A THEORY OF BRASSWIND EMBOUCHURE BASED UPON FACIAL ANATOMY, ELECTROMYOGRAPHIC KINESIOLOGY, AND BRASSWIND EMBOUCHURE PEDAGOGY

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The purposes of this study are to identify and describe the function and control of facial muscles as related to sound production on brasswind instruments, to explore electromyographic theory and techniques with particular regard to the function and control of facial muscles, to identify basic theories of embouchure among brasswind teachers and performers, to develop a theory of brasswind embouchure based upon the preceding factors, and to propose recommendations with regard to brasswind pedagogy.

Existing theories of embouchure were investigated by reviewing the extensive brasswind pedagogical literature, and by interviewing teachers representing two widely differing views.

Electromyographic kinesiology of facial muscles was investigated as follows: a description of facial muscles was formulated by collating anatomy books; related electromyographic literature was reviewed; electromyographic recordings of facial muscles during the performance of various

facial muscle tasks and during brasswind performance were made using indwelling fine-wire electrodes.

The following fundamental questions were raised: (1) What are the elements of brasswind embouchure, and what is the effect of each upon performance? (2) Is there a single embouchure mode which may be considered most efficient, and if so, what facial muscles are involved, and how may they be trained?

Based upon all of the above, the following theory of embouchure is advanced: There is a single embouchure mode which is most efficient for all brasswind players, on all brasswind instruments. The term <u>efficient</u> refers to the minimal expenditure of energy consistent with the ends to be achieved. A rationale is presented supporting the following facial-muscle-and-jaw posture and facial muscle activity pattern as most efficient in brasswind embouchure: The mandible is positioned so that the incisal teeth edges are vertically aligned during performance throughout the entire range of the instrument, with 1/4 inch basic aperture between the upper and lower incisal teeth; vertically, the modioli remain in their natural resting position; horizontally, they remain either in their natural resting position or are moved medially; the upper and lower lips touch opposite the center of the teeth aperture, inverting slightly, but not crossing the incisal teeth edges; the mouthpiece inner edge rests above the red of the upper lip, approximately centered vertically opposite the lip aperture, and is centered horizontally opposite the largest part of the incisal aperture; mouthpiece pressure is greatest near the midline of each lip, and is distributed slightly more to the bottom lip; the modioli are fixed vertically by the levator anguli oris (LAO) muscles and their antagonists, the depressor anguli oris (DAO) muscles; horizontally the modioli are positioned by the incisive, LAO, and DAO muscles and their antagonists, the buccinator muscles; the zygomaticus major, platysma, risorius, quadratus labii superioris, and quadratus labii inferioris muscles remain relaxed at all times; the mentalis muscle is slightly to moderately active involuntarily; the lips touch and invert by combined action of the buccinator and compressor labii muscles, assisted by LAO and DAO; postural changes during performance include modifying slightly the size of the incisal aperture and the amount of red-lip inversion; contraction in the active muscles above increases directly with lip vibrational frequency and tonal intensity.

Implications for brasswind pedagogy are discussed in relation to advisement concerning selection of instrument type, training optimum embouchure at beginning through advanced levels of performance, and remedial work.

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INTRODUCTION

Background to the Study

Twelve years ago Robert Weast wrote

> Brass pedagogy could easily be assumed to be in a state of chaos if one examines the highly and bitterly contradictory theories purported to be the truth . . . . A good deal of prejudice exists, and this, plus lack of a concise, specific brass vocabulary, adds to the general confusion (31, p. 1).

In the ensuing years this statement has become less true with regard to all physiological aspects of brasswind performance except embouchure. Critical examination of breath support, tongue and jaw action, lip vibrations, and mouthpiece pressure has led to better understanding of these aspects of brasswind performance. Scientific investigation of embouchure, however, has not materialized; and the confusion and contradictions referred to by Weast still exist. Wide variations are to be found in embouchure description and function. Furthermore, there is disagreement among players and teachers concerning the importance which should be assigned the subject. Some believe that the development of embouchure should be left to the natural tendencies of the individual, while others believe it too great a risk to be left to chance.

Tanner (29, p. 50), for example, interviewed one hundred teachers of trombone at American colleges and conservatories and found a prevailing attitude toward building the breathing process and letting embouchure take care of itself. This attitude is also common among professional players, who often have been fortunate enough to solve embouchure problems without giving much thought to the processes involved. Faulkner (7, p. 299) tells of asking Harry Glantz, first trumpeter of the NBC Symphony under Toscanini, to describe his embouchure. He replied, "I just screw up my lips and blow."

This attitude is not shared by all. Many brasswind pedagogists believe the teaching of embouchure to be the most acute problem they face. However, a lack of adequate equipment and investigative techniques seems to have been one deterent to continued research in this area of concern.

Developments in two areas of medical research have opened the possibility that such techniques are not available: (1) electromyography, which provides information concerning the electrical activity in muscles; and (2) thermography, which gives measurements of minute temperature changes in segments of the body. In this study, inquiry is made concerning the feasibility of employing electromyographic theory and techniques to elucidate brasswind embouchure.

Statement of the Problem

The problem is a study of (A) facial muscle function and control, (B) electromyographic kinesiology, and (C) brasswind embouchure pedagogy.

Purposes of the Study

The purposes of this study are to

A. Identify and describe the function and control of facial muscles related to the production of sound on brasswind instruments.

B. Explore electromyographic theory and techniques with particular regard to the function and control of facial muscles.

C. Identify basic and accepted theories of brasswind embouchure among teachers and performers on brasswind instruments.

D. Develop a theory of the function and control of the embouchure in sound production on brasswind instruments based upon electromyographic theory and techniques.

E. Propose recommendations with regard to brasswind pedagogy.

Fundamental Questions

Fundamental questions to be considered in this study include

1. What are the elements of brasswind embouchure, and what is the effect of each upon brasswind performance?

2. Is there a single embouchure mode which may be considered most efficient for all brasswind players on all brasswind instruments?

3. If there is a single optimum mode of embouchure, what are its physiological and kinesiological characteristics? What facial and jaw muscles are involved, for what purposes, and to what extent?

4. If there is a single optimum mode of embouchure, how may it be trained?

Definition of Terms

1. The term kinesiology is a combination of two Greek verbs, kinein, meaning to move, and logos, to discourse. Kinesiologists--those who discourse on movement--in effect combine anatomy, the science of structure of the body, with physiology, the science of function of the body, to produce kinesiology, the science of movement of the body (5, p. 21).

