Bodybuilding Science

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Thank you for choosing Exercise ETC's ***RACE*** correspondence program for your continuing education needs. To earn your CECs/CEUs you will need to read the following article, *"Bodybuilding Science."* After you have read the article, take the test that appears at the end of the article. Remember to choose the best or most correct answer.

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Learning Objectives

After reading *"Bodybuilding Science"* you should be able to:

1. Define weight training, weight lifting, power lifting and bodybuilding.
2. Identify the formula for force, work and power.
3. Describe basic muscle physiology and the characteristics of Type I, Type II-a, and Type II-b fibers.
4. Describe and define the neuromuscular aspects of muscle contraction including motor units, the all-or-none principle and the summation of nerve impulses.
5. Describe the recruitment pattern for a set of 10 to 12 repetitions versus a set of 1 to 6 repetitions.
6. Discuss the principles of training such as overload, specificity and SAID.
7. List and discuss adaptations that occur as a result of resistance training.
8. Discuss various training protocols for different goals such as strength, power and hypertrophy.
9. Discuss various issues related to bodybuilding such as fat reduction, symmetry, sectional development, rest, nutrition, and supplements.

Bodybuilding Science

INTRODUCTION

Muscle building began many years ago when man realized by accident that he could make himself bigger by repeatedly lifting heavier and heavier objects. The primary purpose of having bigger muscles was for protection and to perform physical labor. As the world became more civilized and the need for physical labor and large muscles diminished, building muscles became a sport. Over the years, bodybuilding has not only grown into an extremely large amateur and professional sport, but it has also become a part of mainstream exercise programming for both men and women.

As the interest in bodybuilding for sport and recreation grew, so did the number of training methods. No longer was it just lifting heavy weights repetitively: Training systems were born and dietary supplements became a huge market. How many repetitions, sets, and exercises should you do? What about supplements? Are they safe? Is there anything you could take to maximize the time you spend in the gym?

Unfortunately, as every bodybuilder, or bodybuilder "wannabe" knows, it is often difficult to find any hard-core, black and white recommendations for how to build muscle mass. The medical and research communities, who have never taken bodybuilding very seriously as an art **OR** a science have not devoted a lot of time, energy or funding into the study of muscle hypertrophy, For this reason, many aspiring bodybuilders turn for advice to the popular fitness media, such as "***Muscle and Fitness***" magazine, anecdotal advice from those with whom they work out and the breathless advertisements promulgated in the print and visual media. In desperation, it is not unusual for aspiring bodybuilders to turn to supplements of questionable efficacy, diets that are potentially harmful and illegal muscle growth drugs. It is the intent of this article to take a look at bodybuilding as an art **AND** a science, and to apply sound, physiological principles to a bodybuilding routine.

DEFINITIONS

There are a number of terms used to describe the various methods of resistance training. Some of these terms are synonymous, but many are often used in the wrong context. A definition of some common terms follows:

- **Weight or Resistance Training:** Using various forms of external resistance to improve the strength of one or more areas of the musculoskeletal system.

- **Weight Lifting:** A competitive sport in which the goal is to lift the heaviest weights overhead using the *Snatch* and the *Clean and Jerk* movements. The training is oriented toward technique and power. This is the only Olympic strength/power sport.

- **Power Lifting:** A competitive form of lifting where the goal is to move a maximum amount of weight. The weight is calculated by the sum of three lifts: Bench Press, Squat, and Dead Lift. Often used in assessing

the status of strength athletes, it is presumed to correlate with sport performance.

- **Bodybuilding:** A paradigm of resistance training designed to maximize the size, symmetry, and visual quality of the physique, where strength or power are not the ultimate goals, merely the means to an end. Sometimes engaged in for the purpose of competition, more often than not it is for the sake of one's own body image or appearance or self –esteem.

RESISTANCE TRAINING GOALS

The principle of **specificity** of training implies that physiological adaptations to training will be specific to the nature of the stimulus. This stimulus must provide an **overload** that demands more from the system than it ordinarily encounters. For symmetry and visual quality, a program of balanced attention to all the superficial muscles must be achieved, however, muscle hypertrophy is the essential element in a bodybuilding program. In order to get maximum hypertrophy, fitness professionals must understand several mechanical and physiological issues:

- **Force:** Force is the effort and/or ability to overcome the inertia of an object. (Force equals mass times acceleration.) Often equated with strength, as in "How much can you lift?"

