THE PHYSIOLOGY OF ATHLETIC TRAINING

A Thesis Presented for the Degree of Master of Arts

By

Darwin B. Keye, B. S.

OHIO STATE UNIVERSITY

THE OHIO STATE UNIVERSITY

1947

Approved by:

[Signature]
TABLE OF CONTENTS

Chapter I - Introduction ......................................... 1

Bibliography .................................................. 12

Chapter II - The Contributions of Training to the
Physiological Development of the
Athlete .............................................................. 13

Bibliography .................................................. 57

Chapter III - Diet and Athletic Training ...................... 61

Bibliography .................................................. 79

Chapter IV - Fatigue and Staleness ............................ 81

Bibliography .................................................. 96

Chapter V - The Affect of Tobacco, Alcohol and
Caffein on the Performance of the
Athlete ................................................................ 97

Bibliography .................................................. 109

Chapter VI - Summary ............................................. 111

759209
CHAPTER I
INTRODUCTION

The title of this study, at first glance, may give the reader the impression that it covers a very wide field. Or, on the other hand, one might think it is to be a discourse on the practices which are carried on in the well known "training room".

The "physiology of athletic training" is of utmost importance to all teachers in the field of physical education. Therefore, an understanding of physical education is necessary at this point in order to clarify the relationship of physical education and the subject of this thesis.

According to Hetherington, physical education is that phase of education which is concerned, first, with the organization and the leadership of children in big muscle activities, to gain the development and the adjustment inherent in the activities according to social standards; and, second, with the control of health or growth conditions naturally associated with the leadership of the activities, so that the educational process may go on without growth handicaps. (5)

The physical education program of most high schools and colleges consists of three integral phases. First, is the service class program for all students, with a wide variety of activities; second, the intramural program for those interested in participating in sports activities after school hours; and third, the interscholastic or
intercollegiate sports program for those having sufficient capabilities to participate in this varsity sports program.

Although a knowledge of training is of value in the first two phases mentioned of the physical education program, it is usually only thought of in connection with the third phase, or varsity competition.

On reading through literature that had been written in this field, it was found that most authors were well agreed on the meaning and scope of the term "training".

The field of training can also be broken down into several phases. Bilik states, that on analysis, training is found to be divisible into the following branches:

(a) Conditioning - preparation of the athlete for the intense muscular and neural exertions which are incidental to competitive athletics; development to the highest possible degree of vitality, endurance, strength, and resistance to injuries. (b) Treatment of injuries - practical and efficient application of first aid and the elements of minor surgery. The trainer's methods in this treatment of injuries are more drastic than a physician's because the former deals with vigorous youth possessing great powers of recuperation, while the latter has real invalids. (c) Specialized Training - development, to the highest possible degree, of skill in the application of the individual's efforts in his chosen field of athletic endeavor. (2)

Bilik's analysis of training is considered too inclusive for this study. Therefore, the author has limited
this topic by the following definition of training. Athletic training is that phase of the physical education of the athlete, pertaining to the conditioning period of carefully guided exercise and properly selected diet, which develops the highest degree of physiological proficiency as preparation for competition in the interschool athletic program.

Therefore, the greater part of the material collected in this survey was taken from the field of physiology.

It is probably due to this fact that McCurdy and Larson express the opinion that there is a need for a closer association between the physical educator and athletic coach, and the physiologist. To date, they have been working separately as investigators and contributors to the program of physical education. Even now a third group is entering the picture, the psychologist and educator. (6)

Dawson feels that there should be further distinction made in the field of athletic training by separating "practice" and "training". He states that, speaking in general terms; training produces fitness, while practice produces skill. (3) So many authors speak of both as though they were one and the same thing in their compositions on athletics. There is no doubt of their close relationship from a coaching standpoint, since the coach is guiding the development of both phases at the same time. Part of his conditioning comes with the practice of the skills of the particular sport which he is coaching.
Again the unity of the two terms is implied by Gould and Dye, who feel that training may be defined as the progressive improvement and ultimate perfection of one's ability to execute an act through repeated performance of that particular act. Regardless of the type of activity, training depends upon its frequent repetition or upon so-called practice. (4).

In the past, and even today in many instances, the practice is stressed over the actual conditioning of the athlete for interscholastic or intercollegiate competition. The coach spends so much time teaching and practicing the skills of the game, with no conscious effort toward conditioning, because he feels one of two ways about it. Either, that the skill of the game is more important in gaining success in the sport, or, that conditioning will take care of itself as he runs the boys through their paces, while stressing the actual game skills.

The coach who does stress skill over condition, probably, recognizes the fact which is revealed by McGurdy and Larson in reporting, that perfection of skill movements is the most conspicuous result of training. (6)

The author feels that due to the necessity of developing skill and conditioning at the same time, the competitive sports phase of the physical education program can be directed most satisfactorily by a highly trained physical education teacher.
An interest in this special field of study was aroused by several factors: (1) discussion that came up in physical education classes in graduate school, among coaches pertaining to this subject of training; (2) some extra study in the field of physiology; and (3) the author's experience in coaching athletics in high school.

The differences of opinion among coaches, with regard to various practices used in training, and a lack of agreement among various other contributors to the field, challenged the author to make a comprehensive study of the physiological research that had been performed pertaining to the field of athletic training.

A selection of the most pertinent facts established, to date, in the field of physiology, has been made in order to cast a definite light and understanding on the subject chosen.

Because many, who are interested in this important phase of athletics, do not have a technical understanding of physiology, an attempt has been made to keep the interpretations as elementary as possible. Some reference to the various sports has been made to aid in clarifying some points.

Since becoming interested in physical education and its specialized phase of athletic coaching, the author has had the desire to pick up a book that presented the scientific information regarding the things to do and not to do in
training a squad of boys. Most articles are written by coaches who use only their own opinions developed from experience, or from the training program their old coach introduced to them. Because a coach had a fine record was never considered as proof that his training practices were the most desirable or acceptable. Then, on the other hand, when searching for some definite facts pertaining to athletic training in Journals and textbooks of Physiology, nothing except the results of some very specific pieces of research could be located, having but a minute bearing on the whole problem of training. These facts were usually written up in highly technical language which was almost meaningless to the average reader.

Thus, it was the author's desire to assemble these studies, in order that an appreciable amount of information might be made available for members of the coaching profession.

In the interscholastic or intercollegiate competition phase of the physical education program, coaches are dealing with the choice individuals of their school or community. As is stated by Bainbridge, physical prowess is a trait instinctively admired by men in all walks of life, and the athlete has long been pictured as the ideal type of man. (1)

People go to the athletic fields, gymnasiums, diamonds, tracks, pools, and rings, to watch the cream of our American manhood perform. There is some kind of an attraction which draws these people and they marvel at the
techniques, skills and feats, which these physically
trained men exhibit before them.

Therefore, from the coaching viewpoint in athletics,
one cannot help but feel that it is his duty to give these
excellent performers the best possible training in order
that they may develop into the best conceivable athletes.

The military leaders of World War II gave much credit
for our success in the conflict to the leadership ability
of our men, which they felt was developed by participation
in competitive athletics.

In the Army, Navy, and Air Forces physical training
programs, the development of stamina and endurance was
stressed. These same qualifications are of vital impor-
tance to the success of the athlete. The training program
must be intelligently supervised in the effort to reach
these desired goals. For the athlete should become
stronger and healthier as a result of their participation
in athletics, rather than suffer any harmful effects, as
is the case many times, due to improper supervision. This
is usually the result of the lack of knowledge on the part
of the athletic coach, or his great desire to win at any
cost.

Then, on the other hand, if the coach is doing his
part in giving the boys the best possible training, he can,
in return, demand the whole-hearted cooperation of the
athlete in carrying out and following his prescribed
program.
In collecting data for this thesis, it was necessary to make a comprehensive study of all authentic sources in the fields of physical education, athletics, and physiology. There have been many studies made on hundreds of related problems in physiology, and it is the result of accumulating the facts proclaimed by these various and sundry experiments that more general and meaningful facts accrue.

Doing things the customary way has been the procedure of many coaches. Whether these customary ways were right or not is debatable.

The author has found, in a survey of the literature, that some of the practices used in conducting athletic training are questionable. Furthermore, it might be said that these teachers have assumed that their methods were correct without evidence to support the same.

Therefore, with these aforementioned ideas in mind the author assembled some of the assumptions made by coaches in the past. It is contended that through the course of this study the status of these assumptions will be determined. The evidence presented will either prove them to be correct, incorrect, or show them to be debatable issues. Some points may remain unsettled due to the lack of evidence of any nature.

The following assumptions are a few of those which have been made in the past by athletic coaches:
(1) That no special attention need be given to conditioning, since the daily practice routine will take care of it.

(2) That no water should be consumed during athletic participation.

(3) That supplementary feeding of vitamins is of no benefit to the athlete.

(4) That athletes should not drink coffee during the training season.

(5) That as long as a sufficient number of calories are eaten the type of diet which furnished them is of no significance.

(6) That the athlete should not exercise, even lightly, immediately after eating.

(7) That if a boy is in condition for football, he should be in condition for basketball competition at the close of the football season.

(8) That muscle soreness in early training is of little significance except to show that the program is getting results.

(9) That sports competition causes enlargement of the heart.

(10) That athletes are born, not made.

(11) That diet is of minor importance in the training of an athlete.

(12) That alcohol and tobacco have no place in the training menu.
(16) That "second wind" is just an imaginary phenomena.

(14) That the feeding of supplementary foods having a high sugar content is of no benefit, before or during athletic events.

(15) That gelatin is of no use in the training diet, either before or during competition.

(16) That the pre-practice or pre-game warm-up has no physiological benefits.

(17) That staleness is an unavoidable phenomena that may develop during the conditioning period of a highly competitive and long sport season, which is of little significance.

(18) That the pulse rate becomes gradually lower during the period of athletic conditioning and participation.

(19) That there is no danger of working athletes too strenuously in the early part of the conditioning period.

(20) That breathing through the mouth should not be tolerated during athletic participation.

(21) That athletic training brings about an increase in size of those muscles specifically used in the activity.

(22) That a coach can check on the relative condition of his men by noting the length of time it takes them to recover from any certain activity.
With this introduction to the subject to be discussed, it is hoped that the reader now has a clear picture of the reasons for making the study, how it was done, and what was expected to be accomplished.

In chapter two, a detailed discussion of the contributions of training to the physiological development of the athlete has been presented.
BIBLIOGRAPHY - Chapter I


CHAPTER II

THE CONTRIBUTIONS OF TRAINING TO THE PHYSIOLOGICAL DEVELOPMENT OF THE ATHLETE.

It is the general opinion of all those, who have a knowledge of athletic performance, that practice makes participation in the sport easier. Also, it is recognized that as one takes part in any given activity, a greater frequency of participation gradually makes it possible for the athlete to carry on a prolonged and sustained effort before reaching a state of fatigue. This period of practice and exercise has commonly been called training.

Athletic training has progressed through a period of improvement since the days of the early coach, who was a professional athlete in retirement, with no knowledge of the reasons for training except that he had been trained that way. He had a knowledge of skills and techniques in his particular specialty and a book full of "don'ts" by which his proteges were to train.

There is very little known about the physiological reasons for training among the laity or coaches, in many instances.

In this chapter, the author hopes to relate enough research in the field of training to make it possible for those of the coaching profession to set up their training program on a scientific basis, if they are interested in doing so.
According to Schneider, training is a progressive phenomena. First in training comes the learning of movements, the acquiring of skill. Next in order comes the effort to strengthen muscles, and a third requirement of training is endurance. (33)

Then, those in the coaching profession, who feel that athletes are born not made, may get some satisfaction from Hill's statement that to a great extent, the skill and grace associated with athletic prowess is natural and inborn. However, it can be produced by training and breeding. (21)

Some coaches, known by the author, aired the opinion that a study of this sort could not be of value to coaches for training athletes in all the major sports. That is, they felt that a separate training program would be necessary for each sport. The author's intention is not to set up a definite training program for any specific sport. Rather, he wishes to reveal the physiological facts which have been disclosed regarding the subject; thus, making it possible for the coach to set up his training program for any certain sport in such a manner that he will promote the desired development in the athlete. The author's attitude receives support from Gould and Dye, who state that training influences, particularly, the immediate systems and structures employed in the activity and thus becomes more or less specific for that particular act, but training in one form of activity may influence, beneficially, other
forms of activity as well. Training affects the mechanisms of circulation and respiration which are involved in common for all types of activities. (16)

EFFECTS OF TRAINING ON MUSCLES

Size

People have always thought that the way to develop larger muscles was by exercising them. Physiologists are not completely agreed on that point, but Dawson cites some work done on this matter which shows why there is probably some uncertainty. It is known that, in general, training results in muscle growth. If, however, we look into this matter carefully, we find it necessary to distinguish between exercise which requires a great expenditure of energy in a short time and those in which endurance is required. The first leads to hypertrophy, while on the other hand endurance exercise usually does not cause muscle hypertrophy. It may even cause a slight decrease in total muscle mass. And yet the absolute power of the muscle rises enormously. (10)

Bainbridge supports Dawson's hypothesis when he states that whether or not the actual size of the muscle is increased by training (about which there is some question) is apparently a function not only of duration and intensity of repetitive effort but also of the character of the work done. He gives some sound support to the idea of the athlete having variety in his training program to promote
complete physical development. That is, if all the skeletal muscles are to participate in the end result, particularly, as to the increase in mass. For this reason, well trained oarsmen, for example are given cross-country running and other types of exercise in addition to rowing. (2)

Schneider states that regular and heavy muscular work tends to thicken and toughen the sarcolemma of the muscle fiber and to increase the amount of connective tissue within the muscle. The employment of the muscle causes an increase in its size. (33)

**Strength**

There have been differences of opinion among coaches regarding the reasons for increase in strength of the athlete's muscles, when in training. It has long been agreed by physiologists that muscle fibers contract completely upon stimulation and that increase in strength comes from more fibers being stimulated. This is better known as the "all or none" theory of muscle contraction, which means that when a muscle fiber is stimulated it contracts with its greatest possible strength or it doesn't contract at all. Gould and Dye express their beliefs in regard to this, by saying, that as one trains, more and more muscle fibers, formerly unused, are drawn into the response. The maximal number of fibers which can be called into action simultaneously is increased. It seems highly probable that the main increase in muscle power brought
about by training is due to the development of these "latent" fibers rather than to the further development of fibers which have been used day after day in the ordinary activities of life. The power and rapidity of the response, that is, the gradation of the response is determined by the number of muscle fibers responding to any given stimulus, the contraction of each individual fiber being at all times maximal for the conditions. (16)

According to Schneider, the gain in power is out of all proportion to the gain in size. Such an increase in power suggests that training improves the quality of contraction. (35)

Bainbridge believes there is a limit to the individual's capacity for muscular work. This will be reached, either, if the force and rate with which the muscles are contracting reaches its maximum, although their supply of oxygen provided by the respiratory and vascular systems, becomes insufficient for the demands of the skeletal muscles, the heart, or the brain. The available evidence reveals that this limit is imposed by the supply of oxygen to the muscles and brain rather than by the functional capacity of the skeletal muscles. (2)

