Think protein and most of us think muscles. We know that it's important to get enough protein in our diets, and most of us are also aware that world wide, lack of adequate protein is a factor in malnutrition, starvation and death, particularly of children. But few of us really know what the "right" amount of protein is for our body needs. It's safer to just eat a lot. Most of us, too, think that eating protein-rich foods is healthy, and won't make us "fat" like sweets and fatty foods might. Learning about what protein is, what proteins are needed for in our bodies and how much we need to maintain health and fitness is an important part of nutrition.

Proteins are large molecules composed of combinations of 20 different amino acids. Proteins have both structural and metabolic functions in cells (discussed later). A single cell may have 10,000 or more different proteins. This diversity of proteins is essential for the functioning of each cell in a living organism.

**Protein Structure**
The precise physical shape of a protein is critical for its function. Each protein has a unique shape or conformation. However, all proteins are composed exclusively of subunits of amino acids, which join together in long chains called polypeptides that fold or coil into the unique shape of the functional protein.

In order to discuss proteins, we need to first learn about amino acids and second, how proteins are formed from amino acids.

**Amino acids**
- Amino acids contain carbon, hydrogen, oxygen, (just as carbohydrates and lipids do) plus nitrogen, and sometimes sulfur.
- Amino acids have two function groups

![Amino functional group](image1)

![Carboxyl functional group](image2)

- Both functional groups attach to a specific carbon, the alpha (a) carbon, of the carbon chain. The third bonding site of the alpha carbon is typically Hydrogen.
The alpha carbon will have at its fourth bonding site a side group, or "R" group (a distinct molecule) which gives the amino acid its unique structure and properties.

There are 20+ different amino acids in protein. All have a common structure except for the side group. (The common amino acid structures are shown in Appendix C of your textbook.)

Some amino acids have side groups that are polar (so they are hydrophilic), some R groups are nonpolar (and hydrophobic), some have acidic side chains (generally with a negative charge) and some are basic. Two, cysteine and methionine, contain sulfur in its R group. Cysteine can form disulfide bonds (disulfide bridges) with other cysteine molecules.

Essential Amino Acids
Many of the amino acids can be synthesized by the liver from an available nitrogen source and glucose or fatty acids, or by rearrangement of other amino acids.

Eight or nine amino acids cannot be synthesized, and are essential in our diet. Two other amino acids are made only from two essential amino acids; cysteine can be manufactured only from methionine and tyrosine can be manufactured only from phenylalanine. Both methionine and phenylalanine are essential amino acids, so if the diet is lacking in methionine or phenylalanine we also cannot make cysteine or tyrosine.

How do amino acids form proteins?
• A protein starts as a chain of amino acids, called a polypeptide
• Amino acids are joined together by a dehydration synthesis (condensation) of between the amino and carboxyl groups of adjacent amino acids forming a peptide bond.
The polypeptide chain is referred to as the primary structure of the protein. The specific amino acids in the polypeptide chain will determine its ultimate conformation, or shape, and hence, its function. Even one amino acid substitution in the bonding sequence of a polypeptide can dramatically alter the final protein's shape and ability to function.

How do polypeptides vary?
- Number of amino acids in the chain: 50—1000 or so
- Which kind of amino acids are in the chain (of the 20 types)
- How many of each kind of amino acid
- The bonding order or sequence of amino acids

After forming the polypeptide, the protein coils or folds, forming a secondary structure, and then folds on itself again to form a uniquely shaped molecule, the tertiary structure that is the functional protein. How each protein forms its functional shape depends on the precise amino acids in its sequence. Quaternary proteins are formed from two or more polypeptides, often with mineral complexes. Hemoglobin is a quaternary protein of four polypeptides complexed to iron.
**How do proteins acquire shape?**
The side chains of individual amino acids are responsible for determining the functional shape of a protein. The different pH, acidic, basic, polar and non-polar groups contribute to the coiling and types of folding that occur in the secondary bonding that forms the final functioning protein shape. The secondary bonds that form the secondary and tertiary structure of proteins are weak bonds, making proteins fragile molecules.