- **Work:** Work is the ability to lift a weight through a distance. (Work equals force times vertical distance.) Often equated with endurance, as in "How much work can he do?"

- **Power:** Power is the ability to perform more work in less time. (Power equals the amount of work done divided by the amount of time it took to do the work.) This is often equated with speed or short bursts of high intensity, as in "How high can you jump?"

These three mechanical variables are attributes of physics that are applied to weight training goals. These variables can be applied either individually or collectively to accomplish the specific goals of a bodybuilding routine. These goals are:

- **Strength:** Strength is the ability to create external force by exerting internal forces against the skeleton via muscle contractions. Strength is usually equated with Force and expressed as 1RM, or the maximal repetition one can lift.

- **Power:** Power is the ability to lift a mass at a high rate of speed, or to attempt to move a heavy load as rapidly as possible.

- **Hypertrophy:** Hypertrophy is the ability to stimulate the deposition of more protein, water, glycogen, ATP and collagen in a muscle cell. This causes an increase in the amount of actin and myosin proteins which in turn increases the size and number of myofibrils inside the muscle fiber. The end result is an increase in the diameter of the muscle fiber.

Hypertrophy is a result of the volume of training. The formula for calculating the volume of training is as follows:

Volume = sets x repetitions x intensity x frequency

It should be noted that strength and power are two distinct goals that require different training protocols. Bodybuilders do not necessarily train for either strength or power; rather they train for increases in strength and power as a means to an end: hypertrophy. Increasing strength and power places physiological demands on muscle which cause it to increase in size. Keep in mind, however, that there is not necessarily a correlation between hypertrophy, strength or power: the ***biggest*** muscle is not necessarily the ***strongest*** one.

MUSCLE PHYSIOLOGY

One of the traditionally best-kept secrets of bodybuilding is that virtually **ALL** of the results your client will get are genetically predetermined. The blueprint to how we will respond to strength training, including limb length, muscle length, tendon insertion and muscle fiber distribution, are hardwired into our genetic history, and are determined by the second trimester of our mothers' pregnancies. It is not uncommon for two individuals of similar age, size, gender and body type to have identical exercise habits and dietary habits and get wildly different results. It is safe to say that many successful bodybuilders are successful because they were born to be successful. This is not to minimize the hard work and sacrifice they exhibit to hone their bodies but, all things being equal, they often have the proclivity which, through training, they maximize.

Fitness professionals need to have an understanding of muscle fiber types and their functions in order to develop effective programs aimed at building mass. Muscles are made mainly of water, (approximately 75%) protein (20%) , and minerals (5%). Our muscles are comprised of different **fiber types** that allow us to be more efficient at meeting the various demands that are placed on the muscles such as endurance, strength and power. A brief description of the various muscle fiber types is as follows:

- **Type I:** Type I muscle fibers are commonly referred to as **slow twitch**. They get their ATP for contraction from the aerobic system. They have a greater number of capillaries per square centimeter, as well as more mitochondria, myoglobin (the oxygen-carrying molecule of the cell), and oxidative enzymes in the individual cells.. These fibers are smaller in size, have a slower twitch rate and less force output. Since they are oxidative fibers and are more fatigue-resistant, they are well suited for endurance activities.

- **Type IIa:** The Type IIa fibers are often referred to as **fast twitch fibers,** or fast, oxidative, glycotic **(FOG).** Type IIa fibers use a combination of oxidative and anaerobic energy sources for muscle contraction. Compared to Type I fibers, they have greater stores of glycogen, phosphocreatine, and glycotic enzymes. In addition, the Type IIa fibers are larger in size, have a greater force output, and require a larger or more frequent nerve impulses in order to fire. They also fatigue more rapidly than Type I fibers. The type IIa fibers have a chameleon-like quality to them: Depending on the training regimen that is pursued, they

can become more oxidative in nature, like the Type I fibers, or glycotic, like the Type IIb fibers.