**Chemical Conditions**

According to Whipple, the color of muscle is due to the amount of hemoglobin present. Furthermore, the amount of hemoglobin in the muscle depends upon exercise and its presence determines largely the latent power of the muscle. (38)
Schneider states that the color of the trained muscle is darker than that of the untrained and invariably contains a greater content of glycogen; this indicates a more favorable condition for obtaining oxygen. (33)

Gould and Dye state that since glycogen is the immediate source of muscle energy, trained muscles should have a greater energy capacity. (16) According to Embden and Habs this condition of the muscles is relatively stable, since the high glycogen content of trained muscles does not return to normal for two weeks or more after the cessation of the training. (16*) Eckert and Makabayashi have further shown that the total glycogen stored in the body is increased through training. On the other hand, the glycogen content of the liver and in fact the total organism is exhausted earlier in an untrained than in a trained individual. Under normal conditions, as the muscle glycogen is consumed its loss is made good from the blood glucose in the liver and the transfer of the latter to the blood (glycogenic function of the liver). Not only is the immediate store of potential energy of the muscles increased through training, but the total store of glycogen in the entire organism is thereby increased. (16*)

In trained muscles there is an increase in the rate at which lactic acid is oxidized. This is due in part to an increased capacity of the oxygen intake, but probably in part also to an increased capacity of the muscles to oxidize lactic acid or glucose. (16)
Schneider reminds us of the fact that for a long time it was believed that mental activity had an extraordinary influence on phosphorous metabolism. Hence, foods rich in phosphorous were recommended to "brain workers" as a special aid in the development of mental power. (33) Today, the claim is made that the ingestion of phosphorous in trained men permits a greater output of muscular power. There are reasons for believing that phosphates play a part in the metabolism of sugars in the body. Embden has shown that "phosphated sugar" is the immediate precursor of the lactic acid which appears in muscle. It is clear, therefore, that a shortage of phosphates in the blood would seriously handicap the muscles in their recharging process. (33#)

Havard and Reay found that after a given exertion the phosphates of the blood in the trained man do not fall as low as in the untrained. It is suggested that during the progressively increasing activity of a muscle, brought about by training, a larger amount of the "phosphated sugar" is laid down in the muscle. A well trained muscle very likely already contains a maximum amount of these substances and, therefore, manufactures less than the untrained in the recovery or recharging process. (17)

**Efficiency**

As stated by Schneider, the work accomplished by maximal effort of a muscle or group of muscles varies inversely
with the speed of contraction, being greatest at low speeds and less at higher ones. The maximal net efficiency is attained at some intermediate speed. (33) Training probably shows its effects by increasing the rate at which the greatest efficiency can be maintained.

McNelly found that training had no effect upon the mechanical efficiency of the muscles in any of his subjects. (30) Other factors contributing to efficiency will be discussed later in this chapter under the topics, Recovery Period, Respiratory Quotient, and Efficiency.

**Coordination**

Coaches have been well acquainted with the fact that every potential athlete just cannot make the grade as a varsity competitor, no matter how persistent and conscientious they may be in their desire to make the team. They are agreed that there are some who have the "knack" or are spoken of as a "natural", while others are not blessed with this inborn ability to coordinate their actions. Bainbridge acknowledged this fact in stating that while training improves muscular coordination there is no doubt that certain intrinsic properties of the nervous system are necessary for the development of the athlete. (2)

Schneider reiterates that training teaches the best combination of muscles. We learn to do away with superfluous muscle contractions, thereby increasing precision and endurance. (33)
Training further conditions a better coordination between antagonistic muscles, such as the extensors and flexors of the limbs. Muscles are normally in a state of tonus, which tends to oppose their extension. When the flexors contract, the extensors must give or undergo a diminution of tonus and vice versa. Normally, the antagonistic muscle is inhibited as its partner contracts. Since this power of coordination does not reside in the muscular, but in the central nervous system, a reciprocal innervation of the opposing muscles in any particular instance is required. Through training, more efficient timing and adjustment is effected so that, when one muscle contracts, its antagonistic offers a minimum of resistance to its most perfect response. (16)

Reaction Time

In the field of athletics, probably, the two things that have the most to do with determining whether an athlete will be a mediocre performer or a "star" are the degree of finesse in coordination which he can develop and his ability to react to the situation properly and precisely.

In many sports, "reaction time" is the deciding factor in determining an athlete's success and adaptability to a sport. Gould and Dye give a very good discussion on "reaction time". According to them, it is from the time of willing to produce a response or from the application of the stimulus in the case of reflex responses,
an appreciable interval is required for the proper neuromuscular coordinations before the response begins. This may be termed the "reaction time". A portion of this interval is required for the transmission of the nerve impulse over the nerve fibers which constitute the structural connections between the point of origin of the response and its termination in the muscle fibers. A relatively greater part of this time is taken for conduction through the nerve centers, synapses. When psychic processes are involved, an additional interval may be required, especially, if there is some uncertainty as to the exact response which is required, dilemma. These processes may be appreciably shortened through training.

The total reaction time varies considerably among individuals from time to time in the same individual and for different responses. It may be shortened within limits through training or by increasing the strength of the stimulus. This is possible because of more efficient coordinations of the neuromuscular mechanisms and the gradual elimination of spurious and unnecessary muscle contractions, that is to say, the responses become more exact and less clumsy. The physical neuromuscular make-up of an individual is probably a limiting factor which militates against super-performance. (16)

Soreness

At the beginning of any sport season, the coach expects a certain amount of soreness among his squad members.
This is due to the collection of waste products within the muscle before the circulatory system becomes adjusted to the requirements of the renewed activity. Also, when athletes change from one sport to another, a certain amount of soreness is expected because of the use of another set of muscles. It is because of this feature, that the wise coach doesn't overwork his men in the early sessions of the training period. Then, another kind of stiffness or soreness sometimes appears due to overexertion or injury to the muscles.

McCurdys and Larson explain this occurrence very fully by stating that muscular soreness or lameness is of two kinds: first, general soreness due to the presence of diffusible waste products; second, soreness due to ruptures within the muscle fiber or the fibrous covering and attachments of the muscle to the bones. The pain due to accumulation of waste products in the muscle is most severe during work. About one half hour after the exercise, the muscle is lame and sore to touch. The second kind of soreness is not noticed during the exercise nor for several hours after the exercise. This lameness gradually passes away in three to four days. (29)

The first kind of soreness is aided by work which through alternate contractions forces the waste products out of the area and allows fresh blood to enter with needed nutriment. The second kind needs rest with heat, and only enough contractions to prevent adhesions between the sore
muscle fibers. These contractions avoid tearing the adhesions and are more apt to stretch them without as severe pain. (29a)

In the army reconditioning program, it was found that even light exercise as soon as possible after muscle injury aided greatly in speeding up recovery and maintenance of the former state of condition.

Good body mechanics may aid in avoiding strain and soreness. Such as the sprinter holding his breath in starting, thus fixing the muscles of the trunk. (29) There is a proper position for each part of the body and definite degree of muscle tension necessary for the most efficient performance of each activity. It is through repetition of the act that this is developed. Thus, reducing the number of superfluous muscle contractions and, in turn, decreasing the amount of muscle strain and soreness.

Relaxation

Probably one of the most common expressions used by coaches in addressing an individual athlete or the entire team is "relax", keep yourself loose. This has good physiological basis since it is known that muscles held in a state of contraction or rigidity fatigue more easily and prevent the smooth, coordinated reactions which are so necessary to a good athletic performance.

The almost synonymous relationship of relaxation and coordination is revealed upon close analysis of the two terms. Therefore, it is necessary to refer to the explana-
tion of coordination given by Gould and Dye, previously in this chapter, as evidence of this fact. According to those authors, normally the antagonistic muscle is inhibited as its partner contracts. By continued repetition of specific actions, muscles contract with a minimum of antagonistic resistance to its most perfect response. (16)

These inhibited antagonistic muscles are, possibly, in a state of relaxation. When the coach speaks of relaxation, he is attempting to get his boys to slacken those muscles which are unnecessary in the activity and inhibit the normal effectiveness of the neuromuscular coordination developed through training.

The inexperienced athlete, many times, "tightens up", by calling upon extra muscular contractions when he feels the need for greater performance under the pressure of the game situation. This, of course, acts in reverse to his desire causing him to give a comparatively poor performance.

Schneider gives support to this fact in stating that relaxation involves also a light, flexible posture which shifts with the movement and uses the momentum of the moving mass rather than heavy rigidity, whenever possible. (33)

THE INFLUENCE OF TRAINING ON THE CIRCULATORY-RESPIRATORY MECHANISM.

Influence on Pulmonary Ventilation

Gould and Dye point out that pulmonary ventilation is probably never the limiting factor in supplying oxygen to the tissues. Notwithstanding this fact, there are apparently certain respiratory adjustments brought about
through training which diminish the strain placed upon the external respiratory mechanism, with an associated diminution in the subjective symptoms of respiratory distress. Trained individuals have a greater capacity for delivering oxygen to the tissues as a result of both improved respiratory and circulatory adjustment. Evidence has also been presented in support of the fact that the respiratory rate is diminished and the vital capacity increased through training. (16)

Gemmill and Booth et al found that training also diminishes the total lung ventilation during the exercises for which the individual is trained and quickens the return to normal at the cessation of the activity. (14)

According to Schneider, systematic physical exercise will increase the vital capacity of children and young people approaching maturity. (Vital capacity of the lungs is measured by the largest quantity of air which a person can expel from his lungs by a forcible expiration after the deepest possible inspiration). (33)

There is reason to believe that vital capacity of the lungs is not increased after the athlete reaches maturity, but only a more efficient and complete use of the lungs takes place with training. Gordon, Levine, and Wilmaers found that the vital capacity, as based on surface area of the body and height, was normal, which indicated that prolonged vigorous training did not increase the breathing space of the lungs, in their study of men who participated in the 1924 Boston Marathon run. (15)
It is evident that the efficiency of breathing can be greatly increased by athletic training. This improvement depends not solely or largely on an increase in vital capacity, but on the mechanical ability to increase lung ventilation. It seems that the untrained man is unable to use the maximum ventilation capacity of his lungs. (33)

Schneider and Ring showed by the analysis of the exhaled air of two men during training that they absorbed a greater proportion of the oxygen from the air and also exhaled a greater percent of carbon dioxide. The results of the tests also exhibited the fact that even the first week of moderate physical training increases the load carrying ability, but that from five to seven weeks of training is required to bring about the full effect. It is a well known fact that the trained man breathes much less air for the same accomplishment than does the untrained subject. (35)

The first limiting factor in man's ability to perform work is the maximal amount of oxygen that an individual may take in per minute. Another such factor is the maximal ability of the respiratory mechanisms to augment their activity to meet the demands of the body for obtaining oxygen and ridding itself of carbon dioxide. (3)

The breathing during and following exercise increases and diminishes in accordance with the changes in the acid-base balance of the blood which results from the acid produced in the active muscles. Since it costs the body
approximately 5.5 cc. of oxygen to remove a liter of air into and out of the lungs, it may be assumed that slow deep breathing is the most efficient type of respiration. Unquestionably the deep breath gives the more adequate pulmonary ventilation. (33)

Pembrey states that the man who resists the inclination to breathe through the mouth during active exercise throws on additional and unnecessary amount of work upon his respiratory muscles and thereby increases his discomfort and distress. (33*)

**Blood Changes**

**Red Corpuscles**

There has been much discussion and disagreement among physiologists as to just where the increased number of red corpuscles come from during exercise or a period of training. But they do support the fact that there is an actual increase in red cells during training.

Many feel that the spleen is the storehouse of red corpuscles, while others disprove this theory. Dill, Talbot, and Edwards noted a four percent increase in red cells in two men with spleens removed. (13)

In 1915 Schneider and Havens presented a set of observations to indicate that the increase in red corpuscles caused by exercise was due to the presence of a reserve supply located in the abdomen within the splanchnic circulation. (34)
Karpovich states that when intensive physical exercises are performed day after day for a considerable length of time, there is the possibility of an absolute increase in the number of red blood corpuscles. The blood manufacturing tissue located in the red bone marrow is stimulated to greater activity and the total number of the corpuscles increases. (25) This has long been one of the accepted theories as to the source of red cells during the training period.

There is no agreement, according to Steinhaus, as to whether a period of training produces a lasting change in the number of red corpuscles. The current belief that training induces a gradual increase in the percent of hemoglobin, the total mass of corpuscles, and the total volume of blood, rests on meagre experimental data. (36)

The daily rate of destruction of the corpuscles in the blood is not definitely known. An estimate of Abderhalden gives a daily destruction of 450,000,000,000 red corpuscles, or roughly one sixtieth of the red corpuscles in the body. Therefore, it would take two months to replace all the red corpuscles in the body. This time coincides roughly with the time taken in training men for speed work. (23x)

Hawk found the normal blood of athletes contained 5,500,000 red corpuscles and 8,800 leukocytes per c.m.m., which is, of course, above normal; for the ordinary individual's blood contains 5,000,000 red cells and from 5,000 to 7,000 white cells per c.m.m.. (29)
Schneider relates that while our picture of the changes in red corpuscles and hemoglobin of the blood during physical exercise is far from complete, it is nevertheless clear that during short periods of work an adaptive rise in percentage of these gives a condition favorable to a more adequate delivery of oxygen to the tissues. It is also clear that in the sedentary individual prolonged strenuous muscular effort results in an excessive destruction of red corpuscles and that the loss cannot be made good. Consequently, some degree of anemia results for a period of from several days to two or three weeks.