2. Electromyography is the recording of muscle potential, or the electrical activity within a given muscle or group of muscles. When a muscle contracts, an electrical impulse spreads from that muscle to the skin. The activity can be measured by inserted electrodes (needle or wire electrodes inserted into the muscle fibers) or by surface electrodes (electrodes at the skin). The total amount of voltage varies with the number of muscles contracting simultaneously--the more fibers contracting, the greater the

voltage. "Electromyography is unique in revealing what a muscle actually does at any moment during various movements and postures. Moreover, it reveals objectively the fine interplay or coordination of muscles" (2, p. 22).

3. Facial muscles included in this study refer only to the muscles intrinsic to the upper and lower lips, and all muscles inserting into the lips.

4. Lip vertical mass includes the amount of lip between the tip of the vibrating area where the lips touch as a part of the vibration cycle, and the point in a vertical direction where the vibrating area of each lip ends.

5. The term embouchure refers to the lip technique involved in producing and controlling sound on brasswind instruments. It will not preclude the effects of such contributing factors as breath pressure, tongue, and jaw setting; but it will emphasize the function of the facial muscles in the playing of brasswind instruments.

Review of Literature

Recent utilization of modern technology has precipitated more objective inquiry into the various physiological activities associated with brasswind performance. For example, breath support has been critically analyzed, and the findings have shown much of the pituresque language on this subject appearing in teaching texts and journal articles to be erroneous. The term diaphramatic support has taken on a different meaning, as actions of the diaphragm, abdominal, intercostal, and other muscles of respiration have been studied scientifically (2, 4, 5, 6, 7, 8, 27). In addition, oral adjustments during brasswind performance have come under scientific study (1, 13, 14, 22), as actions of the mandible, tongue, and pharynx have been described through use of radiographic, fluoroscopic, and X-ray techniques. Measurements of heart volume and rate (10), interthoracic pressure (8), and blood gases (9) during brasswind performance have been made.

Scientific studies describing lip vibrations during brasswind performance (15, 16, 31) have produced considerable information regarding lip activity while playing. These studies bear indirectly upon brasswind embouchure, showing particularly that the lips touch as a part of their vibration cycle. However, no knowledge has been advanced concerning those embouchure factors which cause the lips to touch or to vibrate in the manner described.

Nowhere in the literature could a critical study of embouchure be found. Furthermore, a survey of anatomy books (11, 25, 26, 33) showed that ordinary descriptions of facial muscles provided little aid for understanding what muscles are active in embouchure. Also, it was found that studies of normal facial muscle kinesiology were rare (3, 18); no studies were concerned with facial muscle kinesiology as applied to embouchure.

If accurate, detailed information concerning the function and control of facial muscles can be obtained, perhaps many of the misconceptions and contradictions found in brasswind playing and teaching can be resolved. These contradictions may be found in every aspect of brasswind embouchure. A survey of brasswind literature, to be discussed in detail in Chapter 4, shows that there are widely varying opinions concerning the placement of the lip corners, the amount of tension in the lips, the location of tension, the relationship of the chin to embouchure, the location of the lower lip horizontally, the amount of lip compression, and the movement of the lips.

The great controversies in embouchure center on the extreme high range, especially on trumpet. Most players have very little trouble with the middle and low ranges, but they experience some difficulty in mastery of the high register; and they are unable to manage the extreme high range without undue mouthpiece pressure, which is damaging to the lips. Teachers at the college level usually discourage their students from working in the extreme upper range, considering it more a detriment to normal performance than a desirable goal. Many believe (30, p. 338) that "high note" players are "born not made," and that different embouchure control is needed for the extreme high register than for ordinary playing. However, some noted writers disagree, offering the highest register to all who follow the particular approach to embouchure advocated by them (21, p. 28). Instructions in such texts are often cryptic, however, and take on different meanings for different readers. Communication suffers for want of a clear, precise vocabulary describing the components of embouchure, their function and control.

Basic scientific study of brasswind embouchure is needed if these confusions and contradictions are to be resolved. Such study must be concerned initially with two principal considerations: (1) anatomical, identifying the facial and jaw muscles involved; and (2) kinesiological, identifying the amount of involvement of each muscle in brasswind embouchure, and the timing or pattern of muscular activity. These anatomical and kinesiological considerations must be weighed in terms of brasswind performance factors, such as tone quality, pitch, and dynamic range, flexibility, control, and endurance. This inevitably involves musical value judgments, which are highly subjective in nature, but which also involve efficiency factors, which can be approached objectively. The term efficiency refers to the minimal expenditure of energy consistent with the ends to be achieved (20, p. 124). Probably some facial muscles are not used in brasswind performance when the embouchure is functioning in a most efficient manner. If this is true, training for efficiency must involve the isolation of the correct muscles at the appropriate level of activity.

Few studies were available which were related to the normal kinesiology of facial muscles. Scientific discussion of embouchure must start by identifying the facial muscles involved, and by seeking kinesiological information concerning the involvement of these muscles as prime movers, synergists, stabilizers, and antagonists. Electromyography has provided the best approach to such study in other muscles.

There is some question concerning the possible effectiveness of electromyographic techniques in the study of facial muscles. Long (19) is not sure that electromyography can give the information needed, and Moldaver (23) doubts that a study of the kinesiology of facial muscles is feasible. In contrast, Basmajian (2, p. 334) discusses the need for electromyographic study of the facial muscles; this interest has led to his cooperating in the present study.

Procedures

The following procedures were used in this study:

1. An extensive review of the literature was made to determine those aspects of brasswind embouchure needing critical study. Attention was focused particularly upon areas where empirical views were most divergent.

2. Interviews were held with certain brass teachers representing two widely differing views on the subject of brasswind embouchure. A description of these views may be found in the Appendix, followed by a listing of questions

raised. Two authorities representing each view were interviewed, including John J. Haynie, Professor of Trumpet, North Texas State University, representing method number one, and Roy Stevens, Costello Studios, New York City, representing method number two. Two additional teachers were questioned, as recommended by Mr. Haynie and Mr. Stevens.

3. Electromyographic theory and its possible use in a study of the kinesiology of facial muscles as used in brasswind embouchure were investigated as follows:

a. A detailed description of facial muscles was formulated by collating materials from certain leading anatomy texts.

b. Literature in the area of electromyography was reviewed, and a summary of electromyographic theory presented.

c. Electromyographic recordings of facial muscles during the performance of various facial muscle tasks and during brasswind performance were made. (These recordings were made at Emory University Regional Rehabilitation Research and Training Center, Atlanta, Georgia, with the advice and assistance of J. V. Basmajian, Director of the Center.)

d. Fundamental questions were developed which served as the groundwork for a theory.