- **Type IIb:** These fibers are entirely anaerobic and often referred to as **fast glycotic** (FG). Compared to the other types, they have the greatest concentration of glycogen, phosphocreatine, and glycotic enzymes as well as the greatest force output and twitch rate. In addition, they fatigue the most rapidly of the different fibers and require the greatest nerve impulse before firing. These Type IIb fibers are sometimes referred to as **true fast twitch** muscle fibers.

- **Satellites:** Satellites are individual cells that are interspersed throughout muscle tissue and are attached parallel to other muscle fibers. Training for hypertrophy requires a combination of training methods in order to achieve enlargement of the various muscle fiber types; it is theorized that these satellites cells may develop into functional fibers with sufficient hypertrophic stimuli.

MUSCLE CONTRACTIONS

Muscle contraction is a result of complex communication between the nervous system and the muscular system. The nervous system will respond to external resistance and movement speed in order to determine how many muscle fibers to recruit, as well as which ones to recruit. Muscle fibers of the same type are grouped together in what is called a **motor unit**. Each motor unit is innervated by a **motor neuron**. What we refer to, genericly as "muscle tissue" is actually made up of many of these motor units: When gross motor control (strength) is the norm for a muscle group, such as the gastrocnemius, a single motor unit may have 1,000 muscle fibers. On the other hand, when fine motor control is necessary, such as in the eye, a motor unit may consist of only 5 or 6 muscle fibers.

When a sufficient nerve impulse is sent to the motor unit, all of the muscle fibers in that motor unit will contract maximally, or none of them will. This is what is known as the **all-or-none principle**. The amount of force a muscle produces in response to an external resistance is dependent not on the number of individual fibers, but on the number of motor units recruited. It is important to note, however, that even though an individual motor unit is incapable of a less than maximal effort, unless a muscle is working at its 1RM, all of the available motor units ***will not*** be firing.

RECRUITMENT PATTERNS

The order in which the various types of fibers are recruited is dependent upon the number and frequency of nerve stimuli and the nature and duration of the task. The **size principle** of recruitment suggests smaller Type I fibers are recruited before Type IIa; Type IIa fibers, in turn, are recruited before Type IIb fibers. High-force eccentric activities preferentially recruit fast twitch fibers and inhibit recruitment of slow twitch fibers. Examples of typical patterns of recruitment are as follows:

- Recruitment for a set of 10 to 12 repetitions: Type I, Type IIa, Type IIb
- Recruitment for a power or strength set of 1 to 6 repetitions: Type IIa, Type IIb

PRINCIPLES OF TRAINING

Fitness professionals should be constantly aware of the basic principles of training. The first of these principles is **overload**. In order to stimulate an improvement in musculoskeletal function or size, the body must be subjected to resistive forces greater than those it normally encounters. Creating training overload is both an art and a science. The overload must be sufficient to create a challenge for the existing muscular system in order to force the body to make an adaptation, but if the challenge is too great the body will fail to adapt and overtraining or injury will occur.

The second principle of training is specificity. **SAID** (specific adaptation to imposed demands) is an often used acronym for the principle of **specificity**. When an overload stimulus is encountered by the body, the adaptation will be specific to the nature, type, intensity, frequency and duration of the overload. For example, a client performing high repetitions with low weight will see improvement in the ability of the muscle to contract repeatedly with submaximal resistance, but with very little change to their one repetition maximum.

When a specific overload is applied in the form of resistance training, several adaptations occur in order to allow the client to lift progressively heavier weights. During the first 4 to 8 weeks the adaptations are mostly **neurological** in nature. These adaptations include increased motor unit recruitment, less inhibition in the Golgi Tendon Organs and more inhibition from the antagonist muscle(s). During this time period there are also changes in the **connective tissue**. Increased collagen deposition in all components of the muscle and tendon enable these tissues to apply or resist greater forces without injury.

Following these changes comes **hypertrophy.** Typically, hypertrophy is not a factor in strength development during the first 8 weeks of beginning a program. Hypertrophy is the result of a number of changes that occur in response to increasing overloads. These changes include:

- Increased protein synthesis within the myofibrils (actin and myosin), particularly in the perimeter of the existing actin and myosin.
- Decreased **catabolism** (muscle tissue breakdown) due to increased anabolic hormone influences: In a bodybuilding routine, serum testosterone levels have been shown to increase dramatically. **Human growth hormone** levels are highest in programs with high total work.
- Increased storage of glycogen and ATP.
- General increases in the cross-sectional area of the fibers and the muscle body, mostly in Type IIa fibers.
- Possible **hyperplasia** (increase in the number of individual muscle fibers.) The fact that muscle fiber size is not always greater in bodybuilders suggests the likelihood of hyperplasia although this is still speculative.