It is furthermore clear that regular exercise, or a period of training, so develops the red marrow of the bones that any ordinary destruction of corpuscles is quickly made good during, or soon after, exercise and that the total mass of red corpuscles is permanently increased. (33)

**Blood Sugar**

Numerous experiments have been made on the blood sugar content during exercise. Moderate work doesn't change the level of blood sugar, but, if exhaustive work is carried out, the blood sugar may fall to very low levels. (27) Numerous speculations have been offered to explain these results. It may be that during moderate work increased glycogen in the muscles and thus the glucose content of the blood remains constant. During more severe work secretion of adrenalin may cause a more rapid liberation of glucose by the liver than is required by the muscles and,
therefore, the blood sugar rises. However, if the exercise is extended over a long period of time, the supply of carbohydrate in the liver is exhausted and the blood sugar falls. (3)

**Acid-Base Balance**

According to Bock, Vancaulaert et al., blood lactic acid and carbon dioxide are quantitative indices of efficiency upon which physiological training produces a profound effect. During the process of training for any particular activity, the amounts of carbonic acid entering the blood diminish progressively with successive repetitions until training is complete. The oxygen requirements of trained individuals are so adequately met that in relatively severe forms of activity the resynthesis of lactic acid to glycogen keeps pace with its production. (7)

The carbon dioxide carrying capacity of the blood is diminished by the entrance of lactic acid into the blood since this diminishes the alkaline reserve. (16) With this, there will be a greater accumulation of acid metabolites within the tissues and, hence, a more rapid fatiguing of the muscles and a more drastic stimulation of the respiratory center. From the facts, it would also follow that the fall in pH would be considerably greater and appear earlier in the untrained than in the trained individual. Bock, Vancaulaert et al. found this to be the case. (7) Training increases the capacity of an individual to maintain a normal pH of the blood and in turn to maintain that of the tissues also. (16)
Schneider relates that since the bicarbonate of the blood constitutes its alkaline reserve and, therefore determines its capacity to buffer the lactic acid formed during exercise, it follows that the less there is of this reserve the sooner will fatigue result with a given exercise. It is believed, therefore, that physical training actually increases the alkaline reserve. (33)

Karpovich states that so much is heard at present (1935) about the alkalinity and acidity of the blood. Many diseases, including the common cold, are blamed on the "acid condition" of the blood. First of all, let us bear in mind that the blood is never acid unless the person is dead. Human blood is always slightly alkaline. The purpose of this alkalinity is to neutralize the acids produced during body activity. When the acid content of the blood increases, it will cause a shift toward acidity. It is obvious that a higher degree of alkalinity will neutralize a greater amount of acids; postpone the fatigue and increase endurance. (25)

**Steady State**

The "steady state" is generally recognized as that level of muscular activity at which a person can maintain the work without building up an oxygen debt. Bock, Vancaulaert et al. relates that during continuous muscular exercise a "steady state" is reached when the demand for oxygen is adequately met. Such a steady state implies
a relatively constant total ventilation, elimination only of carbon dioxide produced in metabolism, steady pulse and respiratory rates and a constant internal environment. These conditions may be associated with an oxygen debt provided it is not cumulative but is chiefly acquired in the period from the beginning of work until the steady state is reached. (7)

Crest Load

The coach is really trying to condition his athletes so that they can maintain this "steady state" at the highest possible level, which is known as the "crest load". Briggs states that the "crest load" is when the intake of oxygen is still equal to the demand, but when the oxygen supplying mechanisms (the breathing, the circulation, and the unloading of oxygen) are all working at capacity. Therefore, these mechanisms are unable to increase further the delivery of oxygen to the tissues. The "crest load" really becomes a measure of stamina. The higher the "crest load" the greater the stamina. (8)

Schneider concludes that the "crest load" is increased by physical training and is decreased by disease. It is increased by moderate daily exercise and again decreased by the neglect of physical exercise. He cites the case of a young man who spent an hour a day for two months playing tennis or handball the "crest load", which was 3000 ft. lb. as determined on a bicycle ergometer prior to beginning training, advanced to 7000 ft.-lb. during the first week
of training, then more slowly to 8000 ft.-lb. by the end
of the fifth week, and finally to 9000 ft.-lb. at the end
of the seventh week. Then, because of a Thanksgiving Day
recess with complete neglect of exercise for four days and
less regular indulgence in exercise thereafter, the "crest
load" dropped back to 8000 ft.-lb. (33)

Oxygen Debt

It has been a long established fact that the individual
develops an "oxygen debt" from the beginning of exercise
until the "steady state" is reached. Then any requirement
over that of the "crest load" is added to this debt until
exercise ceases. This is then made up during the recovery
period.

Best and Taylor give a very good discussion on this
topic in stating that when an individual indulges in
moderate or strenuous exercise, the amount of oxygen taken
into the body during the exercise is never sufficient to
meet the requirement. It may be said that during exercise
the body goes into debt for oxygen, and that this debt is
repaid during the recovery period which follows the exer-
cise. The amount of debt varies with the physical condi-
tion of the individual, with his state of training for
the particular exercise, and with the intensity and extent
of the exercise taken. (6)

Many define "Oxygen Debt" as the amount of oxygen
used during the recovery period over that which would
normally be consumed for that period of time.
Recovery Period

The recovery period is generally accepted as that period of time from the instant that exercise ceases until the person has returned to normalcy. The respiratory rate, heart rate, oxygen intake, carbon dioxide expulsion and lactic acid resynthesisization have subsided to pre-exercise figures.

Man can continue to increase the intensity of work which demands more energy than can be supplied by his maximum oxygen intake during work. This is done by increasing the recovery period. The relationship between the duration and velocity of work can be explained on this basis. For short distances, the runner may depend mainly on his recovery period; for long distances, he must run in a steady state and the metabolism cycle must be completed during the exercise. For moderate distances, the runner may depend on both factors. (3)

The body or some group of muscles of the body can, during a period of a few seconds, exert the maximum power by the use of stored energy without calling upon the oxygen-supplying mechanisms. As for example the one hundred yard dash. (33)

McNelly found that in trained subjects, recovery as measured by the oxygen consumption occurs more rapidly than in the untrained. (30)

Respiratory Quotient

With the rise in oxygen consumption there is a corre-
sponding increase in the carbon dioxide output. The change in the relation between these two variables, the respiratory quotient, has been studied extensively during muscular work. At the present time, it is thought that moderate exercise does not change this quotient from the basal level. In the case of strenuous exercise, however, there is considerable disagreement among the investigators of this subject. (3)

Schneider and King stated that the conspicuous feature of all their data is the fact that the respiratory quotient was decreased by training. The decrease in the respiratory quotient indicates that one or the other, or both, of two things, happened as the result of training. Either the reconversion of lactic acid into the precursor, glycogen, was more adequate during work; or the muscles were better buffered so that less lactic acid escaped from them during the period of training than when they were out of training. (35)

McNelly found the mean respiratory quotients in all periods of rest, work, and recovery of all individuals in training are lower than those of men not in training. (30)

Bock, Vancaulart et al. in analyzing their experimental data and taking into consideration the nature of the organism as a whole, adhere to the following hypothesis with reference to the significance of the respiratory quotient as a means of interpreting the process of catabolism. The primary source of energy for muscular contrac-
tion in early stages of work is carbohydrate, as many others believe. In the average man during moderate work glycogen is utilized, but at the same time the velocity of reactions involving synthesis from fat or other processes by which other sources of energy may be utilized nearly keep pace with the rate of glycogen utilization. The resultant respiratory quotient will rise only slightly above the resting level. Given more severe work to do, muscles utilize stored glycogen, the utilization of which may be considered to occur with a velocity of the first order, and the resultant quotient approached unity. Time relations are now such that the conversion of fat at a velocity, let us say of the second order, has no appreciable effect upon the respiratory quotient. The quotient will continue to remain high until the store of glycogen is considerably lowered. That depletion of readily available glycogen results in speeding up the reaction of changing fat into glycogen, or whatever other processes lead to the utilization of other substances, seems likely. The quotient will then reflect this reaction. (7)

Thus, as long as available carbohydrate is being used, the respiratory quotient remains high or near unity. But as its supply is diminished and fat has to become the source from which glycogen is made, the quotient drops.

**Heart**

**Size**

There has been much controversy over the effects of
strenuous or violent exercise on the heart. Many believe it causes enlargement or dilation of the heart, while others have proven that if the heart is sound in the beginning it does not materially increase in size.

According to Bard, a strain is thrown on the heart when the work it has to perform is increased, whether this result from an inadequate valvular action or from an increased peripheral resistance. The strain may also result from disease of the heart which weakens the force of the muscular pump, and renders it inadequate to accomplish readily a normal amount of work. When compensatory mechanisms allow such strain to be met without cardiac failure, though with the loss of some reserve power, the condition is said to be compensated. Compensation is achieved through two normal mechanisms, dilatation and hypertrophy. The dilated heart is one whose size is increased out of proportion to the work performed, and which is utilizing, even under basal conditions, some of its reserve force. This dilatation is attained through a raised venous pressure. The hypertrophied heart is one whose size is large, but in which the increase in size is not out of proportion of the work performed. The increase in size here depends on increased muscular tissue. Such hearts fall within normal limits in comparison with other normal hearts. The cavities may be large, but the venous pressure is not raised, and the reserve force is not prematurely exhausted. (3)
Many physiologists support the theory that long periods of severe exercise cause dilatation of the weak and diseased heart, and hypertrophy of the normal, sound heart.

Some abnormally large hearts are caused by dilatation following hypertrophy of the heart. (3)

Abrahams, from a detailed review of the effects of violent exercise, discovered by means of teleradiography of the heart that a large number of athletes show no dilation above normal. He found no evidence that arteriosclerosis is a result of constant exercise, or that so-called "overstrain" leads to heart failure. (1)

Bainbridge states that the greater size and power of skeletal muscles, which results from regular physical training, is accompanied by a similar development of the lungs and heart. It is generally recognized that the heart is larger, that is to say, more muscular, in athletes than in sedentary individuals, and that the heart grows in size as the result of all forms of regular exercise. Carefully graduated exercise, in fact, is a recognized method of improving the nutritive condition, and developing the muscular power of the heart. (2)

Herzum made an orthodiagnostic study of the heart of adolescent sportsmen among whom there was a high incidence of sizes above average, which was related to the amount and duration of competitive activity. If the larger than average heart was associated with a high vital
capacity, the boy also had a slower than average pulse rate and low blood pressure, and possessed a capacity above normal for the performance of work. (18)

The Kahn's note that cardiac strain may occur with exertion following acute illness or during anemia, or after fatigue or prolonged grief with insufficient sleep. Even when a person is used to a laborious occupation, an excessive strain, as from lifting especially in an uncomfortable position, may cause heart injury. (24)

Levine and Likoff found that exercise produces systolic murmurs in normal individuals and the intensification of a systolic murmur has no pathological significance. (28)

Stine studied university boys and concluded that the normal heart does not hypertrophy because of college athletics. (37) Keye and Friedell found no significant increase in the heart size of collegiate athletes. (26)

According to the evidence disclosed by these studies it may be concluded that training makes no spectacular changes in the athlete's heart. A strong, sound, heart seems to reveal no ill effects from athletic training and competition. The diseased, or weakened heart is probably susceptible to dilatation when the athlete is participating in a strenuous training program. Therefore, it is imperative that a physical examination, with special attention accorded to the condition of the heart, be given to the
athlete before permitting him to participate in athletic training.

**Pulse Rate and Stroke Volume**

Schneider states that after a period of training the pulse rate during definite exercise will be less rapid than before, and this gives to the heart a reserve power which assures an adequate adaptive response on heavier loads. In the trained subject, the frequency of the heart beat will reach a steady state, while in the untrained subject it will continue to increase throughout the more severe exercises. In strong athletes, the pulse rates are ten to twenty or even thirty beats slower than in men of sedentary habits. It has been concluded that the regular exercise of training brings about a marked increase in the tonus of the vagus center in the brain and that this makes itself evident in the slow pulse of the athlete. (33)

Thus, it seems that proper, well supervised training should be advantageous to the athlete, rather than injurious as is the feeling of so many people.

Sufficient evidence shows the strengthening, if not enlargement, of the heart muscle, a reduction in the pulse rate which means, because of the gain in strength, the heart pumps more blood with each stroke, thus reducing the number of times it needs to beat to supply a given amount of blood to the body. This, therefore, allows for a greater amount of rest for the heart muscle between beats,
which is the only time the heart ever rests. It seems that should be a very important factor in prolonging the life of the heart, barring other complications which might affect it.

Henderson, Haggard, and Dolly have shown that not only is the heart rate of athletes much slower and the stroke volume relatively larger, both during rest and exercise, than in the non-athletic individual, but that, whereas, the non-athletic individual's heart output is nearly doubled in passing from a state of rest to one of exercise, that of the athlete may be tripled under the same conditions. The slowness of the pulse is found to have the advantage of allowing longer diastoles with ample time for the ventricle to relax and fill with blood. (19)

The time required for the pulse rate to return to normal after exercise depends on the amount of work accomplished, the load carried, the physical condition of the worker, and the time with respect to the last meal. In men in good physical condition, the return occurs more rapidly than in fatigued and poorly trained subjects. A slow pulse rate in the reclining and standing positions, with a small difference between the two, are usually regarded as signs of excellent physical condition according to Schneider. (33)

Physiologists have agreed upon the fact that one of the most easily observed signs of physical condition is to
check the time required by the pulse to return to normal after exercise.

Unit Circulation

This includes the pathways of the blood stream from the heart to the most remote tissues and cells of the body. It is also affected by training. Gould and Dye state that the maximum unit circulation possible under conditions of physical exercise is considerably greater in the trained subject; an athlete not only has a relatively more abundant supply to his resting tissues, but also a far greater reserve through which he is able to increase the blood supply during activity. (16)

Schneider relates that training results either in the formation of new capillaries or in the opening up of hitherto unused capillaries. These provide for a more advantageous circulation and, therefore, a better supply of fuel and oxygen and removal of waste substances. (33)

The degree of increase in unit circulation during exercise is determined by the pulse rate and stroke volume. (16)

Efficiency

A discussion of the effects of training on the general efficiency of the body is made here in addition to that which has preceded in discussing muscles and the respiratory quotient.

Any time that there is fuel or energy being transformed into work or exercise, it is being accomplished with
a certain degree of efficiency. We are always interested in the efficiency of a machine because of the cost of running it. Therefore, there is no reason why we shouldn't be interested in knowing the factors that affect the efficiency of an athlete.

In the first place, according to Mcnelly, there is no measurable influence of training upon the mechanical efficiency. (30)

The maximal efficiency obtained in any process depends upon the speed at which this process is carried out. Not only does the speed of work affect the efficiency, but also the amount of work. Only about 20 percent of the energy expended during muscular exercise is converted into kinetic energy, the rest, 80 percent is liberated in the form of heat. (3)

Wallrich and associates summarize other work to show that severe physical labor is more efficient if it is interrupted by short periods of rest. The bicycle study showed in summary: (1) when exercise is heavy, efficiency is increased by spells of rest, (2) when exercise is light, efficiency is decreased by rest, and (3) the neutral point where work is neither light nor heavy varies with the individuals and their training. (38)

Benedict and Cathcart found that the net efficiency averaged around 20 percent for untrained men, 25 percent for most trained men, and from 33 percent to 41 percent for very strong athletes.... Because of the improvement in
the efficiency of the bodily mechanism of the trained man, there is a smaller expenditure of fuel and oxygen than in the untrained man when equal amounts of work are accomplished. In other words, it costs the body of the trained man less to do a particular piece of work. (4)

**Effects of Emotion on Exercise**

It has been generally concluded and a well known fact by many that individuals are capable of performing extraordinary feats of muscular effort during the stimulation of fear, anger, and other emotions. The emotions of the athlete are played upon by his schoolmates the day of a contest, by the coach, before and during the contest, and by the band, crowds, and cheers throughout the progress of the event. Athletes have been known to give almost superhuman performances, especially near the close of a game. There has been much research performed in this phase of physiology and, although there are still some points upon which complete agreement has not been reached, many facts have been established.