4. A theory of brasswind embouchure function and control was propounded.

5. Recommendations for brasswind pedagogy, based upon findings in the study, were made.

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CHAPTER II

MUSCULAR STRUCTURE AND ACTION

Muscles supply the force for moving, or holding immobile, segments of the body. They do this by virtue of two characteristics: (1) their unique ability to contract, and (2) their attachment to bone or other tissue. The term voluntary is frequently used in classification of muscles, but the description is merely a convenient convention applied to muscles that take part in movements made of one's own free will. The will orders a movement but does not ordinarily select the muscles required, nor alter the definite order in which their activity performs the movement (17, p. 150).

The basic function of muscle is to convert electrochemical energy into mechanical energy, a process that has been described in detail by biochemists and need not be discussed here. However, for the reader with limited background in human anatomy and kinesiology, certain information concerning the structure and action of muscles should prove useful throughout this study.

Muscle tissue is composed of bundles of individual cells known as muscle fibers, of highly elaborate structure.

These fibers are thread-like, less than 1/1000 of an inch wide, and from 0.1 to 4.0 cm. long (6, p. 119). Because of this short length, muscle fibers rarely, if ever, run the entire length of a muscle, but rather form overlapping relays (6, p. 124). Muscle fibers occur in groups known as fasciculi, or small bundles, the number of fibers per bundle being variable. Each bundle is surrounded by fibrous tissue which separates it from the others. These groups constitute the muscles as we see them grossly.

Each muscle is provided a motor nerve which branches out to bring all parts of the muscle under its control (6, p. 120). A single motor nerve fiber innervates a number of muscle fibers. It has been found that muscles performing delicate movements have a small number of muscle fibers per nerve fiber, as few as three in some instances (4, p. 64). A motor nerve fiber with the muscle fibers it innervates is called a motor unit, consisting of anywhere from three to hundreds of muscle fibers, all stimulated by a motor nerve fiber, and all contracting when a stimulus occurs.

An individual is endowed at birth with a fixed number of muscle fibers which cannot be increased. Even the largest bundles of these fibers are quite small. In producing movement a muscle may contract to approximately one half its length; or where no movement occurs, it may be in a full state of contraction without changing length. The terms contraction and tension are used synonymously, whether shortening occurs or not.

Dynamically, a muscle only contracts or relaxes. A brief twitch (contraction) occurs when a nerve impulse reaches a muscle fiber, and the contraction is followed by rapid and complete relaxation. The duration of this twitch is from one to four milliseconds (4, p. 12), during which time a minute electrical potential is generated which dissipates into the surrounding tissues. Such electrical activity in living tissue is related to the existence of polarized membranes at the cellular surfaces, the resting electrical charges being positive on the external surface of the muscle fiber and negative on the inner surface. When the fibers are activated, these charges are reversed, producing an electrical current (33, p. 49).

All the muscle fibers of a motor unit do not contract at exactly the same time, although they respond as a unit. Some are delayed for several milliseconds, prolonging the electrical potential developed by a single twitch of all the fibers in the motor unit to about five to twelve milliseconds. The electrical result of the motor unit twitch, then, is an electrical discharge with a median duration of nine milliseconds and a total amplitude measured in microvolts (4, p. 12). The majority of these motor unit potentials is around 500 microvolts.

A steady muscular contraction is achieved my many scattered motor units within a muscle contracting repeatedly and asychronously. The upper limit frequency at which a nerve may send impulses to a motor unit is usually below fifty per second. If stimuli arrive close together, the twitches of a motor unit tend to fuse somewhat, producing a higher force. If stimuli arrive fast enough, fusion of twitches becomes complete, giving a steady maximum force typically four times that of a single twitch maximum (4, p. 64).

A muscle can act either as a whole or by parts; therefore, a total or partial movement of any one muscle may occur. Muscular strength is dependent primarily on the number of motor units employed in a given task and on the frequency of their contraction. The larger the number of motor units and the greater their frequency of discharge, the greater the force generated. Efficiency factors are also of importance. The optimum angle of pull for any muscle is a right angle (6, p. 122), and as a muscle approximates this angle, it becomes more efficient. Conversely, as the angle becomes more obtuse, the muscle becomes less efficient. A muscle, then, is weakest when at maximum length and becomes stronger as it shortens to form approximately a right angle. Stated yet another way, a muscle stretched from its resting length performs less efficiently than when at its resting length or shorter.

Another factor in muscular strength is the cross-sectional measurement of muscle fibers. The greater the area of cross section of individual fibers, the greater the force exerted during contraction. This cross-sectional area can be increased through appropriate exercise.

Range of movement is dependent upon the length of the muscle fibers involved; the longer the fibers, the greater the range of movement available. Where range of movement required is short, and power needed, Nature provides numerous short fibers; for wide range of movement without need for strength, long but fewer fibers are supplied.

When a muscle contracts, its fibers not only well, but become harder. A muscle, then, is active when it hardens (5, p. 95). A relaxed muscle fiber offers resistance to forces that stretch it, due to its viscous and elastic properties.

Two terms, <u>isometric</u> and <u>isotonic</u>, are often used to describe muscular action, the former meaning equal length, the latter, equal tension. During isometric contraction there is no appreciable change in the length of muscle fibers as the tension increases. During an isotonic contraction, the tension remains somewhat constant as the muscle shortens, mechanical advantage or efficiency factors causing some alteration in the tension.

Muscles are named according to various characteristics, including their shape, size, location, and known or presumed action. Anatomically, it is of interest to determine the origins and insertions of muscles, the origin often being the more fixed point; the insertion, the more mobile. However, these roles may be reversed in different actions, so that it is less confusing in some instances to label both merely as attachments. The most important feature of a muscle, its action, may roughly be judged by approximating the two attachments. However, this judgement does not take into account the interaction of that muscle with other muscles.