ISSUES IN BODYBUILDING SCIENCE

The issue of **"regional hypertrophy"** is one that science has had little motivation to study, but it is very important for the bodybuilder. Regional hypertrophy deals with the most effective way to get a specific muscle to achieve a certain "look" or "cut." Regional hypertrophy attempts to achieve the definition of a particular muscle or group of muscles that is an integral component of the competitive bodybuilding routine. A specific "twist" here or a "bend" there that make a muscle pop up in such a way as to get a "peak" or cut is a huge concern to the bodybuilder, yet researchers traditionally have had little reason to investigate or study the effect of specific training variable on hypertrophy. It is because of the lack of hard, scientific study that so much of a bodybuilder's routine has traditionally been made up of hearsay, anecdotal information and superstition.

However there are some issues of concern to bodybuilders that are known, even though perhaps not exhaustively researched. For example, we know that hypertrophy rates differ wildly for upper and lower body. This makes sense: we use our legs all day to move our body weight around, but our arms are rarely utilized enough to get a hypertrophic stimulus. (How often do our arms have to move our body weight?) One study found that it takes approximately 10 weeks of consistent training for hypertrophy in the upper body and approximately 20 weeks for the lower body. It makes sense, doesn't it? The weaker (untrained) upper body muscle respond more rapidly to overload than do the traditionally stronger (better trained) lower body muscles.

Another point: increases in cross-sectional area are not consistent throughout the muscle tissue. Often, there is a higher concentration of Type I fibers deeper within the muscle tissue. For example, more Type I fibers are found in deeper regions of the vastus lateralis, whereas more Type II are found superficially. A recent study reports that prone hamstring curls stimulate the superficial (Type II) biceps femoris fibers while the Romanian dead lift gets more of the deeper (Type I) fibers. In addition, it makes sense that those areas that have a higher percentage of Type II fibers will experience greater increases in cross-sectional area than those with a higher percentage of Type I fibers. This fiber distribution, however, can vary significantly, even within a particular muscle: For example, one MRI study of the biceps brachii found a 73% difference in cross-sectional area between two areas only 10 mm apart.

TRAINING THE BODYBUILDER

Hypertrophy is a result of the **volume of training**. For each muscle/muscle group bodybuilders will typically perform a minimum of 3 to 6 sets of exercises consisting of 6 to 12 repetitions each. Generally, they will follow this routine for anywhere from 3 to 20 different exercises. The **rest period** in bodybuilding routines is usually abbreviated as well: generally, a bodybuilder will make do with a rest of between 15 and 60 seconds between sets for each muscle group.

This type of **high volume** training must be done secondary to a basic strength program, with a slow progression, to achieve this magnitude of overload without overtraining or injury. The competitive bodybuilder must be willing to make an enormous commitment in both time and energy. It appears that, when all is said and done, **variety** of exercises and routines has more impact on hypertrophy than any one routine or protocol.

FAT REDUCTION

Hypertrophy will enlarge a segment of the body, but fat deposits will play a major impact in the size and shape of the body apart from the appearance of the muscles. The ultimate goal for those

training for hypertrophy is to develop as much muscle as possible while keeping **subcutaneous fat** to a minimum. Bodybuilders need to consume sufficient calories to not only sustain their intense training but also to also increase muscle mass: Surplus calories are necessary to build muscle.

This surplus becomes a tightrope act for many aspiring bodybuilders, however: Too much of a surplus will not only build muscle but also add additional fat stores to the body. Some bodybuilders still follow a plan of large weight gains in both muscle and fat during the post competitive season followed by strict dieting before competition. One of the major problems with this plan is that too much muscle is also lost during this dieting period. The body is not physiologically designed to either gain weight or lose weight rapidly. A more sensible approach while "building" is to make every effort to maintain body fat levels to within one to two percent of the competitive range at all times. This allows for additional weight gains to be smaller, and to come primarily from muscle rather than fat.