Cannon and others secured evidence to support his thesis that the supra renal-sympathetic mechanism serves in the animal organism as an emergency mechanism for the mobilization of every reserve which it has at its command. The following adrenal-sympathetic effects have been shown by him and his coworkers to be associated with emotional excitation: (1) an increase in blood pressure, (2) an
increased rate and force of heart beat, (3) inhibition of the gastro-intestinal tract, (4) concentration of the blood due to an increase in the number of red corpuscles per c.m.m. or circulating blood, (5) a decrease in the coagulation time of the blood, (6) an increased mobilization of the liver glycogen, (7) an increase in blood sugar and at times a glycosuria, (8) a decreased susceptibility of fatigue and, (9) diminished respiratory distress. These effects of emotional stimulation were practically abolished in the absence of the adrenal glands. From this, it is to be concluded that during such emotional stimulations, the adrenal glands are stimulated to pour out greater amounts of adrenin, which is the primary factor in the emergency mechanism of the animal body. (9)

Bainbridge states that under the stress of violent emotion a man can often carry out muscular efforts of which he is normally incapable, and this not only involves greater muscular activity, but also places a greater strain on the circulatory and respiratory systems. (2)

It is due to this very fact that competitive athletics for the Junior High and High School boy have been frowned upon by many in the fields of Physiology, Medicine, and Physical Education. The growing youth, who is usually very sensitive emotionally to the stimuli about him, may, under the stress and strain, during the heat of the game, over exert himself. If he uses up his reserve supplies and capacities, he may go until in a state of exhaustion, without realizing that he is even tired.
The Kahn's give support to this theory in stating that young growing boys should be prevented from participating in excessive athletics. More mature youths should be examined as to cardiac strength before they are permitted to join athletic teams and then should be examined frequently following athletic contests to note how well the circulation is withstanding the strain. (24)

**Fatigue**

It is this phenomena which is probably the most obvious result of physical exercise. It is closely related and dependent upon the developments which have been discussed before in this chapter. The purpose of training is to offset or delay the onset of fatigue for as great a length of time as possible in the athlete.

Physiologists also feel that the athlete becomes conditioned to the sensation of fatigue and can carry on even when fatigued, to a certain degree, because of the desire on his part to stay in there for his teammates and school.

McCurdy and Larson relate that fatigue shows itself by the inability to do accustomed work without extra stimulation. In muscles, fatigue is a more or less complete loss of irritability and contractility. This fatigue is caused by the reduction of available contractile material by the presence of fatigue products formed during metabolic activity; their presence may be due to overproduction of waste products or to faulty elimination.
Faulty elimination, in the case of football men, may be due to tight garters at the knee causing cramps which are immediately relieved by removing the constriction. Under ordinary conditions, the presence of the fatigue products give warning before this happens; but men under great excitement, or the stimulus of a strong purpose coupled with a strong will, may apparently remove or obliterate the metabolic danger signal so that more or less complete exhaustion may occur. (29)

Dill states that fatigue appears to depend on the rates of the work done to the capacity for work. In maximal work a temporary steady state may be attained, but a breakdown eventually occurs for which any one of several functions may be responsible. The most intensive work is chiefly anaerobic and here no steady state is reached. Fatigue increases with the rapid depletion of energy reserves and the accumulation of unoxidized end-products. (11)

Recovery Process

Gould and Dye conclude that local recovery in muscles is normally a rapid process, but under those forms of activity which are associated with the diffusion of large quantities of lactic acid into the blood, recovery may require ninety minutes or more for its completion. In the light of these facts, and since the critical level of oxygen consumption at which lactic acid enters the blood
stream is increased through training, it would logically follow that recovery would be more prompt in trained individuals.

It would seem only logical that recovery from a given task is effected more quickly by a trained individual than in an untrained one, since (1) his oxygen debt would be considerably less, (2) his oxygen intake greater, and (3) the lactic acid which has diffused into the blood and other tissues considerably less. (16)

Thus it seems that recovery depends on the amount of work that has been done and the state of training the individual has reached.

THE PHYSIOLOGY OF THE WARM-UP

There has been much difference of opinion among coaches and even individual athletes as to the amount of warm-up that is necessary before athletic participation in order to receive the most efficient performance.

Probably this is due to individual difference in the physiological make up of the athlete. Thus, each one does not require the same amount of preliminary, light exercise to cause the respiratory-circulatory mechanisms to become adjusted to exercise.

Track coaches have used the warm-up extensively, but coaches in other sports, in many cases, have overlooked the necessity or advantages of it.

Meanwell, formerly basketball coach at the University of Wisconsin, states that the need for the warm-up is as
great for basketball men as for runners. Basketball is essentially a dash event in which the runs are interspersed with sudden stops, turns, and jumps. The possibility of muscle and tendon strain and especially foot strain is certainly great if the preliminary warm-up is neglected. (31)

Gould and Dye state that better performance through warm-up is accomplished by exercise at a non-fatiguing level just prior to the event in which the athlete is to participate. The influence which this brief activity may exert on the efficiency and performance of the muscles and body as a whole, and which have been alluded to previously, may be summarized at this point as follows:

1. To get the benefit of the treppe effect. When athletes begin their events their muscles are, therefore, contracting more powerfully than they would have been without warming up.

2. To remove the effects of possible contracture which may arise early in the activity period.

3. To increase the body temperature and, therefore, approach as nearly as possible the most favorable temperature for muscular activity.

4. To increase the body heat and thereby improve muscle tonus.

5. To increase the body heat and thereby shorten the length of the relaxation period and, hence, more evenly balance the duration of the phases on contraction and
relaxation. This may, in some cases, prevent the tearing and "pulling" of muscles.

6. To improve the general circulation of the blood by certain cardio-respiratory adjustments which have been discussed earlier. (16)

Hill believes that an occasional sprinter may "pull" or tear a muscle because he can run faster than his muscles are able to endure. Such individuals, he states, have a very small "factor of safety," because the viscosity of their muscles, which in the ordinary person acts as a "brake" or "governor" and keeps his speed within the limits of muscular endurance, is such as to provide little lee-way between safety and danger. Even these individuals may benefit by warming up and decrease their chance of injury. (20)

"SECOND WIND" AND IT'S PHYSIOLOGY

This is a topic about which coaches and athletes have known very little, except that they use the expression to designate a certain time during physical exertion when a feeling of relief seems to follow a period of distress, in the early part of the activity.

Most athletes have experienced the period of breathlessness and uncomfortable feeling in the early part of the game or event. They look forward to getting their "second wind" for they know that upon its appearance they will be able to carry on at, probably, an even faster pace and with possibly no feeling of distress.

Much research has been carried on regarding this phase
of work and exercise, with a great amount of correlation in their findings. Therefore, many studies could be cited, all supporting the same hypothesis.

In general, it has been found that a certain level of exertion must be attained before second wind will be experienced. It seems to follow the pattern of developing the steady state so nearly, that there is some belief that "second wind" is manifested when the "steady state" for the activity is attained. This belief is upheld by Hill, Long, and Lupton. (22)

Gould and Dye state that not only is there respiratory relief, but cardiac relief as well, and furthermore one often feels as if a new supply of energy has been liberated when "second wind" appears. (16)

Schneider lists some of the symptoms that precede "second wind". There may be a look of distress on the face, the head may "swim", the breathing is rapid and comparatively shallow; the pulse is rapid and fluttering or irregular. The person may feel a sense of constriction around the chest, but outstanding among the symptoms is the feeling of breathlessness. (33)

There are several factors which might affect the respiratory center to cause this state of breathlessness as is explained by McCurdy and Larson. The heart may not bring the blood back to the lungs fast enough to be oxygenated, which could be due to inequalities of the heart structure to carry such a load. The blood may be the
cause itself. There may not be enough volume of blood in proportion to the size of the individual, as in the case of fat persons. Then, there may be a lack of red corpuscles or hemoglobin in the corpuscles. They further state that the ordinary cause of breathlessness is the increase of hydrogen-ion concentration of the arterial blood due to chemical changes in the blood resulting from muscular catabolism. (29)

There is also evidence according to Pembrey and Cook, that "second wind" begins at about the same time as the onset of visible perspiration and once established tends to persist throughout the duration of the exercise, even though it becomes severe. (32)

Berner, Garrett, et al. noticed that the sensations of "second wind" appeared earlier and were more definite, the greater the rate of work, and occurred earlier in a warm room than in a cold one, and probably earlier when the subject was more heavily clothed. When the subject was lightly clothed and in a very cold room, no "second wind" was recognizable. (5)

Dawson throws light on the subject from another angle when he concludes that since we know that during exercise the spleen and perhaps other viscera contract, squeezing erythrocytes into the circulatory blood and thus increasing the power of the latter to carry oxygen, it seems not unreasonable to suppose that this may also be a factor
in the production of "second wind". It is conceivable also that a constriction of the spleen might play a role in causing a stick in the left side. For the right side, it might be due to passive congestion of the liver and on either side relatively insufficient blood supply to the diaphragm. But all this is speculation. (10)

Wenckebach believes a congestion of the arteries in muscle before the peripheral blood vessels open can bring on slight pain and other conditions of oppression. As the peripheral vessels open, the relief of "second wind" comes.(38x)

There is a general concensus of opinion among those who have studied this problem that training causes a more gradual development of "second wind". It comes earlier and with less discomfort in the trained than in the untrained.

In summary, we can say that "second wind" is apparently an adjustment of all the coordinating mechanisms in the heart, lungs, muscles, metabolism, elimination, and nervous system. The working muscles need oxygen, failure of any one of these coordinating factors causes breathlessness, Complete adjustment is found in the trained athlete. (29)

**SUMMARY**

The author wishes to summarize this chapter with the generalizations of two leading physiologists, in the field of muscular exercise, about the overall effects of athletic training on the athlete, or anyone that may take part in such a program.
Schneider states that it is a matter of general experience that practice makes the performance of work easier. Training makes possible prolonged and sustained effort by athletes. It is also common experience to find that a man in poor physical condition is easily exhausted by mental and physical exertion; he is irritable, likely to have morbid thoughts, petty ailments, and a low morale; he may have a sallow complexion and dull eyes; and he frequently complains of constipation, headache, nervousness, and insomnia. On the other hand, it is equally common to observe in a man of good physical condition evidences of mental and bodily vigor, such as alertness, cheerfulness, high morale, bright eyes, elastic step, healthy complexion, and capacity for arduous mental and physical work. It is believed that these two conditions are but the outward expression of physiologic differences within the body. (33)

According to Bainbridge, training leads to increased economy of effort, and the trained man is better equipped at almost every point to perform muscular work than is the untrained man. By developing his skeletal muscles, his heart, and his lungs, training extends very greatly the range of the exertions of which a man is capable; and, by bringing about better coordination of his movements, it enables a man to take moderate exercise with a minimum expenditure of energy and with scarcely any sense of effort. Nor are the advantages conferred by training purely
physical, since the sense of strength and well being which
it usually engenders colours and reacts upon the individual's
outlook and actions as a whole. (2)
BIBLIOGRAPHY - Chapter II

Note: * denotes secondary source has been cited, since the primary source was not available to the author.


CHAPTER III

DIET AND ATHLETIC TRAINING

In so many instances, it seems, coaches have stressed the development of skill and endurance in athletic training without much attention being paid to the diet of the athlete.

This may be due, in part, to the failure of many coaches to realize the importance of a balanced diet of sufficient proportions to furnish the great amount of energy expended by their athletes in fulfilling their training requirements.

On the other hand, in making a survey of the literature on this phase of training, it was revealed that many of the successful coaches have prescribed definite diets for their athletes to follow. These diets have been set up through a knowledge of nutrition, physiology, and experience in training athletes over a period of years.

Physiologists have made several studies in the field of nutrition. They have contributed immensely to the collection of knowledge which makes it possible now for a coach to set up, what may be called, a scientific diet for his squad.

CARBOHYDRATES - FATS - PROTEINS

There has been much discussion and failure of agreement among coaches with regard to just what food stuffs are necessary and which ones should be eliminated from the athletes' diet. Up until the last decade, many coaches
punished an athlete for using sweets, such as candy and pastries, as severely as if he used tobacco or alcohol.

Within the last few years, it has become evident that since carbohydrates are the main source of energy, these forbidden items, which are mainly sugars and starches should be encouraged in their use by athletes.

The main issue at present, regarding diet, is the determination of the proper amounts of carbohydrates, proteins, fats, vitamins, and minerals to include in the athlete's diet to promote the best possible performance.

Cathcart states that the great majority of training systems, both modern and ancient, lay particular stress on protein, and most frequently on meat, as an article of diet. Furthermore, all tend to reduce the intake of carbohydrate. Too often, the content of protein rather than caloric intake is the point thoughtlessly emphasized. (4)

Many experiments have been performed attempting to find the exact uses of the three basic types of food. It has been almost unanimously agreed that carbohydrates are the major and quickest source of energy.

In 1913, Benedict and Cathcart performed an experiment regarding the effects of diet on the respiratory quotient and they concluded that, whatever may be the character of the diet, the energy of muscular work is derived mainly from carbohydrate. They found that so little protein is oxidized during work it can be disregarded. (21a)
Experiments with a Yale crew by Henderson and Haggard support the conclusion that sugar is not the sole fuel for muscular energy, but they do indicate that it is the fuel most immediately available for muscular work and that it is utilized with much less distress to the subject than is fat. The data of the Yale physiologists indicate that at least two-thirds of the energy expended by most athletes is derived from fat. (21*

March and Nurlin disclosed that the subject felt fine on a special high carbohydrate diet, but became sleepy on a high fat diet. On the latter diet the work seemed harder, although the same as before. (14)

Bassett and associates also revealed evidence of sleepiness in their subjects upon the ingestion of 300 g. of meat in their diet. They also discovered that the presence or absence of meat from the diet for periods as long as one week had no effect upon the capacity of doing an amount of work so graded as to reach the limit of the physical capacity during a short period of time. (2)

It is possible that coaches do give too much attention to the meat content of the diet instead of to the carbohydrate content.

Christensen and Hansen disclosed in a study of the combination processes in severe and protracted work that the subject could work two or three times longer on a carbohydrate diet than on a fat rich diet. (8*)

There has been much debate as to whether protein is
used for energy, since it is understood that the main purpose of this food material in the diet is for growth and repair of worn out tissue.