Muscles are also described according to their role in a particular movement. A muscle ordinarily does not act alone; rather, its activity is usually coordinated with that of other muscles. Such terms as prime mover, antagonist, fixator, and synergist are used in defining the particular role a muscle plays in a given movement. Prime movers are the principal muscles actively producing a movement. Antagonists are capable of preventing or reversing a particular movement, or may regulate its power and speed. Fixation muscles steady one part, thereby providing a firm base for movement executed by other muscles. Synergist muscles aid the prime movers, preventing unwanted action of the prime movers. Actually, this latter term is rather broad and overlaps to some extent the function of the fixation and antagonist muscles. A muscle may be a prime mover in one situation, an antagonist in another.

The preceding terms are not completely standardized in their usage, allowing for some confusion in describing the roles of muscles. Some authors (4, p. 87; 17, p. 150) believe that the term antagonist, for example, is a poor choice because the antagonists actually assist in a movement by relaxing as the prime mover contracts. According to Lockhart (17, p. 150), the stronger the action of prime movers and the greater the resistance they encounter, the more relaxed are the antagonists. When the prime movers are engaged in a careful precise movement, the antagonists are relaxed but ready to steady or moderate the movement almost as a guy rope. In isometric contraction, both prime movers and antagonists may act at the same time under the will.

Basmajian (4, p. 86, 88) states that the rule is for the antagonists to relax. Further, there is evidence that activity of antagonists in some movements is a sign of nervous abnormality, or, in the case of fine movements requiring training, a sign of ineptitude. Reducing or eliminating unneeded synergist muscle activity is an important feature of training.

The word tone (or tonus) is used in evaluating the condition of muscular tissue. There has been a misconception that a muscle at rest preserves a certain firmness known as "tone," brought about by a small amount of neuromuscular activity. The usual definition of tone should be modified to state that the general tone of a muscle is determined both by the passive elasticity or turgor of muscular tissues and by the active (though not continuous) contraction of the muscle in response to the reaction of the nervous system to stimuli (4, p. 71). Muscles develop increased tonus through exercise.

Certain muscles can be shortened by exercise within a limited range of movement (25, p. 57). When a muscle is habitually held and used in a shortened position, the muscle will shorten in time and accommodate itself to the new length with restoration of normal tone; the joint affected will then have a new resting position. This implies, of course, that the antagonist muscle group will be correspondingly stretched, and that it will accommodate itself to the new length and re-establish its normal tone.

A muscle, therefore, can be modified or improved according to the manner in which it has been used. Obviously, such factors as efficiency, frequency, and appropriateness of activity affect the development of muscles.

Earlier it was stated that the will orders a movement but ordinarily cannot select the muscles required. This would appear to confirm the belief, held in the past by neurologists, that the human brain can "think" or "picture" only movements of joints--that it cannot consciously call upon isolated contraction of specific muscles. However, Scully and Basmajian (27, p. 480) have shown that 80 per cent of normal people, provided with audio-visual electromyographic feedback, can recruit single motor units in isolation while consciously inhibiting all the neighboring units. This can be done with very little difficulty, within fifteen minutes, and even by two-year-old children (11, p. 66). With addtional training, a normal person can maintain motor units in regular isolated activity, manipulate the frequency of motor unit discharges at will, and even produce specific rhythms of single motor unit activity such as drum cadences (27, p. 625). Such fine control can be maintained not only while the body is relaxed, but also during distractions produced by voluntary movements elsewhere in the body, and with most subjects, after the removal of audio-visual cues.

The comments of subjects undergoing motor unit training are cryptic; they can only explain their control over activity of single motor units by saying that they "think" about them. Basmajian (8, p. 1,428) noted that the proprioceptive influences over motor unit response seem to be of prime importance. He suggests that training involves structural or functional modifications of the nervous system which have not been determined with certainty. A generally accepted proposal is as follows:

> Voluntary effort is reinforced by a feedback mechanism, which is simply an output-input system. The output is the motor unit; the input system consists of different sensory pathways. Sensory systems detect the internal and external environmental changes by way of specialized receptors: proprioceptors, exteroceptors, and interoceptors (7, p. 1,429).

Techniques for training conscious control over individual motor units provide a method of testing the acquisition of a fundamental motor skill and factors which influence it. For example, Scully and Basmajian (27) have shown that manually skilled subjects could not isolate single motor units in the hand as well as unskilled subjects. Therefore, they suggested that neuromuscular pathways acquire a habit of responding in certain ways; and it is not until old habits are broken that new skills can be learned.

Simard, et. al. (30) studied the effects of circulatory changes on the behavior of a single motor unit by applying a tourniquet just above the knee. During occlusion of circulation, the maintenance and recall of isolated activity of the trained motor unit were extremely difficult, due possibly to suppression of the innate proprioceptive feedback mechanism and to a decrease of motor-nerve conduction.

From a therapeutic point of view, perhaps the most significant application of single motor unit training has been in the area of rehabilitation of paralyzed patients and in the provision of myoelectric prostheses and orthoses for disabled persons. Of particular interest to the brasswind player is the discovery that when a muscle or a part of a muscle is found to be permanently denervated, residual motor units from other muscles, or from several parts of the same muscle, can be recruited and trained to overcome the disability (8, p. 1,427). For example, if those facial muscles essential to brasswind embouchure could be determined, it is conceivable that partial paralysis of one or more of these muscles, or damage resulting from abuse as a result of improper playing techniques, could be overcome and excellent playing conditions achieved.

From the above, it would appear that if the brasswind player understands the musculature of the face, and the functional relationship of facial muscles in brasswind performance, he may be able to analyze his technique and perhaps to improve it.

Muscles in Brasswind Performance

In brasswind performance certain muscles of the jaw and face are active in forming the embouchure and in holding the proper lip setting while playing. The muscles affecting jaw movement are to be differentiated from facial muscles and are of secondary interest in this study. However, due to their proximity to the facial muscles and their importance in positioning the lower jaw in embouchure, it seems useful to describe them here.

The muscles of jaw movement are of interest in brasswind performance in that they regulate the opening between the upper and lower front teeth, through which air must pass from the lungs to reach the lips, and they establish the angle at which the instrument must be held for efficient performance. These muscles include the mylohyoid and digastric muscles, which forcefully depress the jaw, and the muscles of mastication, which elevate the jaw, move it laterally, forward, or to a lesser degree, backward. Muscles of mastication include the temporalis, masseter, medial pterygoid, and lateral pterygoid.

The mylohyoid muscle is named for its attachment to the jaw (mylo) and to the hyoid bone (a slender U-shaped bone whose outer surface can be felt through the skin at the meeting-place of the front of the neck and the floor of the mouth). This paired muscle arises from the mandible, and its most posterior fibers reach the hyoid bone (Figure 1). Farther forward, the fibers of the two sides meet and interlace in the midline, forming a raphe (seam). The mylohyoid contracts to forcefully depress the jaw.