Most proteins are **globular** in shape. **Fibrous** proteins, such as the protein found in muscle tissue have a more-pleated or folded secondary structure.

**The Uniqueness of Protein Structure**
Because the functional shape of the protein depends on which amino acids are next to each other for the coiling and folding, amino acids in a polypeptide cannot usually be substituted without changing the functional shape of the protein. This is best illustrated with the protein, hemoglobin, the oxygen-carrying protein that coats our red blood cells. The normal "donut" shape of our red blood cells is determined by the shape of hemoglobin. A genetic disorder, sickle-cell anemia, is caused by a mutation that causes an amino acid substitution of valine for glutamine in the sixth amino acid in one of hemoglobin's polypeptides. Valine alters the shape of hemoglobin so that the red blood cells take on a "sickle" shape. The altered red blood cells do not carry oxygen well, and do not travel effectively through the capillary beds. Severe sickle cell anemia is fatal.

Normal and Sickle-shaped rbcs
Altering Protein Shape - Denaturation
- As stated, proteins have a physical structure maintained by weak bonds. Many of these bonds are hydrogen bonds formed from the polarity of the side groups of the amino acids
- If these weak bonds are broken, the protein structure is altered and the molecule can no longer function. This process is called **denaturation**.

**Things That Denature Protein:**
- Heat (as low as 110°F, many @ 130°F)
- Heavy metals (eg, silver, mercury)
- pH changes
- Alcohols
- Other chemicals

**Note:** Consuming denatured proteins is fine. We do it all of the time when we eat cooked foods. Denaturation affects the structure of the protein, not the individual amino acids. We digest all proteins consumed into their constituent amino acids. We need the amino acids to assemble our own proteins in our cells and tissues.

**Synthesizing Proteins in Cells**
- Each cell must synthesize the proteins it needs from amino acids delivered by the circulatory system. Recall that a cell may need as many as 10,000 different proteins to function.
- The number and ratio of amino acids in circulatory system are pretty much determined by our diet and any modifications the liver can do.

**Protein synthesis in the cell is genetically controlled.**
Our genetic molecule, DNA, in the nucleus of the cell contains coded information on how to synthesize each specific protein.

DNA is not used directly as a template for protein synthesis, a process that occurs in the cytoplasm at ribosomes. DNA molecules never leave the nucleus of the cell. To carry the information stored in DNA to the cytoplasm, we use the molecule, **RNA (ribose nucleic acid)**.

DNA instructions for specific proteins are transcribed in the nucleus to **messenger RNA** (mRNA). mRNA delivers the instructions message from DNA to the cytoplasm of the cell where proteins are synthesized at **ribosomes**, tiny structures composed of protein and a second RNA, **ribosomal RNA**.
At the ribosomes, a second process, called **translation**, occurs. During translation, the information carried by the messenger RNA molecules is used to direct the assembly of specific amino acids into proteins.

Specific amino acids are carried to the ribosomes by a third type of RNA, *transfer RNA* (tRNA). Each specific amino acid has its own form of tRNA. The tRNA molecules read and translate the mRNA message on the ribosomes, bringing in the appropriate amino acids one at a time to peptide bond in the correct order. When the mRNA reaches the end of it message, the polypeptide chain is released from the ribosome and converted to its functional protein shape.

Controls of gene expression are one of the most active areas of biological research, in particular searching for how and why normal gene regulators malfunction in diseases such as cancer, or how the process of aging affects gene activity. The role of nutrients in gene regulation and chronic diseases is also being studied. For example, there is evidence that polyunsaturated fats affect positively lipid enzyme assembly.
Relating Protein Synthesis to Protein Intake

- If the cell is missing a specific amino acid needed for the protein - the assembly will stop - and the protein will not be manufactured.
- Amino acids do not accumulate for future needs. Any excess amino acids consumed beyond daily protein needs are converted to fat and stored as adipose. This is also true for specific amino acids consumed beyond what the body can use or convert to other amino acids.
- If a cell is deficient in fuel (not enough glucose or lipid fragments, or if in the brain, just glucose), amino acids will be used for fuel and protein synthesis for the body's protein needs will be affected.
- Therefore, it's important to have:
  - an adequate amount of protein in the diet to provide amino acids to our cells, but not excessive protein when total calories exceed energy needs
  - balanced proportion of amino acids, especially the essential amino acids