Best and Taylor give a very reasonable and concise explanation of the exact uses of protein in the body. Protein is made up of amino acids. Each amino acid is made up two parts. One of these is composed, like fat and carbohydrate, entirely of carbon, hydrogen, and oxygen, and hence can be burned by the tissues. The other part contains nitrogen; which cannot be burned. Should the whole amino acid be required for building or repair purposes, it may be used in its entirety; but if it is not required for either of these purposes, it is separated into its two parts; the carbon part is turned completely, just as though it were fat or carbohydrate, but the nitrogen remains unconsumed. It is this portion which is excreted in the urine as urea. (3)

McCurdy and Larson apparently do not feel that protein is used at all for energy. According to them, nitrogen secured through the eating of lean meat, eggs, milk, and cheese is an expensive portion of the diet. The use of more than is needed for building and repairing tissue is not only wasteful economically, but places an additional unnecessary burden on the kidneys in eliminating unusable material. (15)

Cathcart, in supporting his theory that protein is an important part of the diet, even though carbohydrate is
the main source of energy, states, let it be granted that
the main supply of energy is drawn from non-nitrogenous
sources, still the substance of the muscle is rich in
nitrogen. The fact remains that if the conditions are
not optimal, there is very soon unmistakable evidence of
excessive wear and tear is definite proof of the delicate
chemical balance which exists in the muscle. (4)

It can be concluded then that all three types of food
substance must be present in the athlete's diet since all
have a function in maintaining his state of training.
Carbohydrates are the immediate and most efficient source
of energy, fat is energy stored and is called upon when
the carbohydrate supply is diminished. Whether it is
changed directly to glycogen or goes through other steps
in the transformation, has not been proven. Protein has
as its main function the maintenance of the body structure
in order that it can perform efficiently. Then, if some
protein is not used, it may be transformed into energy or
given off as urea.

ACID-BASE BALANCE

Although it has been found that the blood remains
remarkably constant during metabolism of foods, whether
they are extremely acid or alkaline (15), many physiolo-
gists feel that an alkaline reserve can be built up by
eating a predominance of alkaline foods. Thus the blood
is able to buffer the acid formed in the muscles for a
greater length of time and delay the onset of fatigue.
Sparks, who attributes his success with swimming teams to diet, feels that keeping the diet basic in order to increase the alkalinity of the blood is just as important as storing energy. He sites the failure of the U. S. Olympic team in 1928 at Amsterdam as an example of a squad over-eating proteins, an acid diet. (23)

Although all evidence on the subject isn't entirely agreeable, it might be well to use a diet for athletes that is on the alkaline side in order to receive the advantages of developing a degree of alkalinity in the blood if it is possible.

**CALORIES**

In speaking of diet, just analyzing the chemical make-up of it, does not answer the question of how much food should be eaten by the athlete.

Of course, it is important to know what should be included in the diet and why, when choosing the amount of food which is necessary to provide the number of calories needed by the body to perform the activity required of it.

Authorities agree that a diet containing 3500 to 5000 calories daily is sufficient for high school and college athletes. This may vary with the individual and with the sport. The greater amount of energy expended requires a greater caloric intake.

According to Morehouse, a well balanced diet should be broken up as follows: carbohydrate - 55 to 70 per cent,
fat - 20 to 30 per cent, and protein, 10 to 15 percent. On the day of the game the fat should be reduced and the carbohydrate increased. The protein should remain constant. (18)

Wishart revealed that under any condition the athlete needs a high calorie diet, regardless of the type of food that is furnishing the calories. (24)

**DIGESTIBILITY OF FOODS**

Authorities have agreed that fats tend to slow up digestion. That is the reason it is suggested that fat be withheld from the diet on the day of the game and especially in the pre-game meal. That is also the reason for omitting fried foods from the pre-game meal, otherwise, fried foods are tasty and add to the variety of the diet which is important. The grease on fried foods, it is thought, tend to slow up the process of digestion.

It has long been felt that one should not exercise, especially, vigorously after eating. This theory has been proven correct by Hellebrandt and Miles in their study of the effects of exercise on gastric acidity. They found that gentle exercise before or after meals aid digestion. Exhaustive exercises with excitement decreases gastric ability. The nearer the meal and the more severe the exercise the slower the digestion. (9) It is for this reason that athletes should not be given a big meal too soon after a vigorous practice or a game.
VITAMINS

It is now known that a diet which is lacking in the various vital substances, which have a hormonal action, called vitamins, will not provide for proper growth and protection of the body.

According to Bard they are a link between the plant and animal kingdoms, since they are produced by plants and needed by animals. (1)

Vitamin "A" has been found to increase vigor and vitality, and to be essential to a feeling of well being. (5) It also aids in growth and strengthens the eyes. Deficiencies have been found to cause "night blindness". (1) This is of particular interest in sports played under the lights. Sherman and Smith consider Vitamin "A" the fat soluble vitamin and believe that it increases resistance to infection. (22) Studies by Keith and associates showed clear evidence that muscular exercise increased the demand for vitamin "A". This vitamin seems involved in the metabolism related to increased voluntary muscular contraction. (12)

Vitamin "A" should be found in foods with yellow pigment, such as, carrots, yellow sweet potatoes, yellow corn, butter, and cod liver oil.

Vitamin "B" at first was considered as one vitamin but later was divided as it seemed to have some very closely related duties. Each appears to be distinct in its nature
and have definite sources. It is now called the vitamin "B" complex.

Originally, it was called the antineuritic vitamin, which stimulates the appetite, and is thought to stimulate glandular secretion and carbohydrate metabolism. Quigley states that in the presence of vitamin "B" deficiency starchy foods are not completely, nor properly oxidized. This means that toxic materials will be formed, which act to hasten the appearance of fatigue. Cowgill reveals that the more food eaten the more vitamin "B" the body needs to insure its complete oxidation and utilization. Furthermore, the vitamin "B" requirement of the body is increased with greater physical activity.

Vitamin B₁ prevents beriberi and also has the antineuritic factor. It can be found in wheat germ, bran, tomatoes, prunes, eggs yolk, kidneys, oysters, yeast and nuts.

Vitamin B₂ is necessary for growth. This particular vitamin appears in spinach, carrots, lettuce, pears, bananas, dried prunes, milk, eggs, liver, beef, and brewers yeast.

Vitamin "C" deficiency causes scurvy and increases susceptibility to infections, and one becomes fatigued more easily. The most common sources are fresh corn, spinach, peas, lemons, oranges, strawberries, apples, milk, and liver.

Vitamin "D" controls the deposition of calcium and
phosphorus in the bones and teeth, and deficiency causes rickets. (1) It is supplied by cod-liver oil, butter, and fat. (17)

Many other vitamins are listed by various authors, but none seem to affect the physiology of athletic training. Numerous studies have been made to find the effects of various vitamins on athletic activities.

Harper and associates studied the effects of supplements of vitamins A, C, and D, in the diets of 69 cadets. The cadets receiving vitamin supplements were less susceptible to minor respiratory and gastro-intestinal complaints than those receiving control tablets containing no vitamins. (7)

Morehouse feels that the lack of any of the vitamins in the diet may give rise to a decrease in physical efficiency long before a readily recognizable disease appears. (18)

Kintaro Yanagi of the Tokyo Imperial University, an authority on nutrition, stated that the main consideration in the diet of the 1928 Japanese Olympic team was in regard to those constituents relating to muscular activity, especially vitamin "B_1". Their chief source of the "B_1" concentrate was a product known as orizman. It was given to the Japanese swimmers before contests and between events. (23

An athlete is no more immune to common degenerative diseases, occurring as the result of prolonged, moderate
deficiencies than is the layman. In fact, vitamin deficiencies develop more quickly in athletes than in more sedentary people. Furthermore, vitamin deficiencies are the cause of many stars becoming a flop from one season to the next. (5)

Therefore, it seems that the most intelligent measure for the coach to take is to supplement his athletes' diet with vitamin tablets as a precautionary measure against the development of any possible deficiency.

Many times the athlete's diet is not sufficiently well balanced, especially in the winter months, to provide all the needed vitamins. In this case the many features which are so important, if the highest degree of physical efficiency is to be attained, may fail to function as was mentioned before. In numerous instances, these factors are the difference between an athlete having a successful season or an unsuccessful one. Therefore, since authorities have agreed that there are no ill effects associated with the ingestion or an oversupply of vitamins the coach has all to gain and nothing to lose by providing vitamins tablets for his squad members. They should consist of those vitamins mentioned earlier in this chapter. This can be done most efficiently under the supervision of the team physician.

SUPPLEMENTAL FEEDING OF SUGAR AND GELATIN

Sugar

This is a subject over which there has been much debate during the past years. According to the evidence
gathered in surveying the literature on the topic, several points are still undecided.

Up to the present time, there has been much evidence provided supporting the theory that supplemental sugar given before and during an athletic event is of benefit to the athlete. It must be understood that this is only of value when participating in such vigorous activity that the athlete depletes his normal supply of carbohydrates.

Christensen and Hansen state that in the presence of hypoglycemia and great fatigue, the capacity for work could be improved by the administering of sugar. (8*)

Gordon and associates observed an improvement in the condition of marathon runners after the administration of sugar. The men finished in much better condition when supplemental sugar was given them before and during the race. (6)

Sparks believes that our athletes should be given quantities of fuel so that it would be possible to store reserve energy in the form of glycogen in the liver and in the muscle tissue. He also proposes a very simple means of doing this. In case any coach may be interested in following his suggestion, it is as follows: add one-half pound of malt sugar or honey to one quart of orange juice. Both are monosaccharides and consequently only have one change to go through in the digestive process before being available as a potential form of energy. There are four
glasses to a quart. Give a glass every hour so the last one will be given at least two hours before the contest. This will add 1200 calories to a normal 300 calorie pre-game meal. He also suggests that it would be well to serve malt sugar and honey freely the day before a contest, on toast and cereals. (23)

Gelatin

There seems to be a great amount of disagreement between the physiologists and the coaches and athletic trainers over the value of gelatin as a supplemental food in the athletes diet. The athletic men support the theory of gelatins worth, while the physiologists tend, in most cases, to discredit its effects.

In 1939, Petry stated that the latest food energizer to come out of the laboratory with a stamp of approval is gelatin. It has been found that this substance has certain properties which feed the muscles. Thus, storing energy which is readily available when needed. Practical research with college athletics have confirmed these tests. (19)

At Cornell University, trainer Frank Kavanaugh conducted a series of experiments on members of crew, basketball, indoor, and outdoor track teams. He found that unflavored gelatin enabled the athletes to take harder training, lose less weight, and to maintain energy over longer periods of time. He also revealed that he could control weight loss with the proper intake of gelatin, and that the substance was an important factor in relieving fatigue. (19*)
In 1939, Ray, Johnson, and Taylor reported that gelatin had a significant influence on the physical capacity of man by allaying muscular fatigue and markedly increasing work output. (20) Their findings were confirmed by Kaczmarek. (10) But since adequate controls were lacking in both investigations, physiologists consider the conclusions reached as unwarranted.

Karpovich and Pestrecov performed experiments on several groups of men in various activities and no difference could be observed between the performance of the group using gelatin and those eating a non-gelatin diet. (11)

The conclusion that may be drawn from these inconsistent results is that the types of subjects used may have caused the variations. The trained men on athletic teams may have been able to take advantage of additional food while the untrained subjects in the physiologists experiments were not able to use this substance to an advantage because of the inability of the physiological processes to adjust and maintain a state of equilibrium over a prolonged period of time. This is only a possibility and is an idea for further experimentation.

Physiologists have agreed that supplemental feeding of any food material is not necessary or advantageous unless the activity which is being performed requires a greater amount of energy than that which is present in the body.

Probably there is very little to be gained from the use of special foods if the athlete is eating a balanced
diet. The most significant results would appear when there is a deficiency in the diet.

**SOME COMMON FALLACIES ABOUT DIET**

Down through the years a certain list of foods have been considered injurious to the best performance of the athlete. When they are analyzed from a physiological or nutritional standpoint they are found to be a necessary part of an athlete's diet.

Due to several articles that have been written by doctors, trainers, physiologists, and coaches, present day coaches have been enlightened about many of the old fallacies. Therefore, it is felt that fads are not so numerous today.

Meanwell made a survey of athletes participating in basketball tournaments, which revealed many fallacies that coaches of that day (1924-25) had regarding diet. It is believed that some of these may still be upheld. The writer thought it might be informative to the reader if some of these fads were not only cited at this time but followed by a few words of explanation as well:

1. That milk "cuts the wind". Meanwell states this is one of the most prevalent misbeliefs in athletics. Milk consists of 87 per cent water. The remaining 13 percent, or roughly about one tablespoonfull to a glass, consists of some of the most easily digested and desirable solid food constituents we possess. He feels, as do numerous others, that milk should be
drunk freely by athletes who enjoy it, at any or every meal except, perhaps, the one just preceding actual play.

(2) That butter "puts fat on the stomach". Butter is one of the best and most easily digested of such foods. It should be eaten freely at all meals.

(3) That fried foods "don't digest". In twenty years of coaching Meanwell failed to find a staple family food which athletes, as a class, could not digest. Fried foods may take a few minutes longer to digest, which is of little significance except on days of competition. Thus, it would be advisable to eliminate them from the game day diet.

(4) That "desserts" should be eliminated from the training diet for they tend to make the athlete soft and fat. Athletes of school age are neither soft nor overweight, thus they don't need to reduce, in fact most of them need to build up. Rich concentrated foods like fats and sugars are not detrimental, but are beneficial to young, alive, growing athletes. They should be used to supplement the meal, not to take its place, on all days except game days. (16)

(5) That "water" should not be drunk during athletic participation. This point has been generally discussed and studied by physiologists. They have concluded that water is a necessity to the general efficiency of the body processes. Thus, when there is considerable
loss of water through perspiration during participation in athletics, the athlete must imbibe a sufficient amount of water to replace that lost in order to maintain the proper liquid medium in which the vital processes of the body may work.

**INDIVIDUAL DIFFERENCES**

In setting up a training diet, due consideration must be given to the individual differences of the athletes. Each athlete has some specific food that isn't tasteful to him or just doesn't agree with him. Therefore, one should not set up a diet of certain foods, but may suggest a variety of foods that contain the fundamental nutritive materials and vitamins. Then permit the athlete to choose his diet from this group. As long as he gets the required elements, vitamins, and calories, necessary it is of minor importance as to where he gets them.

**GAME DAY DIET**

In the discussion throughout the chapter, mention has been made of the various foods that should not be used on the day of the game. Therefore, it would only be repetition at this time to set up a game day diet. As has been stated before the coach can use his own judgment, nevertheless certain factors should be taken into consideration when setting up a season's training diet, a game day diet, and the pre-game meal.

An important step in the intelligent use of this information, it seems, would be to orient the squad members
regarding the physiological reasons for including the fundamental, basic, foods in the diet; the use of a variety of foods in order to obtain all the necessary vitamins; and the importance of an amount of food that will provide the necessary number of calories to carry on the activity properly.

This discussion presents some reasons why the diet of the athlete in training does have an important and influential bearing on the degree of physical efficiency, and amount of success attained by the individual athlete and the squad as a whole.
BIBLIOGRAPHY - Chapter III

Note: * denotes secondary source has been cited, since the primary source was not available to the author.


CHAPTER IV

FATIGUE AND STALENESS

Originally, the author had planned to confine this chapter to a discussion of "Staleness". But, in studying the material available on the subject, it was revealed that staleness and fatigue were so closely related that a thorough understanding of this important problem in training could not be accomplished without presenting material on both topics.