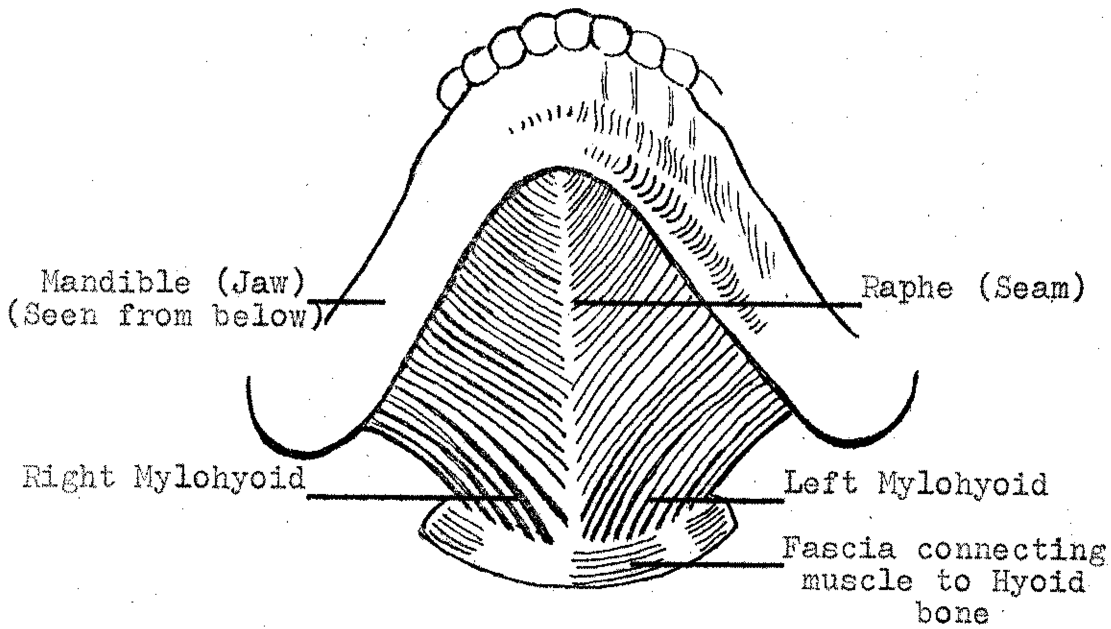

Fig. 1--Right and left mylohyoid muscles form floor of mouth. (After Basmajian.)

The digastric muscles (di = two, gastric = belly) include anterior and posterior bellies. The two anterior bellies lie below the mylohyoid muscle (Figure 2), arise near the midline of the mandible, and descend to the hyoid bone. The two posterior bellies arise from the mastoid

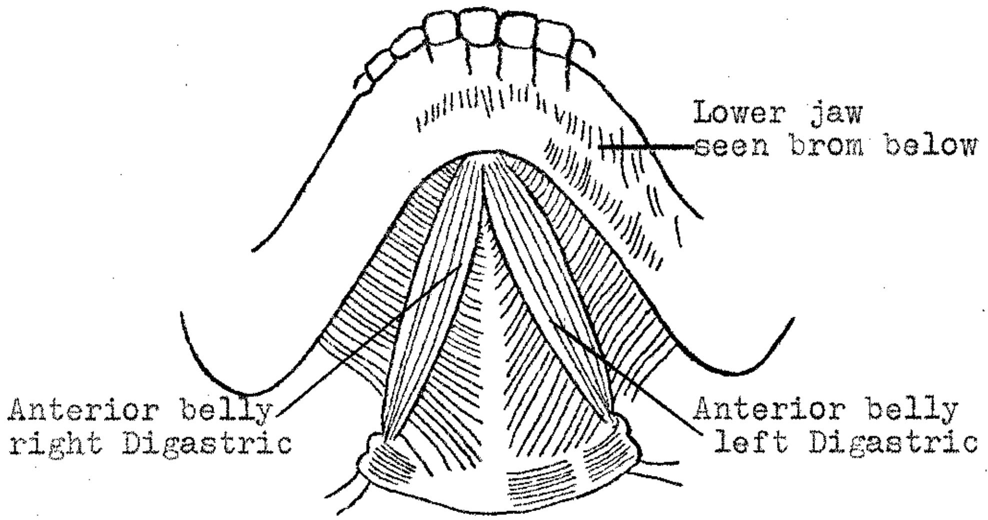

Fig. 2--Anterior bellies of right and left digastrics. (After Basmajian.)

process (projection) and descend to the hyoid bone (Figure 3, page 29). The anterior bellies perform the same actions as the mylohyoid, working together with it to depress the jaw forcefully. In ordinary mastication, gravity is the force which depresses the jaw.

The temporalis muscle, named for its location over the temple (temporal bone), is an extensive, fan-shaped muscle arising from the side of the cranium and descending to the coronoid projection of the mandible where the "handle of the

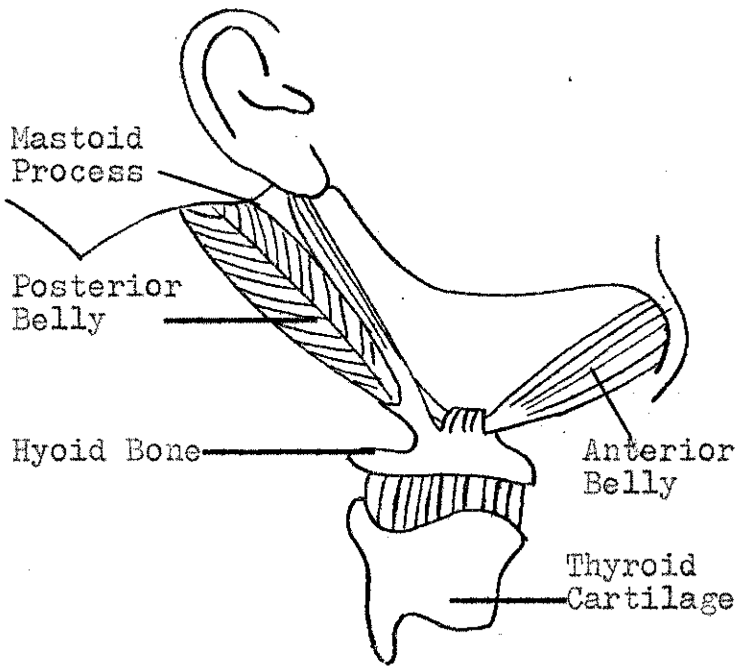

Fig. 3--The two bellies of (right) digastric (after Basmajian).

fan" is inserted (Figure 4, page 30). It is a powerful biting muscle, easily seen on the side of the head when in action. Its posterior fibers recede the mandible.