Note: Virtually all protein ingested is digestible. Proteins are denatured by stomach acid and readily hydrolyzed by the proteases of the stomach and small intestine. Absorption occurs in the small intestine via specific amino acid carrier molecules. There is no basis for enzyme digestion-promoting supplements. Those enzymes are just as readily denatured in hydrolyzed in the stomach and small intestine as any other protein consumed.

Digestion and Absorption of Protein
Protein digestion starts in the stomach where stomach acid denatures protein and activates the enzyme **pepsin**. Pepsin functions to break proteins into smaller polypeptides that can be more readily digested in the small intestine.

- Virtually all ingested proteins are denatured in the stomach, including many proteins sold as "enzyme aids".
- Most protein digestion occurs in the small intestine using a number of enzymes secreted by the linings of the small intestine and the pancreas. Some examples:
  - Amino peptidases breaks polypeptides from the amino end
  - Dipeptidases breaks dipeptides into free amino acids
  - Enteropeptidase converts trypsinogen ---> trypsin
  - Trypsin breaks specific peptide bonds activates carboxypeptidases and chymotrypsin
  - Chymotrypsin breaks specific peptide bonds
  - Elastase breaks polypeptides into smaller molecules
  - Collagenase breaks polypeptides into smaller molecules
  - Carboxypeptidase breaks polypeptides from the carboxyl end

Absorption
Amino acids are absorbed across the intestinal villi membranes into the intestinal cells and moved into capillaries of the intestinal mesentery for transport to the liver for processing. Carrier molecules in the villi attract groups of amino acids. Over-consumption of single amino acids may block carriers from picking up needed amino acids.

Protein Functions
Structural Functions of Protein
Protein is found in muscle, bone, blood, skin and all of our tissues. A little less than half of our protein is found in muscle tissue (for the average person), 18% in bone, about 10% each in blood and skin, and the remainder in the rest of our cells. Protein is a:

- Component of all cell membranes
- Component of the "cytoskeleton", located in the cytoplasm of all cells
- Component of contractile structures, such as muscle, cilia and flagella that generate movement
- Component of hair and nails (Keratin)
- Structural matrix for formation of bone, teeth and connective tissue (Collagen)
- Protein is needed for growth, repair and replacement of cells and tissues. Children have greater protein requirements for body growth than adults have. Anyone recovering from a major trauma involving tissue damage will need more protein. The rate of cell and tissue replacement varies. Some examples are:
  - Taste buds 1 day
  - Intestine cells 1-3 days
  - Skin 30 days
Metabolic Functions of Proteins
Proteins play an important role in metabolism as well as in body structure. From the body's perspective, metabolism takes priority. Muscle tissue will be dismantled to provide essential metabolic protein needs when protein intake is insufficient, as well as glucose fuel needs when too little glucose is available. Metabolic functions of proteins include:

Enzymes
Each chemical reaction that occurs in a cell is catalyzed by a specific enzyme. Most of the 1000's of proteins found in cells are specific enzymes. We discussed the digestive enzymes previously along with some problems that occur when we are unable to synthesize appropriate enzymes (such as lactose intolerance). We can have cellular disorders when we are unable to manufacture the proper enzymes for cell activity.

Each enzyme functions because it has a particular shape with an active site that attracts the reactants of a chemical reaction. The precise shape of the active site facilitates the reaction when the reactants and enzyme enter a transition state. Once the reaction occurs, the products are released from the enzyme and the enzyme is available for more reactants. Enzymes are not consumed in or a part of the chemical reaction. They are used over and over. However, if the enzyme's structure is altered, the reaction can not occur. Enzymes are seriously affected by denaturation. Some heavy metals, such as mercury, block enzyme activity.