In Chapter Two, some discussion of fatigue was included as it pertained to the muscles. Here, a more extensive discussion will be made, especially regarding its importance as the forerunner of staleness.

First, a clarification of the two terms must be made in order that no misconceptions may arise. It is generally agreed that fatigue is a condition of the body after it has undergone excessive activity with a resulting loss of power or capacity to respond to stimulation.

One writer has stated that, the term fatigue is a sort of miscellaneous file, into which are cast a number of conditions all having a common symptom, a diminished capacity to do work, occurring as a result of work. (8#)

According to Schneider, one should recover from normal fatigue with a good night's rest and be completely recovered to start the next day. This he calls a healthy fatigue. But, if this state of fatigue persists after a reasonable amount of sleep and continues day after day, he speaks of
it as an accumulated and persistent fatigue or "staleness".

(3) Thus, the close relationship of the two terms can be comprehended.

**FATIGUE**

A thorough understanding of fatigue and its causes are necessary as a background for the intelligent attack upon the problem of staleness.

Physiologists tell us that fatigue cannot be isolated in one part of the body, as in one set of muscles; or, mental fatigue separated from physical or muscular fatigue. However, some writers believe that fatigue centers in two places; in the motor nerve of the muscle, and in the central nervous system. (3) There is good reason to believe that the fatigue which leads to staleness has its origin within the central nervous system and that, as a rule, staleness is a neural limitation founded on chemical changes within the body. (3) In accordance with this belief, another author states that in individuals not accustomed to the exertion of moderate or heavy muscular work, muscular fatigue may occur earlier than nervous fatigue, whereas in the trained individual, nervous fatigue precedes that of peripheral origin. (3)

McCurdy and Larson state that purely mental work hastens muscular fatigue and vice versa. (6) Gould and Dye support this fact in saying that fatigue of one group of muscles diminishes the amount of work obtainable from
another. Mental work or effort produces similar effects. (3)

Haggard and Greenberg have discussed two distinct causes of fatigue. The first, which gives added support to the reason disclosed by the aforementioned authors, is that in the development of fatigue, energy is expended by the muscles in excess of restorative processes. Only rest is necessary for recovery from this type of fatigue. The second cause of fatigue is the need for food. Rest does not restore the efficiency and capacity to work of one who has not eaten for from three to five hours. Food, not rest, is required for recovery from this type of fatigue. (4) As an example, they cite the man who feels tired, however is not relieved by rest while waiting for a meal, but is relieved upon eating. (5) Thus, the importance of sufficient diet is revealed. It seems logical that recovery will take place during a period of rest if the materials necessary for restoring the organs and systems of the body to their normal condition are present in the body. But, if the energy supplying materials have been utilized earlier by the restorative processes during activity, an added supply must be obtained in the form of food, in order for further restoration or recovery from fatigue to take place.

Another factor influencing the progress of fatigue is disclosed by McGuridy and Larson. They state that the extreme loss of sodium chloride increases fatigue. These losses, through excessive perspiration, are not normally
replaced through food and drink. Prolonged excessive sweating dehydrates the tissues and causes acidosis and
fatigue. Salinized drinks, sodium chloride from 0.25 to 1
per cent, aids in the prevention of fatigue. At least
fifteen grams per day should be ingested. (6) It is be-
cause of this fact that salt tablets are provided for
athletes and individuals in other fields of work when it
is very warm and a great amount of muscular exercise is
being performed.

Gould and Dye feel that fatigue plays a very important
part in the activities of our daily life. Routine tasks
very frequently become monotonous and require an unnecessarily
large amount of nervous energy for their completion. In
these tasks, one system of nervous and other bodily
structures is involved. To shift momentarily to some
other work for which another set of structures is employed
will often relieve the monotony, tension, and resulting
fatigue. (6)

The author can see no reason why this same principle
may not apply to athletic training. There is a need for a
variety of drills and activities related to the specific
sport, for which the athlete is in training, that can be
utilized to prevent the training program from becoming
monotonous.

Steinhaus stresses the significance of tensions in
promoting the onset of fatigue. He states that tensions
are any unnecessary or exaggerated muscle contractions.
These may or may not be accompanied by abnormally great or reduced activities of the internal organs. These tensions are divided into two groups, physiological and psychological. "Physiological tensions" are the direct response to stimuli, which would affect all individuals in somewhat the same way. For example: tenseness and shivering to cold; muscle spasms, where joints are injured as in a "trick knee"; bright light or intense sounds; injury to muscle, as in a "charley horse"; hypertonicity after strenuous exercise; exaggerated stretch reflex in postural errors. Hunger increases the irritability of the central nervous system and, therefore, exaggerates all reflex responses including the tonus reflexes. "Psychological tensions" are responses to stimuli that ordinarily do not call out muscle contractions but that at some time earlier in the subject's experience were associated with a situation in which tension was part of the normal response. Since the brain can connect any two situations that have at some time occurred simultaneously, it is obvious that, dependent on the endless vagaries of personal experiences, individuals may show tension to any and all kinds of stimuli. Some common instances are: tightening up when one hears the screeching of brakes; inability to relax when riding in an auto after experiencing or imagining too many auto mishaps; persons who grow tense in the presence of school teachers and other "superior" adults, because earlier in life they were frightened or ridiculed by elders; tension from fears
in the dark and others. (9)

These instances do not pertain especially to athletics but it can be easily recognized that similar examples do appear as the result of experiences occurring while taking part in athletic training and a competitive athletic program. Some possible "psychological tensions" that might arise in athletes are: fear of an opponent, because of their superior rating or a humiliating defeat administered by the opponent at an earlier date; boys who grow tense when the coach is watching their individual performance; boys who grow tense on appearing before a large crowd because of a past experience; athletes who "tighten up" during the "big game", because of the fear of making a faulty play. Many more of these tensions could be mentioned and are recognized by athletic coaches.

Steinhaus also suggests the antidote for these tensions. "Physiological tensions" are relieved when the stimulus is removed. Thus, a warm bath, closing the eyes, shutting out noises, massage or mild exercise to remove waste products, or the reduction of the joint injuries may relieve the tension caused by the stimuli they remove, thus favoring relaxation and sleep. Eating a moderate meal will reduce the irritability caused by hunger. A heavy meal may introduce new stresses. "Psychological tensions" may disappear when the responsible association is brought into consciousness and resolved one way or another. Although, sometimes, this requires the aid of a psychiatrist to help
uncover the childhood experience in which the association was made. A great deal can be done by self-analysis and understanding. Since all tensions, no matter what the cause, tend to perpetuate themselves by stretch reflex mechanisms, a great deal can be done by giving conscious attention to relaxing muscle groups. (9)

The author feels that this discussion by Steinhaus is of immeasurable value to the members of the coaching profession. For undoubtedly, one of the factors influencing the athlete's performance is the development and control of one or more tensions.

Fatigue is not analogous to exhaustion, but is a forerunner of the latter and serves to give warning for one to stop work before becoming exhausted. Although fatigued, one is capable of performing work, even continuing until exhaustion brings about collapse. One may be fatigued, but under emotional stress or strain, and may forget all about it and perform activities which previously seemed impossible. With every spurt of effort, it is probable that the suprarenal body is stimulated to augment its output of adrenin in the blood stream. (3)

According to Bainbridge, the subsequent fatigue which follows a period of great emotional excitation, must be extreme and out of all proportion to the exertions made. (1)

It is for this reason that much opposition has been voiced by authorities against the participation of Junior
High School boys and possibly High School boys in the more vigorous activities, especially before huge crowds where there is great emotional stimulation as the contest progresses.

Furthermore, it has been revealed that the more complete the exhaustion, mental or muscular, the longer the period necessary for recovery. (8) This point should be taken into consideration by coaches in planning their practice and game schedules. It is due to failure in giving sufficient rest after vigorous participation by athletes, that chronic fatigue or staleness develops. (8)

**STALENESS**

Now that the relationship between fatigue and staleness is understood, it is necessary that coaches analyze this phenomena, which may occur during a period of athletic training. This can be accomplished most satisfactorily by a study of the symptoms, causes, prevention, and treatment of staleness.

**Symptoms**

After the coach understands staleness, it is of utmost importance that he be able to recognize its symptoms as they appear in his athletes. This can be done by always being alert for the appearance of the various symptoms which accompany the onset of this state of chronic fatigue.

According to Schneider, there are three types of staleness; (1) the cardiorespiratory type, which is recognized by an increased frequency of the pulse. There is distress
on slight exertion, accompanied by a rapid rise in pulse frequency, which returns to the pre-exercise rate only after a long interval. The breathing is also shallow and rapid; the extremities of the body are cold and poor in color. (2) The nervous type, shows poor muscular control of balancing movements; fine tremors of hands, eyelids, and tongue; and greatly increased reflexes. (3) The muscular type, manifests itself by tenderness of muscles, by loss of muscle tone, by flabbiness, and loss of power, which may be slight or marked. The tenderness may sometimes be such that it is mistaken for rheumatism. (6)

Additional information on the symptoms of staledness, as given by Bilik, are as follows: the first characteristic sign is loss of weight; listlessness, lack of interest in training work; face drawn, pinched; becomes "temperamental", peevish, irritable; loses appetite; sleeps poorly; "all in"; tires easily; lacks driving power; easily injured, injuries are slow in healing. (2)

McCurdy and Larson give added support to Bilik's battery of symptoms, by making a few comments. They state that the stale person awakens in the morning after eight or nine hours of sleep lacking in energy and ambition. He is often drowsy during the day. Gradual loss of weight is one of the best indices of loss of power, unless definitely accounted for by diet or exercise to reduce obesity. (6)
Meanwell, fully agrees with those indices of staleness that have been given and adds some pertaining to basketball. According to him, staleness in basketball may present itself in one or more of the following ways: a slump in accuracy of shots; lack of former power to finish the game at top speed; indolence, and lack of enthusiasm in practice; and frequently, an irritability of temper quite foreign to the player's normal disposition. He gives an interesting statement regarding the effect of staleness on the team as a whole. According to Meanwell, teams that are repeatedly outplayed toward the close of games and which slow down markedly after a fast start; and also, those which finish a season poorly, after early successes, are more apt than not, to be stale. (7)

With such a definite list of symptoms, it seems that a coach who handles his boys individually will be alert to observe the signs and symptoms alluded to within the preceding paragraphs.

Causes

The fundamental causes of staleness are really the important issue as far as athletic coaches are concerned. If they understand the reasons for staleness, much can be done to prevent such a condition from developing in their athletes.

Authorities on athletic training are almost unanimously agreed on the factors causing staleness. Possibly, the outstanding, over all, cause of staleness in athletic train-
ing is the exerting each day a little more than can be recovered from at night. (8) Meanwell states that the cause of staleness is usually overwork, too much scrimmage, and too frequent games. Mental stress readily produces staleness in case there is family or financial trouble. After a team has been continuously victorious in a number of games, the over-anxiety to win and the continuous nervous strain resulting therefrom, frequently leads to abrupt loss of condition. Thus, an unexpected defeat or two acts as a safety outlet, and is often followed by a return to winning form. (7)

Therefore, the coach needs to be continuously aware of the severity of his practice and game schedule. Since there is no doubt that overtraining and continuous overloading of the players, physiological capacity is the main cause of staleness.

Another point that needs to be mentioned here is that each individual athlete has a different level of efficiency. If an athlete is to improve his level of physiological efficiency as rapidly as possible, he must exercise to the limit of his tolerance and train for tasks of greater severity than those normally to be faced. This means a progressive increase in either the cadence or the load borne, or both. He must progressively run faster, lift or carry heavier loads or speed up the tempo of conditioning drills. This is known as the overload principle in training. (10) It is necessary that coaches follow such
a plan of progressively increasing the work load each day in order to develop each athlete to the height of his capability.

Steinhaus cites a few illustrations of coaches applying the overload principle. Some of these are: (1) The Brooklyn Dodgers wear heavier shoes for infield practice than they do for the regular game. They change to lightweight shoes just before the game starts. (2) It is not uncommon for boxers to practice shadow boxing with one and one-half pound dumbbells in their hands. (3) In training for the twelve pound shot, the sixteen pound shot is used. (4) Some basketball coaches have used a device of having their basketball players walk around the campus with galoshes on their feet, thus strengthening their leg muscles. (5) Progressive weight lifting is systematic overloading. (9)

In carrying out such a program of progressively increasing the daily energy expenditures, the athlete's highest degree of efficiency will be attained in; as most physiologists have agreed, from five to eight weeks. This depends on the original condition of the athlete and the degree of physiological efficiency required by the sport for which he is training. Upon reaching this stage of the training program, the coach must be alert to recognize the arrival of his athletes at their ultimate capacity for performance. For it is at this point that a continuation
of the same training routine may become monotonous, causing tensions to arise, developing additional fatigue, possibly causing it to become an overload and the appearance of staleness. (3) Thus, the reason for the statement by Meanwell that the frequency and duration of scrimmages in the latter part of the basketball season, should be decreased. (7)

Therefore, coaches must become conscious of the ways and means of preventing staleness after they have trained their athletes to the point where they are most susceptible to it.

**How to Prevent**

This is the factor that is really of prime importance. If coaches train their teams well, they will prevent the disappointment of having their players or entire team go stale on them.

On the basis of the material gathered in this thesis, it seems that it would only be reasonable for the coach to give attention to the factors causing fatigue and staleness in order to prevent them from appearing.

As McCurdy and Larson so well state, staleness may be avoided by care in training, chiefly, through control of the factors named previously as those influencing the progress of fatigue. (3)

Bilik feels that staleness can be anticipated by keeping an eye on the daily weight record. Avoid overworking men, and hold them in check at the beginning of the
season when they are apt to be anxious to get into shape quickly. Learn to judge the condition of your men by their general appearance. (2)

Treatment

In case that staleness does develop, special care need be given to the athletes affected in order to relieve them of this undesirable state of physiological condition.

The standard treatment seems to consist of: (1) Laying the athlete off from practice for a few days in severe cases, or just ease off in mild cases; (2) change of activity, such as from a major sport to long walks in the fresh air; (3) change of diet to include plenty of rich, wholesome food, that is easily digested, including much liquid, fats, and sugars; and (4) ten or more hours sleep each night. (2) (7)

The athlete who becomes stale is really ill. He is unable to perform with his normal degree of competency. Usually, he is suffering great mental anguish due to his hampered capacity and thus needs to be reconditioned. It is felt that this reconditioning process may be more delicate to administer in an attempt to aid the athlete in regaining his highest degree of physiological proficiency, than was the original training program, where the overload principle was maintained. Determining the amount of rest or lay off necessary before beginning the reconditioning program and
then the exact load required to gradually return the athlete to the trained condition can only be done through very close observation by the coach of the reactions of the athlete to his prescribed reconditioning program. He must grade his daily training load accordingly. No definite schedule can be established as a reconditioning program, since each case varies with the individual athlete and the degree of severity of staleness he reached before it was recognized.