The masseter (chewer) is a thick muscle covering the outer surface of the ramus (branch) of the mandible (Figure 5, page 30). It arises from the zygomatic (cheek) bone, and its fibers run downward and backward, inserting in the outer surface of the ramus and coronoid process of the mandible. It is a powerful biting muscle and also protrudes the jaw.

The pterygoids (pterygoid = wing-shaped) are so named because of their origin from a muscular plate at a wing-shaped

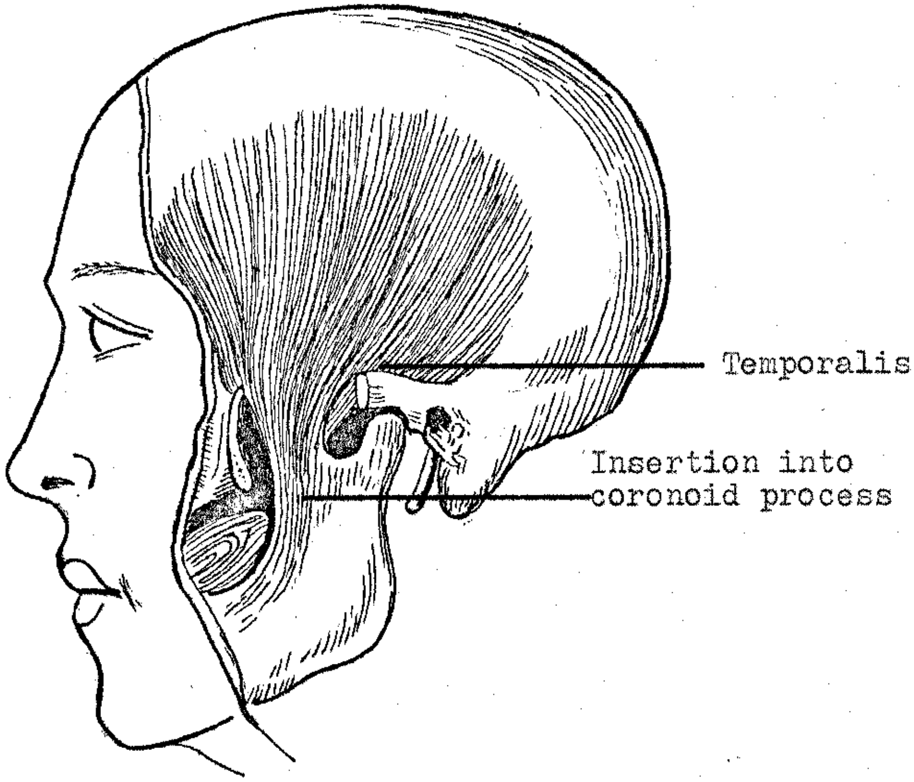

Fig. 4--Left temporalis (after Basmajian)

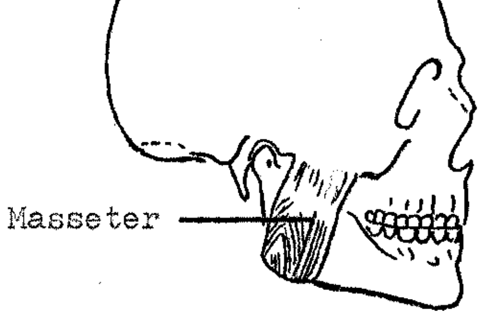

Fig. 5--Right masseter (after Basmajian)

bone in the skull (Figure 6). The medial pterygoid lies on the inner side of the ramus of the mandible and has a general shape and direction similar to that of the masseter. Its origin is on the medial (toward the middle) side of the plate, and it inserts into the ramus in the region of the angle of the mandible. It is a biting muscle similar to the

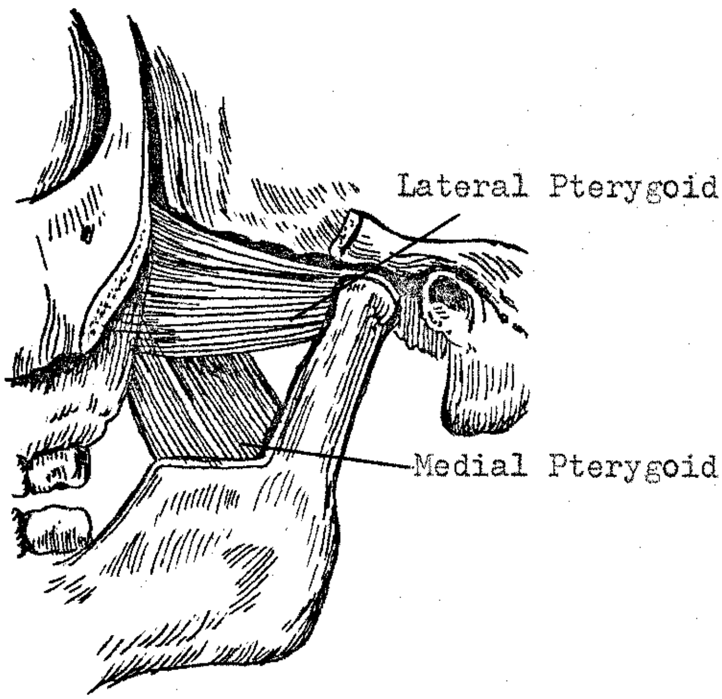

Fig. 6--Lateral and medial pterygoids (After Morris.)

masseter, but in addition, it draws the jaw toward the opposite side in grinding movements, the muscle on the left side moving the jaw to the right, and the muscle on the right side moving the jaw to the left. The lateral pterygoid has an altogether different direction from the preceding three muscles (temporalis, masseter, and medial pterygoid), lying in a horizontal plane which runs backward and laterally. It rises on the lateral surface of the muscular plate and inserts on the neck of the mandible. It pulls the jaw forward, and alternates with its fellow of the opposite side to produce side movements.