Hormones - Regulatory Chemicals
Many of our hormones are proteins, including insulin, glucagon, thyroxin, epinephrine (and norepinephrine) and many pituitary hormones

Energy Transfer Molecules for Cell Respiration
Cell respiration, the process by which cells obtain energy to do work by oxidizing fuel molecules requires a set of energy transfer molecules to control the rate of energy released from the oxidations. Some of these energy transfer molecules, including the iron-containing cytochromes, are proteins. (As a side note, the poison, cyanide, blocks cytochrome function, inhibiting cell respiration.)
**Oxygen Carrier in Circulation**
As discussed, hemoglobin, our oxygen carrier, is a quaternary protein.

**Visual pigments**
Rhodopsin and iodopsin are the light-detecting protein pigments of the rods and cones of the eye. Vitamin A is also needed to make these pigments.

**Antibodies**
A major force in our immune system are antibodies, proteins that target specific antigens (a foreign substance recognized as harmful). Each antibody is specific, and we retain memory cells for immune system response to specific antigens for future use. If an antigen is altered, as often happens with a flu virus, the body's memory cells will not recognize the altered antigen, and the immune system will have to start "fresh" to mount an attack. It takes 10 – 14 days to form new antibodies and other substances that fight off disease and pathogens. Vaccinations contain substances that trigger the immune system to generate memory cells for the antigen we are being vaccinated against. Periodic boosters are needed for many antigens to reactivate memory cells.

**Blood proteins**
We have a set of multi-purpose blood proteins. Blood proteins maintain the osmotic balance of blood by having an appropriate ratio of blood proteins to water in the plasma. When blood proteins seep into the intercellular spaces, they attract water, and tissue swelling, called edema, can occur. Edema decreases the ability of blood to deliver needed nutrients and oxygen to cells and remove waste materials. Blood proteins also maintain the acid-base balance of blood, function in blood clotting and some antibody functions (e.g., gamma globulin). Other blood proteins help carry nutrients such as iron, zinc and vitamin B12 to cells.

**Membrane Transport Proteins**
Transport Proteins serve as carriers for specific substances that need to pass through the membrane by providing a channel. Transport proteins have binding sites that attract specific molecules. Most of our ions (Ca++, Na+, Cl-, K+, etc.), along with amino acids, sugars and other small nutrient molecules are moved through transport proteins. When a molecule binds to the carrier protein, the protein changes shape moving the substance through the membrane. This process may require energy (ATP), and the ATP complex is a part of the transport protein. When ATP is involved with actively moving molecules through the protein channel the process is called Active Transport. Cells maintain sodium and potassium balance using Sodium-Potassium transport pumps.
Proteins and Energy Use (as discussed)
The carbon fragment of an amino acid, after deamination, can be used for fuel.

If total carbohydrate consumed is less than needed for critical tissues and cells, and the short-term supply of glycogen is depleted, body protein tissues will be degraded to supply essential glucose fuel to the brain and nervous system. This will occur even if one has abundant adipose tissue.

Additional amino acids will be deaminated to provide fuel to other tissues of the body, along with mobilized fat reserves as available.

Dietary and cell amino acids will be used for fuel, once deaminated, if total calories are less than energy needs, but protein intake is high. This is the basis of the high-protein diets. It’s very important to remember, that deamination produces the toxic substance ammonia, which is converted to urea for excretion. Urea is osmotically active and requires lots of water to balance it for excretion.

Remember, any oversupply of amino acids will be converted to fat. The human body does not store amino acids.

General Protein Metabolism
Although we don’t think about it much, proteins are constantly being dismantled and reassembled in our cells and tissues. This nitrogen balance is important in determining how much protein is needed. Protein intake and nitrogen excretion is balanced when healthy and protein intake is relative to needs. Excess nitrogen excretion is associated with some diseases, injury and starvation since the body is dismantling protein of damaged tissues or for fuel in the case of starvation. Fasting, as far as the body is concerned, is the same as starvation. Nitrogen intake exceeds excretion during growth, pregnancy, tissue repair and muscle building.