Bodybuilders should also perform some cardiovascular exercise in order to reduce subcutaneous fat stores. Another tightrope: Too much endurance exercise, especially when performed on the same day as resistance training, will reduce strength gains. This may reduce the overall volume of resistance training and hypertrophy. Studies show that cardiovascular running or jogging minimizes hypertrophic stimuli to the upper body. Cycling, especially in shorter duration, higher intensity bouts, may actually maintain or stimulate muscle growth due to the high tension at which one would have to pedal. As a general rule of thumb, sessions of 20 to 30 minutes performed 3 or more days per week are sufficient. Most bodybuilders prefer to perform aerobic exercise after the resistance training in order to spare glycogen for the strength training. In addition, when glycogen stores are depleted, more of the energy used during submaximal aerobic work will come from fat stores.

NUTRITION

Nutrition is the cornerstone for any individual involved in training for hypertrophy, and specific advice should come from a **registered dietitian** or other qualified dietetic professional. There are, however, a number of nutritional practices are common among bodybuilders. Some of these practices can cause serious health risks. Some general guidelines and practices are as follows:

- **Water:** Due to the increased metabolic demands of building muscle, as well as for the sheer volume of exercise that must be performed to result in any significant hypertrophy, the bodybuilder should remain well hydrated. A **minimum** of 8 to 10 glasses (approximately 64 ounces) of water (fluid) is recommended per day. On especially heavy training days, the athlete may want to consider a fortified **sports drink** to replenish the nutrients, including glucose, lost during the workout.

- **Protein:** Individuals involved in heavy training have an increased need for protein. If the diet is balanced and additional calories are added to sustain training, these additional protein needs should be met. One ounce of chicken, beef, pork or fish supplies 7 grams of protein. Bodybuilders need approximately 1.6 to 2.0 grams of protein per kilogram of body weight per day. Protein has also been shown to play an important role in the resynthesis of glycogen. Following training, a snack that combines protein with carbohydrate induces a faster rate of glycogen resynthesis than snacks of either carbohydrate or protein alone. A recent study suggested that a **high-quality** (low fat, low cholesterol) protein snack

one hour **before** and again within two hours **after** a workout increases the amount of glycogen available to the muscle for repair and growth.

- **Carbohydrate:** Bodybuilders need on average 7 to 10 grams of carbohydrate per kilogram of body weight per day. This amount should allow for sufficient resynthesis of the glycogen necessary for training and to synthesize muscle tissue. It is common for bodybuilders to reduce carbohydrate drastically prior to competition. This also has the effect of dehydrating the bodybuilder by reducing the amount of water stored by the body. (Each gram of carbohydrate is stored with 3 to 4 grams of water.)

- **Fat:** Approximately 20 to 25 percent of the calories in the diet should come from fat, with **unsaturated** sources (generally, from vegetables) emphasized over **saturated** (generally, from animal) sources. It is customary for bodybuilders to maintain very low levels of fat prior to competition in order to create a caloric deficit, further reducing subcutaneous fat stores.

It is worth noting that the need for protein supplements is rare if a well-planned diet is followed. Using **American Dietetic Association** guidelines for daily caloric intake (55-60% from carbohydrate, 10-15% from protein, and 25-30% from fat) will provide plenty of protein and energy for the athlete to succeed. For example, let's analyze a 200 pound (91Kg) male bodybuilder on a 5,000 kcal diet/day:

Nutrient	***% of intake***	***Total kcals***	***Total grams***	***Kcals per kg***
Carb	(60%):	3,000	(750 g)	Carbohydrate calories/kg: 8.2
Protein	(15%):	750	(187.5 g)	Protein calories/kg: 2.6
Fat	(25%):	1,250	(139 g)	Fat calories/kg: 1.4

Note that this "standard" recommendation supplies more than enough carbohydrate and protein for the bodybuilder's needs. All that is required is sufficient calories of the right kinds of foods. When caloric restriction becomes necessary, cutting back on fat consumption would not affect the energy demands of training or the protein demands on muscle retention.