**SUMMARY**

The coach has a great responsibility and must have an extensive background in order to do an adequate job in athletic training. His education must include much more than a knowledge of the skills to be taught, if he is to be successful in coaching and training his athletes. His aim is that they will reach the height of their physiological efficiency and capacity and yet not go over the crest and develop a state of staleness.

The author feels that the scope of athletic training has now been covered except for a closely related topic which follows in the next chapter regarding the effects of alcohol, tobacco, and caffeine upon the conditioning of athletes.
BIBLIOGRAPHY - Chapter IV

Note: * denotes secondary source has been cited since the primary source was not available to the author.


10. War Department Technical Manual TM292 Physical Reconditioning, War Department, Dec. 1944, p. 4
CHAPTER V

THE AFFECT OF TOBACCO, ALCOHOL, AND CAFFEIN ON THE PERFORMANCE OF THE ATHLETE.

The topics for discussion in this chapter have been the object of much debate among the laymen as well as the coaches, down through the years. Certain taboo's, relating to training practices, have been established with probably very little scientific backing to support them.

Rules have been set forth by coaches, as a whole, forbidding the use of tobacco and alcohol by their athletes. In fact, in many cases, it has been a matter of necessity, whether the coach believed in it or not. The success and, especially, tenure of coaches in some situations depends on their ability to get their boys to "train", as it is usually spoken of in athletes.

This does seem to be an issue of prime importance to the coach, players, and their loyal public. The author's interest in this entire study was initiated by a desire to assess the available facts regarding the physiological effects of the use of tobacco, alcohol, and caffeine upon the development and performance of the athlete.

It is believed that coaches will have less difficulty in promoting the policy of total abstinence from smoking and drinking among their athletes if they have scientific evidence to support their requests. In many instances, boys feel that they play as well while smoking or drinking
as they would if they were total abstainers. They develop a nonchalant attitude toward the coaches request, that they refrain from the use of tobacco and alcohol, merely because they feel that the coaches regulations are unwarranted.

There is no doubt that the "natural", as was spoken of in Chapter II, can smoke and still give a better performance than many of the less fortunate who can only reach the level of mediocrity even when following the strictest training program.

It is at this point that the coach needs to have something that is factual and has merit enough to convince those who are doubtful, that they cannot give their best performance except by total abstinence from the use of these items.

The author was extremely well pleased with the evidence available on the subject, especially with regard to smoking. Although much more research is necessary, enough was found to give the coach a sound working basis in setting up his training program.

**TOBACCO**

The most common method of using tobacco by high school and college boys is the smoking of cigarettes. This may be the reason for most of the research on the topic being performed with the subjects using tobacco in this form.

The outstanding feature of the information disclosed by the physiologists, who have contributed most to this
study, is that it all credits smoking with counteracting the beneficial effects of training.

Smoking definitely causes an increase in heart rate and blood pressure. (3) (4) Henderson and associates state that since smoking tends to increase the resting pulse rate, the smoker starts the race with an already higher heart rate and therefore his safety limit is decreased. (5)

According to Baumberger, smoking delays the return of the heart rate to normal after moderate exercise for more than 15 minutes in the majority of the cases as compared to 5 minutes for non-smokers. (2) Therefore, the heart will be required to perform a greater amount of work through the demands of an increased pulse rate and deprived of a maximum amount of rest because of a lengthened recovery period.

Smoking decreases the ability of the blood to carry oxygen to the tissues through displacement of oxygen in the hemoglobin of the red blood corpuscles with carbon monoxide. The red corpuscles have 225 times as great an affinity for carbon monoxide as for oxygen. It is estimated that smoking for an hour, with inhaling five times per minute, 22 percent of the hemoglobin in the blood would be saturated with carbon monoxide. However, it is not probable that a maximum of more than 10 percent is ordinarily reached. The withdrawal of 10 percent of available oxygen prevents arduous work endeavor and explains the reason for rules against smoking during training. (2) Since the oxygen
supply to the muscles has been found to be the key factor in offsetting fatigue, this point alone would be sufficient evidence of the incompatibility of smoking and training. Consequently, smoking just deteriorates what training builds up.

Nicotine also paralyzes or slows the transfer of impulses in the synapses, thus, slowing the speed of the athlete. The reduction of physiological efficiency is due to two causes, according to McCurdy and Larsen. First, the reduction in oxygen carrying power of the blood; and second, the loss in muscular efficiency due to the paralyzing effect of the nicotine on the synapses. (11)

O'Shea's study of the effects of smoking on scholarship support the testimony of high school principals and faculties, who believed that smoking lowered student's scholarship and deportment ratings. (14) Thus, it may be concluded that smoking and scholarship are related both to athletic ability and to eligibility. Intelligence tests do not show inferior intelligence on the part of smokers (11), which gives added support to the theory that smoking does not affect intelligence, but, hampers the ability to use it.

Lendenhall summarizes former studies by saying that most of the evidence thus far shows a lower standard of mental efficiency in tobacco users as compared with non-users of tobacco. There is a disturbance of motor reactions
in the direction of lowering the efficiency, especially of finely coordinated movements. There are slight blood pressure changes accompanied by vaso-constriction, and in apparently excessive amounts, there issue digestive and visual disturbances, and irregularities in the rhythm of the heart. Whether the toxic effects of tobacco are due to nicotine or some other constituents has called forth considerable investigation, and as a result most observers are inclined to agree that the toxic results are chiefly due to nicotine and carbon monoxide. (10)

Jurup and Naido found that at a certain oxygen consumption, pulse rate is higher under the effect of smoking than when there is no smoking. Also, the duration of the influence of smoking is ten to forty-five minutes, showing individual variations and depending on the amount of tobacco smoked. (8)

Physical work causes more of a disturbance in organic function in those who smoke than in those who do not. (4)

Many investigators have noticed a fall in the skin temperature due to smoking. They also discovered that the size of the arm decreases as the result of smoking owing to a constriction of the peripheral arteries. (9) Lamson disclosed that after smoking and inhaling one cigarette the constriction of the blood vessels of the skin reduced to about half the amount of blood normally passing through these vessels. This effect lasted for 60 minutes. When the smoke was not inhaled, the action was about as great as
before but lasted only 15 minutes. For a proper functioning of the organism, a sufficient cooling of the body is essential. For this reason, anything that causes constriction of the skin blood vessels should be considered harmful. (10)

A common expression regarding the effects of smoking on the athlete is that "smoking cuts the wind". Henderson, Haggard, and Dolly proved this to be a physiological fact in their explanation of the effects of smoking on "wind". They revealed that the rapid pulse rate of smokers decreases the stroke volume during rest since the venous return is not affected and the ventricles lose the habit and ability of making large strokes. Similar conditions arise during strenuous exercise, that is, with the rapid heart rate, diastolic filling is incomplete and the stroke output remains small. This results in a relatively small unit circulation and oxygen supply to the tissues with the result that an oxygen debt must be increased. This ends in breathlessness and dyspnea. (5)

Mendenhall made a study of 750 students, smokers and non-smokers, of both sexes, in an attempt to find the immediate affects of the use of tobacco. As a result, he discovered that the predominating action of tobacco was one of depression. Seventy two percent of those tested received a depression action while the remaining twenty eight percent were stimulated. This may well explain why people differ in their opinions of the effects of tobacco.
The depressing effect of smoking probably explains the desire of nervous, irritable, high strung people to smoke, while, on the other hand, the stimulating action gives reason for those already depressed to desire stimulation from smoking. (13)

Some studies had revealed that periods of depression were due to smoking, but Raphael's work disclosed that the periods of depression were not due to the effect of smoking on muscles or on motor end plates, but to central nervous system fatigue. (15)

Fisher and Berry came to the following conclusions about the effects of smoking on neuromuscular precision: First, that all smokers showed a loss in physical precision immediately after smoking. Second, that most smokers showed improvement during the interval when not smoking, and third, that smokers showed a greater lack of neuromuscular control after exercise than non-smokers.

One experiment they performed, which should be of interest to coaches, disclosed the effects of smoking on the accuracy of baseball pitchers. The pitchers who were smokers lost 11 percent in accuracy, and the non-smokers 13 percent, after smoking one cigarette. When there was no smoking by any of the men, they all showed improvement in the accuracy of pitching.

Therefore, these authors advise that it is better for most people to avoid smoking at all times. It is essential to the best work during training, since smoking interferes
with the precision of muscular movements. (4)

This disputes the fact some have believed, that a
smoker gets accustomed to the effects of the nicotine and,
therefore, adjustments are made in the systems and organs
of the body allowing them to give like performances whether
smoking or not smoking.

Tests proved that the smoker, like the non-smoker is
less efficient after smoking than he is during a period
of abstinence from smoking. It was for this reason that
Fisher and Berry concluded, that the smoker does not be-
come habituated to the use of tobacco. (4)

The author feels that some conclusive evidence has been
exposed on the subject of the effects of smoking on the
athlete to make it possible for the coach to be demanding
in his request for total abstinence from the use of tobacco
by his athletes.

ALCOHOL

There was very little research material available re-
garding the effects of alcohol on athletic training.

Coaches do not appear to give much thought to the sub-
ject. Possibly, there is less comment on the topic because
there is an insignificant amount of drinking done in com-
parison to the prevalence of smoking among athletes.

Regardless of this fact, the author has never known
of a high school, college, or professional, coach that
has believed in the use of alcohol by his athletes.
Maybe it is because the effects of alcohol are so obvious that no more evidence is needed to convince coaches, athletes, and laymen, that alcohol and athletics are not compatible.

At one time, some considered alcohol a food, because as it was oxidized, it gave off energy. But today, physiologists and pharmacologists are unanimous in their decision that alcohol is not a food, but is alluded to as a drug or poison.

Experiments at the Carnegie Nutrition Laboratory revealed that the oxygen consumption during work was the same whether the man had alcohol or not. This means that the heat derived from oxidation of alcohol cannot be used as a source of muscular energy, and is independent from work. (9*)

Canzanelli and associates concluded from their work that ethyl alcohol cannot be used as a source of oxidative energy for muscular exercise, and in this respect differs from the three major foodstuffs. (5)

Attwater and Benedict made a laboratory estimate of the efficiency of the body as a machine. They found it to be 29.55 percent without alcohol and 25.82 percent with alcohol. (1*) This fact has been confirmed by investigators during mountain climbing tests. (1)

It is very evident that alcohol cannot be of any value to the athlete, and, therefore, has no place in the training diet.
CAFFEIN

There is not so much interest shown regarding the use of caffeine. Most coaches say nothing about the use of drinks containing this substance.

Meanwell states that if a boy is accustomed to the daily use of such drinks with his meals, it is well to continue their use throughout the season. He advises against the excessive use of them, since they affect the digestive processes adversely in some instances.

On the other hand, he feels that it is well to avoid coffee at later meals than breakfast, and especially so if it affects ability to sleep. He has less use for cocoa and chocolate than any other drinks, and never permits their use on game days. (12)

Hyde and associates found that caffeine raised the blood pressure above normal within one hour and kept it up more than three hours. This raised blood pressure was one of the factors increasing the amount of work done due to the effects of caffeine. With caffeine athletes and non-athletes did one and one-half to two and one-half times as much work. Maximum power for work was attained with a dose of 2.24 grains of caffeine. (7)

Other experiments disclosed that caffeine gives only small changes in heart-rate and blood pressure. In co-ordination tests where rapid movement is required, caffeine improved the performance. With acquired motor skills, caffeine impaired both execution and precision. (6)
Vogt found that caffeine decreased the muscular efficiency about 25 percent. (10)

Thus, it appears that the effects of caffeine are not clarified to date, at least not satisfactorily enough for any definite conclusions to be drawn.

The theory which manifests itself, in analyzing the evidence available, is that caffeine may stimulate the systems and organs of the body to put out more work, but hinder the execution and efficiency of doing that work, if such is possible.

**SUMMARY**

According to the evidence collected for this study, it seems one is justified in drawing the following conclusions: (1) that the use of tobacco, especially by smoking is harmful to the athlete in training; (2) that alcohol has no conceivable contributions to make and many undesirable effects or offer to the athlete; and, (3) that caffeine may have some beneficial effects and others which are detrimental, but offers nothing of significance, either way. There may be times, such as at the half of a football game on a cold day or night, that a warm drink of coffee or tea may give the athlete a boost, or feeling of well being. In summing up all three items together, it seems that the athlete will benefit by abstaining from them completely if he wishes to reach his peak performance in athletics.
There are probably other items of interest to coaches, which the author has omitted, either because of oversight or lack of material available pertaining to them.

This is the concluding chapter except for the general summary of the entire study which follows in chapter VI.
BIBLIOGRAPHY - Chapter V

Note: * denotes secondary source has been cited since the primary source was not available to the author.


CHAPTER VI

SUMMARY

The evidence assembled in this thesis continuously exploited the superiority of the trained individual over the untrained, from the standpoint of the capacity of the human body as a machine for the performance of work. The outstanding feature of the influence of training on the athlete is in his ability to meet the demands of his body for oxygen during exercise.

Training, probably, does not increase the efficiency of muscles to transform energy into muscular work, but, training has been shown to increase both the power and size of the muscles involved. Especially, it has been proven that the power of muscles is increased out of all proportion to the increase in size, due to the stimulation of a greater number of muscle fibers, and greater efficiency in muscular contraction.

The dynamic capacity of trained muscles is increased through their higher glycogen content, their increased capacity to tolerate or better lactic acid, their increased content of phosphocreatin (phosphates), and the increased capacity of their oxidation mechanisms.

Through training, better neuromuscular coordination is developed, greater precision and smoothness in muscular action result from improved coordination of the antagonistic
muscle groups. Furthermore, reaction time is decreased due to elimination of superfluous muscle contractions through repetition of the activity.

Muscle soreness is due either to accumulation of excessive amounts of lactic acid in muscle which can be relieved by continued use of the muscles, or to injury to the muscle, as tearing or straining muscle fibers, which needs rest with very carefully graded activity for recovery.

Relaxation of antagonistic muscles allows for smooth performance and offers less resistance to muscle action.

Athletic training develops a lower respiratory rate, an increased vital capacity, a decrease in pulmonary ventilation for a given amount of work, and a wider margin of safety during exercise with diminished respiratory distress. It leads to greater oxygen-carrying capacity of the blood and increases the percentage of carbon dioxide released in the respiratory exchange in the lungs. These factors increase the oxygen supply to the tissues and diminish their retention of acid products. Training is conducive to greater efficiency of breathing by utilizing the maximum ventilation capacity of the lungs, thus reducing the respiratory rate.

The increase in number of red corpuscles of the blood during training initiates an increase in amount of oxygen carried, which is a factor in limiting man's ability to work.

Training reduces the amount of lactic acid being
emptied into the blood stream by fulfilling the oxygen requirement for resynthesis of lactic acid to glycogen in the muscle, which increases the ability of the athlete to maintain a normal pH of the blood.

The proper coordination of the respiratory-circulatory mechanisms leads to the ability of the athlete to maintain a steady state with a higher crest load, while developing a minimum of oxygen debt throughout the activity for which he is trained. This, in turn, reduces the length of the recovery period which is an index to the relative condition of an athlete.