Do we need as much protein as we often think we do?
The average adult person needs from 40 gm of high quality protein to 65 gm low quality protein to meet these recommendations. For most of us .8 grams/kilogram body weight is good. For those who have significant muscle density, such as competitive athletes, as much as 1.1 grams protein/kilogram body weight is OK.

Athletes often think they need more protein because they have more muscle density. In reality, most athletes consume more total calories of food, and if they consume 10 –15% of their total calories in protein, they will be getting more total grams of protein. Our protein intake is pretty much relative to body weight, not calories needed.
Protein and Health

It is difficult in health studies to link specific nutrient intake with disease and health. For example, those who eat lots of meat tend to have a high saturated fat intake. Health issues associated with high intake or saturated fat are known. Would a diet high in meat protein that was low in saturated fat affect health in the same way as the diets that are high in both animal protein and saturated fat? There are few individuals who have such diets. Vegetarians have diets very low in meat proteins, and some have high fat diets, but few have diets high in saturated fat. Many vegetarians have excellent health. But many practice several aspects of healthy living beyond a diet that is low in animal protein sources. Is it the absence of animal protein that promotes health or is it something else? It's almost impossible to isolate individual factors related to health and diet. We do know that those who focus on eating lots of vegetables and whole grains, and consume few high fat foods and few foods with concentrated sugars tend to be, as a group, pretty healthy. Those who also don't smoke and don't drink alcohol are even healthier.

So – what’s the best guess?
Heart disease is more likely among those whose diets are high in animal protein. In addition, those who substitute plant proteins for animal proteins tend to have lower serum cholesterol levels. That's good.

Elevated levels of one amino acid, homocysteine, are correlated with risk for cardiovascular disease. But the medical community doesn't know what causes elevated homocysteine levels in the blood. Caffeine can raise homocysteine levels, as can inadequate intake of folate and vitamins B₆ and B₁₂.

Some cancers are also associated with those who eat more animal proteins.

A high protein intake promotes calcium excretion that may lead to osteoporosis so a healthy balance of protein to calcium intake is desired. A good proportion for a woman is 20 mg of calcium for each gram of protein consumed. But most get less that half the appropriate proportion because we eat so much protein (and don't eat so much calcium). Just like diets high in fat and in concentrated sugars often mean we eat fewer healthy vegetables and fruits, a diet high in protein is often a diet low in vegetables and fruits.

High protein intake makes the kidneys work more, and risks, as well, dehydration. Those at risk for kidney disease need to be especially conscientious about protein intake.

At this time we know of no valid nutritional rationale for a high protein diet. For some people, the taste of protein food encourages them to eat better, and in this case, more protein may encourage healthier eating habits. We have no mechanism for storing protein or amino acids. A cell has a reserve for only one - three days at the most, before excess amino acids are removed for deamination and fat storage.
• High protein intake may cause dehydration.
• High protein intake produces more toxic nitrogen wastes that impacts the kidney.
• High protein intake may promote Calcium excretion and may affect zinc absorption.
• High protein diets for weight loss are an inefficient use of protein. Calories from protein fuel are just the same as carbohydrate.

**Protein Deficiencies and Health**
World-wide, lack of calories and/or lack of protein in diets are responsible for serious health problems. Collectively, this is known as **protein-energy malnutrition (PEM)**. PEM can be short-term or chronic. Although PEM affects all ages, its impacts are seen first with children. More than 30,000 children die in our world each day; most of them are malnourished. Too often, an infection or parasite that a healthy child would rebound from kills a malnourished child. Diarrhea, that seriously dehydrates an already fluid-imbalanced child, can be fatal. Two common diseases associated with protein-energy malnutrition deserve mention at this time.