Oro-Facial Musculature

By definition facial muscles include only those muscles supplied by the facial (seventh cranial) nerve. They are to be distinguished from muscles that move the jaw, and which are supplied by the trigeminal (fifth cranial) nerve. Often referred to as muscles of facial expression, they move the skin of the face and are characterized by their limited attachment to bone and extensive attachment to the skin of the face, and to the mucous membrane lining the inside of the mouth. The number of muscle fibers per motor unit is probably between 3:1 and 5:1, permitting extremely fine control of movement.

There is extreme variability from person to person in development, size, shape, strength, and independence of the oro-facial muscles (26, p. 393; 29, p. 140). These muscles vary from a few pale bundles in one person, to solid, thin muscle plates of dark red color in another. In many cases one muscle will exchange fiber bundles with another, or two neighboring muscles will fuse into one muscular unit, making it difficult, in dissection, to separate one muscle from another. For these reasons it is not suprising to find considerable variation among authors in their description of these muscles.

Primarily the facial muscles surround the orifices, including the eyes, nose, and mouth, and are either sphincters (contracting to close the orifices) or dilators (contracting to open the orifices). Since in brasswind performance it is generally agreed that the upper and lower lips must vibrate, and must touch to do so, interest is centered primarily upon the oro-facial musculature, the mouth orifice. These are described in detail below.

Modiolus

Located just lateral to each corner of the mouth is a concentrated insertion or crossing of muscle fibers. This area is often referred to as a tendinous node or knot, created by the meeting of eight muscles. In brasswind literature the name modiolus (meaning hub of a wheel with radiating spokes) has been used to a considerable extent in referring to this area, and seems destined to become standard terminology (24, p. 9). For this reason, the term will be adopted in this study. The modioli can be felt by placing one's fingers approximately one inch lateral to the mouth corners and pulling the mouth into various positions. Some of the muscles passing through this area arise from bony origins and may be thought of as forming the shape of a cross (Figure 7) as they approach the modiolus. In contracting, these

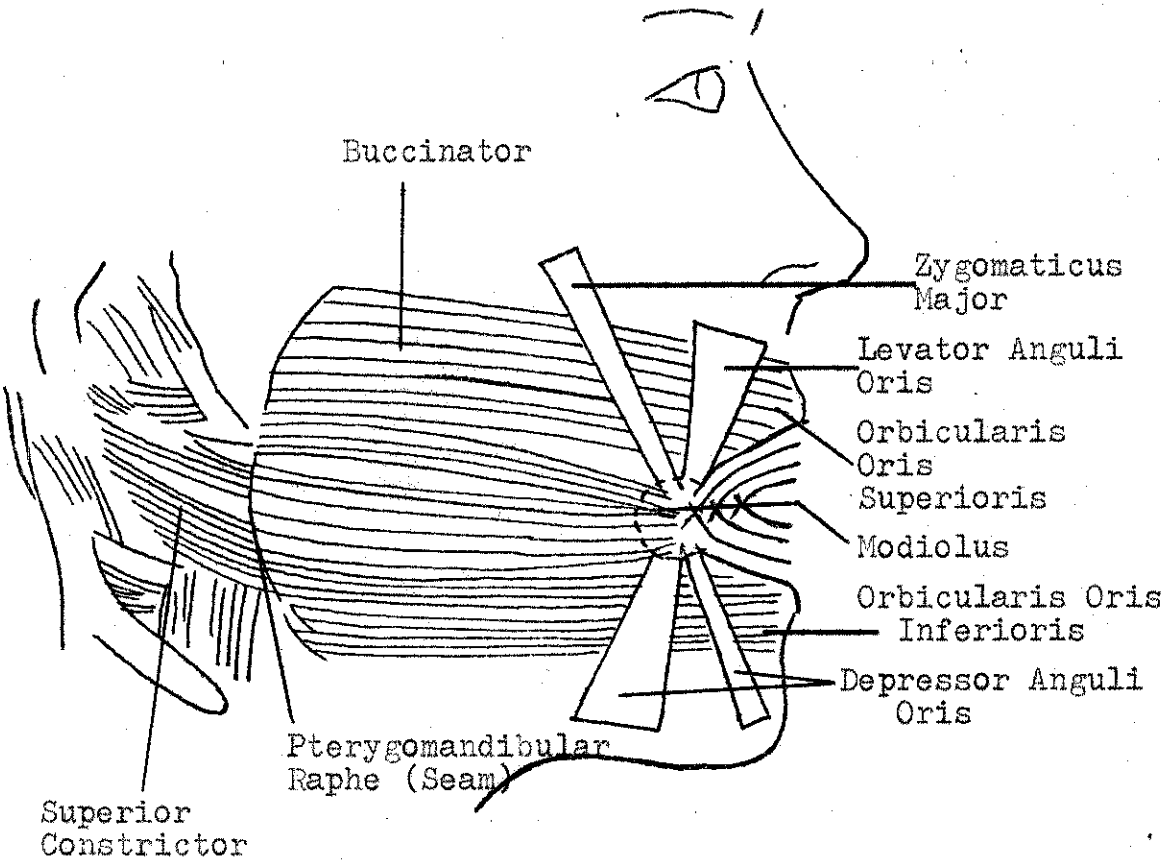

Fig. 7--Modiolus, orbicularis oris, levator anguli oris, depressor anguli oris, zygomaticus major, buccinator, pterygomandibular raphe, and superior constrictor.

muscles fix the modiolus firmly in any of a variety of positions, either forward, backward, up or down, within a considerable range (5, p. 42).

<u>Orbicularis Oris (Orbis = Ring, Oris = Mouth)</u>

The orbicularis oris muscles, or muscles of the lips, often referred to as intralabial muscles, effect direct closure of the mouth. They represent the most complex area of facial musculature, and are the most difficult to describe. They are usually referred to as a single circular muscle, but are actually a curious mixture of muscle fibers, some of which are intrinsic to the lips, while others are a continuation of fibers originating outside the lips.

The orbicularis oris is approximately an inch wide, extending upward almost to the nose, and downward to the groove on the skin midway between the chin and red portion of the lip (13, p. 577). The peripheral part (that part nearest the nose and chin) is thinner in width and thicker in depth (2, p. 314).

The muscle is not circular, there being no true orbicular or circular fibers (16, p. 22); rather, the fibers at the corners cross each other at acute angles, so that there are two separate muscles, the orbicularis oris superioris (upper lip), and orbicularis oris inferioris (lower lip). The majority of fibers are confined to either side, so that orbicularis oris may also be divided anatomically into four sections, upper left and right, and lower left and right. Lightoller (16, p. 22) divides each of these four sections into two parts including marginal (red of the lip) and peripheral (main bulk of the lip), making eight sections. Most authors do not make this distinction.