SUPPLEMENTATION

In addition to the basic nutrients, there are a number of supplements commonly used by bodybuilders in order to optimize training, reduce fat and maximize muscle hypertrophy. Several of the most common:

Creatine is synthesized from arginine and glycine in the liver, pancreas, and kidneys; it is found in meat and fish. Supplementation with creatine may produce an ergogenic benefit by increasing muscular force and prolonging the ability to perform anaerobic exercise. The normal daily requirement for creatine is approximately 2 grams for a 70 kg (154 lb.) person. About one half of this comes from animal protein in the diet and the other half is synthesized by the body. Eight ounces of raw meat contains about 1 gram of creatine. Several studies have shown creatine improves performance in repeated bouts of high intensity physical exertion such as strength training and

sprinting. An analysis of the research on short term (several weeks) creatine supplementation demonstrates an increase in body weight of 0.7 to 1.6 kilograms.

Creatine is thought to result in gains in muscle mass due to fluid retention and/or increased protein synthesis. To date, no serious side effects have been verified in subjects using creatine for durations of less than 4 weeks, but there have been anecdotal reports of muscle cramping and lethargy.

To date, there are no long terms studies to document the possible side effects of long-term creatine supplementation, but some researchers have expressed concern about the effects of long term supplementation, on the kidneys and liver. During long-term supplementation the kidneys must process higher levels of creatine while the liver (along with the kidneys and the pancreas) stop making creatine during supplementation. Until long term studies are available, long term supplementation of creatine is not advised.

Androstenedione is a direct hormone precursor of testosterone. This makes it just one of several anabolic steroids that are legally available over the counter. Manufacturers of androstenedione supplements claim that the product increases the level of the male sex hormone **testosterone** in the body which leads to increased muscle size and strength. There is a tacit concern, however, when dealing with the body's hormonal levels: Hormone formation and use in the body is under control of multiple enzymes, and is highly unpredictable.

Although androstenedione (unlike non-prescribed anabolic steroids) is not illegal, to date, there are no long term studies in the medical literature on the safety or ergogenic effects of androstenedione. Since androstenedione is a steroid, it can be expected to produce the same side effects found in prescription (or black market!) steroids. Documented side effects of anabolic steroids include: acne and premature balding, kidney and liver dysfunction, increased risk of cardiovascular disease due to cholesterol profile changes, irritability and aggressiveness, development of secondary male sexual characteristics in females, testicular atrophy, decreased sperm count, gynocomastia (male breast enlargement) and prostate hypertrophy in men. Of particular concern is its use in young athletes: Steroid supplements can cause premature closure of growth plates and the side effects seen in adults can be a lot more serious for teens. Like all steroids, androstenedione can also compromise the immune system and lead to osteoporosis.

Clinical studies on caffeine have established **caffeine** as an ergogenic aid in that it improves endurance. Caffeine increases the production of **epinephrine** which increases the mobilization of fatty acids. With more available fat for energy, glycogen stores are spared, creating the potential for improved endurance. This improved endurance could translate to increased volume of training for a bodybuilder. Side effects of caffeine use may include the following: diuresis (a diuretic, or dehydrating effect), nausea, muscle tremors, and palpitations. Caffeine, if taken at the same time as creatine monohydrate, may negate its effects.

Ephedrine is a stimulant found naturally in **ma huang**, a group of Chinese herbs. Ephedra is used in many herbal products including supplements promoted for weight loss. Ephedrine also can be chemically manufactured or synthesized. It increases heart rate, blood pressure and performance. Ephedrine is normally released by the body under stress to enhance performance in life/death situations. Ephedrine, ephedra and **pseudoephedrine** are closely related drugs with actions and side effects similar to the hormone **epinephrine** (adrenaline). It has some of the same effects as cocaine and has been known to increase the odds of sudden cardiac death. Caffeine, which is found in coffee, tea, chocolate, and some nonprescription and supplement products, can amplify the side effects of

ephedrine and pseudoephedrine. Products containing ephedrine/pseudoephedrine/ephedra should be avoided unless prescribed by a physician or a registered dietitian.

CONCLUSION

Bodybuilding is a sport which takes resistance training to its highest level. The research community has had little reason or interest in studying the many issues that relate to the bodybuilder's training or diet. However, employing the basic scientific principles presented here will allow for increased muscularity and good, healthy body fat control. Bodybuilding is also an art in that individuals may need to experiment on a trial and error basis to determine which methods work best for them. Fitness professionals should encourage their clients to adopt practices that maximize results and minimize health risks.