<table>
<thead>
<tr>
<th><strong>Marasmus</strong></th>
<th><strong>Kwashiorkor</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Infancy (less than 2 yr)</td>
<td>Older infants and young children (1 to 3 yr)</td>
</tr>
<tr>
<td>Severe deprivation, or impaired absorption, of protein, energy, vitamins, and minerals</td>
<td>Inadequate protein intake or, more commonly, infections</td>
</tr>
<tr>
<td>Develops slowly; chronic PEM</td>
<td>Rapid onset; acute PEM</td>
</tr>
<tr>
<td>Severe weight loss</td>
<td>Some weight loss</td>
</tr>
<tr>
<td>Severe muscle wasting, with no body fat</td>
<td>Some muscle wasting, with retention of some body fat</td>
</tr>
<tr>
<td>Growth: &lt;60% weight-for-age</td>
<td>Growth: 60 to 80% weight-for-age</td>
</tr>
<tr>
<td>No detectable edema</td>
<td>Edema</td>
</tr>
<tr>
<td>No fatty liver</td>
<td>Enlarged fatty liver</td>
</tr>
<tr>
<td>Anxiety, apathy</td>
<td>Apathy, misery, irritability, sadness</td>
</tr>
<tr>
<td>Good appetite possible</td>
<td>Loss of appetite</td>
</tr>
<tr>
<td>Hair is sparse, thin, and dry; easily pulled out</td>
<td>Hair is dry and brittle; easily pulled out; changes color; becomes straight</td>
</tr>
<tr>
<td>Skin is dry, thin, and easily wrinkles</td>
<td>Skin develops lesions</td>
</tr>
</tbody>
</table>

**Kwashiorkor** is most often a post-weaning protein deficiency disease. (The name describes what happens to a child when a new baby is born and the first child is weaned from breast milk to cereals.) Infants are provided calories from cereals and other grains, but receive too little protein. Children are weak, tired and apathetic. They are anemic, suffer liver damage from fat buildup and loss of skin and hair pigments. Loss of osmotic balance (can't synthesize blood proteins) results in edema. Too often casual observers think the children are healthy because of their "plump" bellies. In truth, there are so few muscles that the belly swells from edema. The electrolyte imbalance may be fatal.
**Marasmus** ("dying away") results from an overall malnourished state of insufficient total calories and nutrients, including protein. Marasmus infants simply can not grow properly. Brain development is seriously impaired, since most brain growth occurs in the first two years. These children do not look plump from edema. Ketosis occurs as the body uses itself up trying to supply energy to cells and tissues. Marasmus is literally starvation. As marasmus progresses, the child "shuts down", reserving any precious calories for brain, heart and respiration. At some point, the digestive tract itself, is being resorbed so that food eaten isn't digested or absorbed properly.

Children can have symptoms of both kwashiorkor and marasmus. A marasmus child if deprived of protein but given more carbohydrate will still have the wasting, but adds to this the edema of too little protein. PEM diseases can be reversed, if intervention occurs in time. Proper nutrition rebuilds a wasted body. Restoring fluid and electrolyte balance takes priority followed by frequent but small quantities of energy nutrients. A low protein diet is more effective for recovery than one high in protein, in part, because of the impact of protein on fluid balance.
Protein Quantity and Quality in the Foods We Eat
Most of us were raised with the notion that protein was important and that animal foods contained protein. We do not associate fruits and vegetables with protein. Most learned that vegetarians seemed always at risk of protein malnutrition and had to work very hard to get enough protein in their diets. It's true, there are no high protein plant foods equivalent to the muscle tissue foods we consume from animals. But too few of us realize that the total amount of protein we actually require is nowhere near the amount of protein we consume, or the amount of protein found in those animal muscle tissues.

It is absolutely correct to note that we need a balance of essential amino acids in our diets, and that balance is most easily obtained by eating muscle from any variety of animals -- beef, lamb, pork, poultry, fish and assorted shellfish and dairy products. That would be about 4 – 6 ounces of said animal muscle tissue a day.

But we don't need to be so concerned as one might think – so long as we have variety in our food choices. Most plants are 10 – 15% protein – they have similar metabolic protein needs to humans. They don't have muscle tissue, so the mix of amino acids in plants is not the same as the mix in animal foods. And different plant groups have different amino acid compositions. In the past this led to assumptions that one had to eat very carefully if one chose a plant-based diet.

