronic overstretching of pouch>30mL, dilated anastomosis >21mm, staple line disruption w/ GG fistula, etc
            - Deficiencies

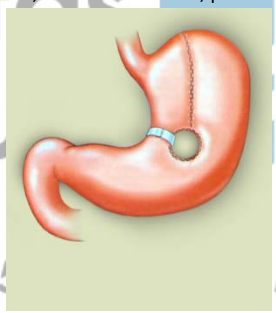
- Check labs (Iron (b/c bypassed duodenum), VitB12, VitD, Zinc, Selenium, Copper, Thiamine, CBC, CMP, FLP, Mg, PO4) at 3mo, Q6mo x3yrs, Qyr
- Supplement all of these along w/ a general MVI

- **Bleeding**
  - **Intraperitoneal (early/fast):** mesentery transection, gastric staple line, trocar site, splenic laceration
  - **Luminal (late/slow):** gastric staple line, anastomotic bleed from marginal anastomotic ulcer
- **Anastomotic Leak**
  - Incidence: 0.5-5.6%
  - Location: anastomosis, injury to other parts of the GI tract during operation especially if LOA was performed
  - Sx: tachypnea, dyspnea, ab pain, peritonitis, oliguria (occurs during the first few weeks of life post-op) *** life threatening ***
  - Dx: Gastrograffin UGIS or CT (60% sensitive b/c many sites are not exposed to contrast i.e. gastric remnant therefore consider ex-lap)
  - Tx: AVOID EGD b/c full dehiscence can occur therefore BS-abx and surgery
- **Anastomotic Stenosis w/ Gastric Outlet Obstruction**
  - generally occurs w/in the first 3mo, at GJ jxn (nl 12-21mm) but also at JJ jxn, Sx generally occur when <10mm, 3-27% incidence, 2/2 ischemia, ulceration, anastomotic leak, hand sewn anastomosis et al, Tx w/ TTS dilation but avoid dilation to >15mm b/c dumping syndrome and weight gain may occur, pts have actually sued GI doctors b/c of weight gain after surgery)
- **Anastomotic Ulcer**
  - S/S: pain, bleeding
  - generally occurs w/in 3mo of surgery, 10-16% incidence though likely higher as most are subclinical, on the jejunal side
  - 2/2 ischemia, foreign body reaction to staples/sutures (if medical therapy does not work consider endoscopic removal), gastrogastric fistula (always look for), large gastric pouch w/ inclusion of parietal cells and resultant acid exposure on intestine, HP (always look for), NSAIDs, etc, increased risk w/ smoking and NSAIDs, decreased risk w/ PPIs)
  - Some recommend PPI Px for the first 12 months
  - NB use soluble PPIs b/c sometimes pills are not absorbed completely b /c the gut is short
- **Obstruction**
  - Location
    - Affarent Limb: dry heaves, RUQ pain, pancreatitis
    - Efferent Limb: non-bilious vomiting
    - Common Limb: bilious vomiting
  - Etiology: anastomotic stricture, adhesions, internal hernia, intussusception, gastric distension
- **Gastro-gastric aka Staple Line Dehiscence, Gastro-cutaneous, Jejuno-cutaneous, etc Fistulas**
  - Etiology: incomplete division of gastric pouch or there is complete division but the pouch and remnant are not completely transected (some surgeons place omentum in b/t to make sure), ulcers, foreign body reaction, etc
  - S/S: regain weight, pain, reflux
  - Dx: usually very small and overlooked
  - Tx: if small and no Sx then try PPI for 8wks and if not closure then endoscopic Tx but If large or Sx then surgical revision
- **GERD** (variable depending on the size of the pouch and size of anastomosis, in some cases GERD decreases)
- **Gallstones** (36% at 6mo but only 7% are symptomatic, b/c of rapid weight loss, ERCPs are difficult (some have tried using an enteroscope to place a guide wire then running an ERCP scope over the wire OR passing an ERCP scope thru a surgical/radiologic guided gastrostomy), consider prophylactic cholecystectomy)
- **Afferent Loop Syndromes**
  - Incomplete emptying of afferent limb w/ resulting accumulation of biliary/pancreatic secretions and bacterial overgrowth limb 2/2 stasis
  - RUQ ab pain and bloating 20-60min after a meal followed by N and bilious vomiting which relieves Sx
- **Dumping Syndrome (refer to gastric dysmotility)**
- **Bile Reflux Gastropathy (refer to gastropathy)**
- **Malabsorption aka Short Bowel Syndrome**

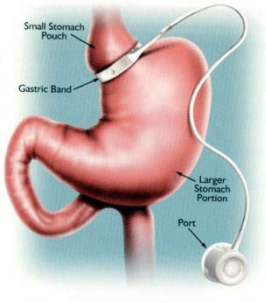
        - Pts often need iron (b/c duodenum is bypassed), calcium, fat soluble vitamins, folate, vitB12
        - 2/2 <100cm common limb, decreased transit time, inadequate mixing of food with bile/enzymes, bacterial overgrowth from afferent loop stasis
    - **Nutritional Deficiency**
    - **Adenocarcinoma of Remaining Gastric Tissue**
        - Occurs in the gastric remnant 15yrs after surgery
    - **SIBO**
- **Biliopancreatic Diversion aka Duodenal Switch (1990s)**
    - Complications: malnutrition, steatorrhea, metabolic bone dz, gallstones



- **Vertical Banded Gastroplasty (1980s)** (0.1% 30d Mortality, 30kg weight loss): cut a hole in stomach, staple and place vertical band
    - Complications: staple line disruption w/ leak/fistula, ulcers, band erosion (endoscopic removal is possible), GERD, outlet obstruction, pouch dilation



- **Adjustable Gastric Lap Banding (1990s)** (0.1% 30d Mortality, 30kg weight loss): place band around proximal end of stomach to create a pouch with a small opening, band can be adjusted in size by adding/removing saline percutaneously to a subcutaneous port
    - Complications: band slippage/loosening/tightening/leakage/erosion, pouch dilation, band/port infections, GERD, impaction



- **Vertical Sleeve Gastrectomy (2000s)**

The Mantas Manual