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CEC/CEU Test for *"Bodybuilding Science"*
Choose the BEST answer.

1. A competitive form of lifting which utilizes maximum weight in the bench press, squat and dead lift is known as:
   A. Resistance training
   B. Weight lifting
   C. Power lifting
   D. Bodybuilding

2. Force multiplied by velocity is the formula for:
   A. Strength
   B. Power
   C. Work
   D. Hypertrophy

3. Muscle is made of predominantly:
   A. Water
   B. Protein
   C. Actin & myosin
   D. Sodium

4. Muscle fiber type that is completely anaerobic and requires a greater nerve impulse in order to fire is known as:
   A. A satellite
   B. A Type I fiber
   C. A Type II a fiber
   D. A Type II b fiber

5. The amount of force that a muscle produces is regulated by:
   A. The number of motor units recruited
   B. The number of Type I fibers recruited in any motor unit
   C. The number of Type II a fibers recruited in any motor unit
   D. The number of Type II b fibers recruited in any motor unit

6. Which of the following is/are true regarding motor units?
   A. They are innervated by numerous motor neurons
   B. The fibers in a motor unit contract sub maximally when recruited
   C. All the fibers in a motor unit contract maximally when recruited
   D. A and B

7. Which of the following represents the order of fiber recruitment during a set of 10 to 12 repetitions?
   A. Type II a, Type II b, Type I
   B. Type I, Type II a, Type II b
   C. Type II b, Type II a, Type I
   D. Type II a, Type I, Type II b

8. SAID refers to which principle of training?
   A. Overload
   B. Reversibility
   C. Specificity
   D. Hypertrophy

9. Hypertrophy occurs due to increased protein synthesis within the:
   A. Myofibrils
   B. Actin
   C. Myosin
   D. All of the above

10. Hypertrophy is primarily the result of:
   A. The amount of weight lifted
   B. The number of repetitions completed
   C. The volume of training
   D. The frequency of training

11.Daily protein recommendations for those involved in heavy training are:

A. 1.0 gram per kilogram
B. 1.0-1.5 grams per kilogram
C. 1.2-1.6 grams per kilogram
D. 1.6-2.0 grams per kilogram

12. The best time to eat protein is:

A. Within two hours of the workout and for the next 24 hours
B. One hour prior to the workout and within 2 hours after
C. 24 hours after the workout
D. 24 hours before the workout

13. Adding carbohydrate to the diet immediately prior to competition will cause:

A. A decrease of water in the muscle
B. A decrease in glycogen in the muscle
C. The muscles to swell
D. A decrease in subcutaneous fat

14. Which of the following statements is true regarding training?

A. Body builders usually get best results from one specific exercise
B. Body builders achieve symmetry by using one training protocol
C. No single exercise or protocol works best so a variety is needed
D. All individuals will get the same results when using the same program

15. Generally body builders perform cardiovascular exercise:

A. Before strength training
B. After strength training
C. During strength training
D. Body builders should not perform cardiovascular exercise

16. Hypertrophy occurs faster in:

A. The upper body
B. The lower body
C. The core
D. Hypertrophy occurs at the same rate throughout the body

17. Which type of muscle contraction preferentially recruits fast twitch fibers and inhibits slow?

A. Isometric
B. Isokinetic
C. Concentric
D. Eccentric

18. Which of the following statements is/are true regarding hypertrophy?

A. Cross sectional area increases in a uniform fashion throughout the muscle
B. Cross sectional area increases differ throughout the muscle
C. Cross sectional area tends to increase in a uniform fashion in the upper body but not in the lower body
D. Cross sectional area tends to increase in a uniform fashion in the lower body but not in the upper body

19. Which of the following adaptations is most likely to occur in the first 4 to 8 weeks of training?

A. An increase in actin & myosin
B. Hypertrophy
C. Less inhibition in the golgi tendon organs
D. Increased strength in the connective tissues

20. SAID is an acronym for:

A. Super Additions In Development
B. Specific Adaptations to Imposed Demands
C. Specific Adaptations to Increased Days
D. Special Adaptations to Improved Development