We often discuss protein quality and researchers have a number of ways of assessing protein to establish protein quality (as defined by the proportion of essential amino acids in the protein relative to our needs). Your text discusses many of the ways of assessing protein quality and studies used to establish our needs.

Protein Quality Vocabulary
- **Complete protein**
  A food that contains all essential amino acids in relatively appropriate proportions is a complete protein source.

- **Incomplete protein**
  A food that lacks at least one essential amino acid is said to be an incomplete protein source.

- **Complementary proteins**
  Complementary proteins are formed from food sources that, **when combined in the diet**, provide all the essential amino acids, so are, in combination, complete proteins. The individual food sources that form complementary proteins do not contain complete protein. Complementary proteins are most commonly formed from plant sources. Plant foods that are high in some amino acids but missing others are combined with plant foods that contain the missing amino acids. It's good to have complementary protein sources in the daily diet, but not essential to consume them at the same meal.
• **Protein Digestibility**
  How digestible a protein is varies with the type of protein and other foods consumed with the protein. Since protein molecules are large, the ability of enzymes to degrade the protein varies. Absorption of amino acids is also variable.

  Body health and food preparation are also important to digestibility
  ▪ Intestinal problems often mean poor absorption.
  ▪ Protein-rich foods prepared with moist heat are easier to digest than methods that use dry heat.
  ▪ It's harder to get at the protein in plants during digestion, plus plants lack complete protein so they have lower quantity protein.

• **Reference Protein**
  The reference protein is the standard for measuring protein quality in foods. Egg protein is considered the reference protein because it has the "best" mix of amino acids. Egg protein is given a reference value of 100.

  Using the reference value, researchers rate individual protein sources by one (or more) of the following methods. These methods score individual proteins. Most of us choose a variety of foods so that unless we have a protein deficiency, most of this is of little concern to us.
  o **Biological Valve (BV) of protein**
    ▪ Measures the usefulness of protein ingested to the amount of nitrogen excreted
  o **Protein Efficiency Ratio (PER)**
    ▪ Measures weight gain over time in growing animals when fed a certain protein. A higher number indicates a better protein source for weight gain.
  o **Net Protein Utilization (NPU)**
    ▪ Measures the amount of protein that is ingested that is retained, rather than eliminated. (looks at digestibility)
Protein in the Diet
Most meats have about 7 – 8 grams of protein per ounce. Since most of us need from 40 – 60 grams of total protein per day, we don't need big portion sizes of meats. A four-ounce hamburger may have 28 - 30 grams of protein.

Legumes, such as lima beans, lentils and black-eyed peas have about 6 grams of protein per half cup serving. That's also a pretty small portion, but few of us would eat two cups of lima beans. Many of us routinely eat 4-ounce meat portions. Tofu has 9 grams of protein.

Most vegetables and whole grains have 2 – 3 grams of protein per serving.

Milk and cheese products are high in protein. We often fail to remember this. Cottage cheese has about 25 grams of protein per cup. Milk has 8 grams per cup, and cheese has 6 – 7 grams per ounce (a bit more than a bite).

Vegetarian Protein Sources
As we have discussed, many of the best sources of protein are those that are also high in fat content. Many individuals are now turning to plant sources of protein, not just to reduce the amount of fat in the diet, but also to have the potential benefit of phytochemicals, not found in animal foods.

No single plant source has complete protein, although soy is close. Fortunately not all plants are deficient in the same amino acids. To utilize plant protein sources we simply use a variety of foods, so that we combine foods that are low in some amino acid with choices that are higher in that amino acid in our diet daily. It's easy. Grains and legumes are good complements. So are green leafy vegetables combined with seeds.