The respiratory quotient is lowered by training, which can only be explained by greater efficiency in the coordination of the functions of the respiratory and circulatory systems.

Training has a beneficial influence on the heart muscle, similar to that found in skeletal muscle, therefore, it is also able to cope with the increased demands of the tissues for blood during exercise. Any change in the size of a normal heart due to training is not spectacular and probably relative to the growth of the individual and the severity of the exercise performed. Because of the increase in strength of heart muscle, the heart rate is decreased and the stroke volume increased, giving the heart a longer period of rest between beats in the trained athlete. The heart of the trained man returns to its normal
cadence after exercise sooner than that of the untrained. Training increases the unit circulation of the blood thus furnishing the tissues with a better supply of blood.

Training does not affect mechanical efficiency of the body but it raises the level of work which can be performed at the maximum degree of efficiency.

The emotions react upon the adrenal-sympathetic mechanism, stimulating it to provide energy for increased strength and endurance during participation in athletic events.

In the pre-activity warm-up process, athletes improve their general circulation, remove the danger of early contracture, and produce a slight rise in body temperature. This rise in temperature improves muscle tonus, quickens the response, especially the relaxation, and most likely diminishes the viscosity of the muscle fluid.

Training causes "second wind" to develop more rapidly and with less feeling of distress. It is the result of complete adjustment of the vital mechanisms to the activity in the trained athlete.

The diet of the athlete in training determines, to a great extent, his ability to reach and maintain his maximum level of performance.

Carbohydrates are the immediate, primary source of energy in the diet. Fats are utilized upon depletion of the carbohydrate supply, but with greater distress to the subject. Proteins are employed for growth, tissue building
and repair, in the body.

Excessive use of acid or alkaline foods cause very little shift in the pH of the blood but it is advisable to maintain an alkaline reserve, if it is possible, to aid in the acid buffer process during exercise.

Three thousand five hundred to five thousand calories are necessary in the athlete's diet, if he is to maintain his weight and provide sufficient energy for the immediate activity. A balanced diet is essential to the best performance of the athlete, and it should consist of from 55 to 70 percent carbohydrate, 20 to 30 percent protein, and 10 to 15 percent fat, regardless of the type of food supplying the calories.

The training diet should include a wide variety of foods, cooked in various ways, in order to appeal to the appetite of the athlete. Fried foods, probably, should be omitted from the game day diet.

Vitamins are an indispensable part of the training diet. They provide for proper growth and body protection. Vitamins A, B₁, B₂, C, and D, are the most essential in the athlete's diet from the standpoint of training. The supplemental feeding of vitamins, under a doctor's guidance, may be of vital importance in preventing vitamin deficiencies in the athlete's diet. Over dosage of vitamins has no significant effect upon an individual.

Supplementary feeding of sugar is beneficial, if the activity is so severe as to deplete the normal sugar
supply of the body. The caloric intake can be increased
tremendously by the ingestion of sugar in some form
before the contest and at intervals during the activity.
Gelatin has been highly regarded by many in the field
of athletics, as a result of their research, but almost
completely disqualified by physiologists. This is very
likely due to the type of subjects used and the kind of
activity experimented with, since a supplemental food is
of no value unless there is a need for added energy.

Many of the fads in diet have disappeared in recent
years. Since sugar is definitely the main source of energy,
many of the fallacies about the use of sweets and desserts
have been discontinued by coaches.

Water, which is a necessity to the proper digestion
and assimilation of foods in the body, should be consumed
whenever needed, even during muscular exercise.

Individual differences must be considered in selection
of the diet. The season training diet should include any
and all of the staple foods which are tasteful to the
athlete. The same day diet should have one normal meal,
with some limitations, such as no fried foods and no milk,
and the pre-game meal should be eaten at least three
hours before the contest and consist of easily digested
foods.

Fatigue is a condition of the body after it has under-
gone excessive activity with a resulting loss of power or
capacity to respond to stimulation. The chief purpose of the training program is to prevent the appearance of this condition during the progress of an athletic contest. The effects of fatigue are general since it cannot be isolated in any certain set of muscles. Mental fatigue affects the onset of muscular fatigue and vice versa. The more severe the state of fatigue, the longer it takes to recover from it. Fatigue, it is believed, centers in the central nervous system. The only antidote to fatigue is rest.

Staleness is the result of an accumulation of waste products produced by mental and muscular activity, which the respiratory and circulatory systems have been unable to remove from the body from day to day. Thus, over a period of a few days fatigue products accumulate in the organs and systems of the body making it impossible for the organism to react properly to stimuli. Therefore, a stale athlete appears tired, lacking in ambition and energy, irritable, uninterested in practice, loses weight, and is inaccurate in his performance of skills. Staleness can be prevented by an alert coach, who observes his players closely and plans the strenuousness of his practices according to the condition of his men. When staleness appears the athlete should be allowed to let up in his practice routine for a few days. In severe cases of staleness, a complete lay off from the sport should be
given and special effort made to return the athlete to his
former condition by providing a rich, wholesome, diet and
changing his activity, such as to taking long walks in
the fresh air.

Research performed relating to the effects of tobacco
on athletic training found smoking to have a deteriorating
effect upon the training program. Smoking increases the
heart rate, decreases stroke volume, increases blood pres-
sure, decreases the oxygen carrying capacity of the blood,
slow the transfer of impulses in the synapse, lowers
scholarship and mental efficiency, causes more disturbance
in function, lowers the skin temperature, and induces
dyspnea. Smoking also had a depressing action in seventy
two percent and stimulating effects in twenty eight percent
of the cases studied. Experiments with smokers and non
smokers proved that both become less efficient in their
performance after smoking, thus, confirming the fact that
smokers do not become habituated to the effects of tobacco.

Evidence of the effects of alcohol on athletes is
very meager, but it is agreed that ethyl alcohol cannot be
used to produce energy as do the three types of foodstuffs.
Alcohol is now classified as a narcotic because of its
depressing effects on the body. Alcohol has no proven
values to offer the athlete and does decrease his ef-
ficiency in performance.

Caffein is still a debatable issue as far as its ef-
flect on training are concerned. In some cases, it has been
proven to increase the amount of work done one and one-half to two and one-half times. Other evidence reveals small changes in heart rate and blood pressure, improved performances in rapid coordinating activity, and impairment in execution and precision of acquired motor skills. In one instance, caffeine decreased muscular efficiency about 23 percent.

According to the information assembled in this study, the writer will prove or disprove the assumptions which were listed in Chapter One:

(1) That no special attention need be given to conditioning, since the daily practice routine will take care of it.

This assumption may have originated from those coaches who recognized that the development of skill is the most obvious result of training. In reviewing the information assembled in this thesis, it is revealed that many physiological changes take place during the course of training. It was found that, if these developments were to take place, the athlete should follow a carefully graduated program of activity based on the overload principle. Furthermore, special attention should be given to the diet, abstinence from the use of tobacco and alcohol, and plenty of rest. Thus, it seems that merely giving attention to the practice sessions in sports will not provide for the development of the highly trained athlete.
(2) That no water should be consumed during athletic participation.

Physiologists, after much study of this problem, have concluded that water is necessary to the general efficiency of the physiological processes. Therefore, when there is considerable loss of water through perspiration, the athlete must imbibe an amount of water sufficient to replace that which has been lost in order to maintain the proper functioning of these physiological processes. If water is needed during the progress of the game or practice, it should be taken in at that time.

(3) That supplementary feeding of vitamins is of no benefit to the athlete.

This assumption may be correct in some instances, if the diet contains a sufficient supply of vitamins, no benefit would be gained from additional ingestion of vitamins. But, in case the diet is deficient in one or more vitamins, supplementary feeding would be of great value in overcoming such a deficit.

(4) That athletes should not drink coffee during the training season.

The evidence presented regarding the effects of caffeine, which is the drug present in coffee, on ability to work was not conclusive. In some instances, it increased the work output of the individual and improved the performance in rapid coordinating activities, while in others it impaired the execution and precision of acquired
motor skills. The coach, whose opinion was cited on this point, expressed the belief that if a boy is accustomed to coffee in his diet, permit him to continue its use. Probably, the drinking of one cup of coffee at breakfast, and one at lunch, with none in the pre-game meal would be a good policy to follow for those who have become accustomed to drinking coffee. Of course, complete abstinence is preferred due to the variance in results of experimentation.

(5) That as long as a sufficient number of calories are eaten the type of diet which furnished them is of no significance.

Physiologists seem to agree with this assumption as stated. Some feel that the diet should consist of definite proportions of the three major classifications of foodstuffs. But, speaking specifically of calories, this policy is correct.

(6) That the athlete should not exercise, even lightly, immediately after eating.

This theory, that a period of complete rest was necessary after eating, was disqualified by experimentation which disclosed that digestion was improved by slight exercise after eating. There is probably no doubt that it would be better to refrain from exercise entirely after eating than to participate in vigorous activity.

(7) That if a boy is in condition for football, he should be in condition for basketball competition at the close of the football season.
The facts regarding this topic suggest that this assumption is partially correct. The respiratory-circulatory mechanisms are affected almost uniformly by training in any of the sports activities. The difference in sets of muscles called upon by the various sports makes this assumption partially incorrect. Each activity calls upon one or more different sets of muscles, therefore, when changing from one sport to another, some time must be given for these new sets of muscles to become conditioned to the activity.

(8) That muscle soreness in early training is of little significance except to show that the program is getting results.

The feeling that muscle soreness is evidence of getting results from the training program seems to be a poor means of measuring those accomplishments. If the program is graduated properly, the soreness will be held to a minimum. It is felt that coaches who try to overload the athletes in the first few days of practice and seem to revel in the amount of soreness they have developed are only decreasing the beneficial effects of training and thus prolonging the period necessary to properly condition their athletes.

(9) That sports competition causes enlargement of the heart.

There have been many studies made relating to this
topic and the results remain incompatible. Some find the athletes heart to be larger than that of the non-athlete, and others have found no change in heart size due to athletic competition. Physiologists are pretty well agreed that the normal, strong heart cannot be injured by athletic participation.

(10) That athletes are born not made.

This assumption is not completely true, but it is agreed among authorities, consisting of both athletic coaches and physiologists, that although training improves coordination certain inherited traits or properties of the nervous system are necessary for the development of an athlete.

(11) That diet is of minor importance in the training of an athlete.

According to the evidence presented pertaining to this subject, diet was found to be of immeasurable importance. An athlete cannot be expected to follow a vigorous training routine without a sufficient amount and variety of the necessary food materials.

(12) That "second wind" is just an imaginary phenomena.

In the trained athlete, especially, "second wind" has been associated with the period following sensations of breathlessness and distress which appears sometime in the early stage of activity. When "second wind" appears, the
athlete is relieved and has a feeling of new strength and carries on with very little or no distress. Thus "second wind" is an actuality instead of an imaginary phenomena.

(14) That the feeding of supplementary foods having a high sugar content is of no benefit, before or during athletic events.

Research on this problem presented evidence that supplementary feeding of sugar is not beneficial unless the supply of glycogen in the body is depleted to the point that the desired level of activity cannot be maintained. After this point, supplementary feeding of sugar products is beneficial to the performance.

(15) That gelatin is of no use in the training diet, either before or during competition.

This point remains in a state of controversy. Physiologists found no benefits derived from the use of gelatin, while coaches who experimented with it were convinced of its great contributions to increasing the capacity to carry on in various activities.

(16) That the pre-practice or pre-game warm-up has no physiological benefits.

Physiologists presented facts which were definitely opposed to this assumption. The warm-up has been found to aid in the adjustment of the physiological processes to the activity, improves muscle tonus, increases body temperature to that most favorable for muscular activity, increases the speed of muscular contraction, and decreases
the possibility of muscular injury during the early stage of the game or practice situation.

(17) That staleness is an unavoidable phenomena that may develop during the conditioning period of a highly competitive and long sport season, which is of little significance.

This hypothesis has been completely discounted. Coaches and physiologists feel that staleness can be avoided by taking proper precautions in administering the training program. After a period of five to eight weeks, the coach should be on the alert for symptoms of staleness and ease up on the program accordingly. On the other hand, staleness is of importance since the athlete in that state of condition cannot perform with his former degree of proficiency and ability. This is detrimental both to the athlete and his team mates.

(18) That the pulse rate becomes gradually lower during the period of athletic conditioning and participation.

This assumption has been proven correct by many studies. The lower heart rate is due to the strengthening of the heart muscles, making it capable of pumping more blood per stroke. This increase in stroke volume decreases the heart rate, gives the heart more rest between beats, and gives it the ability to provide a greater unit circulation when necessary.
(19) That there is no danger of working athletes too strenuously in the early part of the conditioning period.

No evidence was available pertaining directly to this assumption. The only answer to this problem at this time, would have to be derived from related information presented in this study. It seems that there is a possibility of overtraining muscles by overloading them too quickly and entirely out of range of their capabilities. A gradual increase in load is proscribed by the overload principle, thus it appears that any load over this level would have a detrimental effect upon the general conditioning program.

(20) That breathing through the mouth should not be tolerated during athletic participation.

One physiologist proposed the theory that it was desired and necessary that the athlete breathe through the mouth when a feeling of distress appeared while breathing through the nose. Breathing through the mouth gives less resistance to the intake of a greater amount of air and also gives the athlete a feeling of greater comfort. This is necessary to give him added confidence in his ability to continue the work.

(21) That athletic training brings about an increase in size of those muscles specifically used in the activity.

This belief is correct up to a certain point. Exercise of a muscle increases its girth due to the enlargement of
more muscle fibers. After the muscle reaches a certain limit, according to the type of activity, it increases in strength completely out of proportion to its size, but fails to increase in size.

(22) That a coach can check on the relative condition of his men by noting the length of time it takes them to recover from any certain activity.

Physiologists have presented much evidence to support this assumption. An understanding of the development of an oxygen debt gives a basis from which to analyze this point.

Training increases the degree of proficiency of all the physiological processes. Thus, the better the state of conditioning, the less the oxygen debt which will be accumulated while participating in any given activity. Therefore, the less the oxygen debt the less time which will be required to recover from the activity and return the heart rate to its normal cadence.

In conclusion, it is well known that athletic training is a gradual process, requiring from five to eight weeks to develop a boy from an unconditioned state to that of a highly capable, efficient, trained athlete. It is only through the proper direction of the athlete in the application of the facts set forth in this study, that a boy can become a trained individual.

The author feels that an athlete is not trained until he reaches the ultimate maximum development of his
physiological capabilities.

The coach needs to know how to train his athletes and guide them accordingly, but this is of no avail unless the boy gives his wholehearted support and effort toward fulfilling the directions of the coach.

It was quite obvious to the author that very little research in this field of study has been performed by the schools of physical education, which is the most logical place for it to originate.

It is the sincere hope of the author that this humble effort will be of some value to coaches in organizing their training programs in the future.