The challenge is to overcome perception. Most of us can't accept that plants are fine protein sources. We think we need high-protein content foods to get enough protein but eating those servings of grains and vegetables, each of which has some protein, add up to the amount we need. Unfortunately, plants lack Vitamin B₁₂ so a source of B₁₂ must be provided for those who are vegans (strict vegetarians).
Benefits of a Plant-Based Diet

- Except for seeds and nuts (and some legumes), plants are low-fat foods
- Plants have no cholesterol.
- Plants contain fiber.
- Many vegetables and whole grains are nutrient dense, with a good assortment of vitamins and minerals.
- Those whose diets are based on plant foods often see health improvements:
  - Foods high in soluble fiber can lower blood cholesterol
  - Some phytochemicals in foods have anti-cancer properties.
  - A high fiber diet promotes optimal digestive function
  - Reduced cardiovascular disease is seen in those who eat more plant-based foods (correlated to low blood lipid profiles).
- In addition, as a population cohort, vegetarians have a healthy lifestyle:
  - Smoke less
  - Are more likely to be at appropriate weight
  - Consume less alcohol
- Non-diet benefits of vegetarianism include:
  - Economy – plant foods are often less expensive.
  - Ecological lowering of food chain leaving more available resources for the earth.
  - Ease of storage and processing for many plant foods along with a good shelf-life for dry legumes and grains.
- Not a good reason to be a vegetarian
  - "I don't want to eat living organisms." Plants are very much alive!

The Vegetarian Pyramid Revisited

Grains and Legumes = 6 - 11 servings
Non-legume Vegetables = 3 - 5 servings
Fruits = 2 - 3 servings
Nuts and Seeds = 1 - 2 servings
Dairy (Calcium) Equivalents = 2 servings
Protein supplements for specific needs

Muscle Building

- Using muscle increases muscle tissue. Consuming protein does not build muscle.
- If you are working on increasing your muscle density, you have to be doing physical activity. That takes energy (calories). If you increase your food intake commensurate with the increased exercise you will get more grams of protein, and those grams of protein will be used to make that muscle tissue. The increase in food consumed will provide more than enough additional protein, assuming that the diet is a healthy, well-balanced diet.

Protein Powders

- There is no evidence that athletes (or anyone else) physiologically benefits from additional formulations of amino acid, vitamin, and mineral mixtures. A physically active individual requires additional calories to maintain his/her state of physical activity. Eating foods that have the recommended proportions of nutrients will automatically provide more grams of protein. Protein powder supplements are quite expensive. Eating additional wholesome foods will provide the same nutrients at less cost.
- For some, the powders are convenient, and provide "insurance" that he/she feels is helpful to training. Most of the time choosing to consume these supplements is not harmful, and may help you to feel better.

Enzyme aids for Digestive Problems

- As mentioned, it's doubtful if any enzyme aids are effective because most will be denatured by stomach acid. Some pre-digested proteins may work, but they increase secretion of gastric juices.
- As a side note, many such proteases are marketed for cleaning contact lenses. They dissolve protein deposits on the lenses. Some examples are:
  - Papain
  - Pepsin
  - Pancreatic enzymes

Single Amino Acid Supplements

Foods contain proteins, and all proteins are mixtures of a variety of amino acids. Our digestive tract is designed to handle a mix of amino acids, not a concentration of one. Amino acids compete for intestinal carriers and a concentration of one amino acid can inhibit absorption of other amino acids. In addition, some animal studies have shown that excess single amino acids in circulation can cause toxicity.

The two most popular amino acid supplements are lysine, to treat symptoms of herpes, generally oral herpes, and tryptophan, to promote sleep, reduce pain and treat depression. Tryptophan is a precursor of the neurotransmitter, serotonin.
Lysine does help some individuals and appears to be safe in amounts up to 3 grams per day when needed. Lysine appears to repress arginine, an amino acid needed by the herpes virus. Chocolate is high in arginine; however, there is no evidence that links chocolate consumption to herpes infections.

Tryptophan is effective in reducing pain and promoting sleep, again for some, but is controversial. A recall of all tryptophan by the FDA took place in the 1990's because more than 1000 people contracted a rare, but serious blood disease after taking tryptophan supplements. It is still not known whether it was a contaminant, an isomer or something else. Milk is naturally high in tryptophan, which may explain the idea that warm milk before bed promotes sleep. There is no relationship between counting sheep and tryptophan.