Orbicularis oris fibers are attached to the modiolus, skin, and mucous membrane. The muscle also has attachment to bone via several muscles which originate outside the lips.

In the center of the upper lip, the fibers end in an area corresponding to the philtrum (groove under the nose), where the fibers cross the midline, some reaching the nasal septum. In the center of the lower lip, the fibers show a similar arrangement, some fibers interlacing with the lower lip depressor muscles.

The orbicularis oris consists of numerous strata of muscles, having different directions (12, p. 388). Those originating outside the lips make up the greater part of the substance of the lips. They include the cheek (buccinator) muscles, the muscles that elevate and depress the corners (levator and depressor anguli oris), and muscles that pull the lips apart (quadratus labii inferioris and superioris). These are described in detail below, as are other facial muscles which act upon the lips but account for very little lip substance. Buccinator fibers make up the deep stratum. The quadratus labii inferioris and superioris and zygomaticus major muscles send oblique fibers into the lips, intermingling with the transverse fibers. Other oblique fibers (compressor labii), of a more horizontal direction, are the fibers proper to the lips.

The Compressor Labii muscles are the only ones which originate and end in the lips. These muscle fibers pass from under the surface of the skin to the mucous membrane, through the thickness of the lips. Schaeffer (26, p. 395) refers to them as dorso-ventral (front-back) muscles, and names them compressor labii because of their function in compressing the lips.

The Incisive muscles give the orbicularis oris anchorage to the nasal septum and maxilla above and to the medial part of the mandible below. Named for their origin near the upper and lower incisive (front) teeth, they course laterally, closely following the peripheral bundles of orbicularis oris, to end in the modioli (fig. 8). Because of their bony

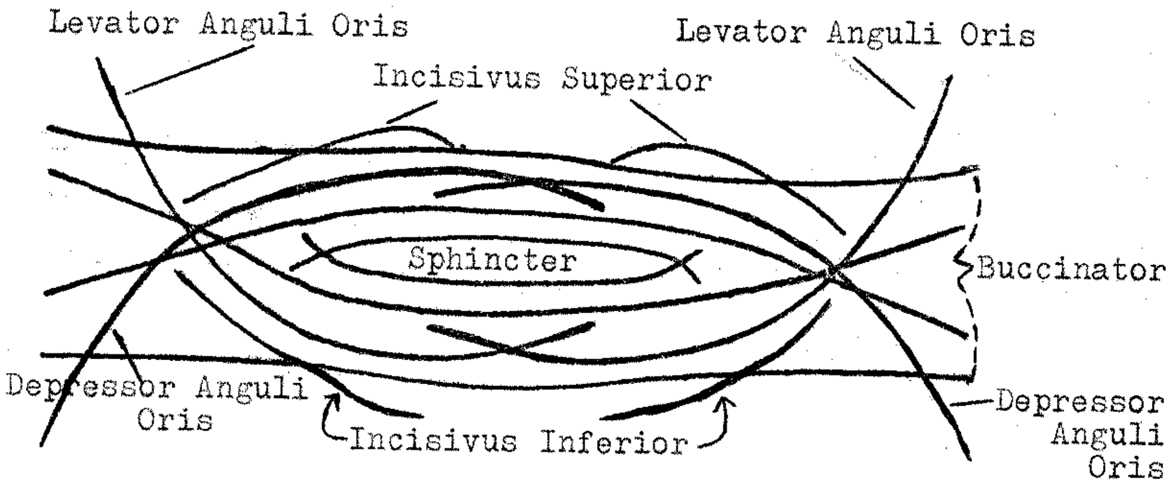

Fig. 8--Diagram to illustrate the architecture of the Orbicularis Oris. (Morris, after T.D. Thane) Note: Oblique fibers intrinsic to the lips not shown.

origin and their close association to the lips, they are sometimes referred to as accessory skeletal heads of orbicularis oris. In contraction they draw the corners of the lips medially, causing the lips to thicken and to protrude forward.

The various muscles of orbicularis oris may act independently, drawing the lips in the directions indicated by their structure, or they may combine with other muscles for various functions. For example, the compressor labii and buccinator muscles acting together draw the lips against the teeth (26, p. 396). The levator anguli oris, which draws the lower lip upward, and the depressor anguli oris, which draws the upper lip downward, act together to draw the lips together.

Buccinator (bucca = cheek, bucinnator = a trumpeter)

The buccinator is the principal muscle of the cheek, forming the wall of the oral cavity lateral to the teeth. It lies deeper than the other facial muscles; superficial to it lie zygomaticus major, risorius, and masseter. Wide, rather thin, and quadrangular in shape, it arises from a horsehoe-shaped line which can be followed from its (a) attachment to bone near the upper molar teeth, (b) attachment to a ligament known as the pterygomandibular raphe (Figure 7), and (c) attachment to bone near the lower molar teeth. Its insertion is complex, a factor which may explain the somewhat differing descriptions found. Schaeffer (26, p. 398) divides the fiber-bundles into four sets: (1) the most cranial extend directly into the upper lips; (2) those just above the mid-line pass through the modiolus into the lower lip; (3) those just below the midline pass through the modiolus into the upper lip; and (4) the lowermost fibers extend directly into the lower lip. The muscle is attached chiefly to the mucosa of the lips near the angle of the mouth; some fiber-bundles extend to the more medial portions of the mucosa, and some extend through the lip to the skin.

The fiber bundles arising from the upper jaw descend in their forward course, and those from the lower jaw ascend (29, p. 156). Thus, the bundles partly overlap each other so that the anterior part is thicker than the posterior part.

The buccinator compresses the cheek, pulls the lips against the teeth, and draws the corners of the mouth laterally (26, p. 398). Goss (12, p. 389) states that when the cheeks have been distended with air, the buccinator compresses them and tends to force the air out between the lips as in blowing a trumpet. However, Schaeffer (26, p. 398) states

> There is a general misapprehension that wind instruments are blown by the buccinators expelling air from the inflated cheeks, and indeed this is true of the bagpipes. But in blowing the trumpet and bugle and playing the cornet the cheeks must be kept flat and the upper lip taut which are in fact buccinator actions.

Lockhart also makes an interesting point:

> The trumpeter in blowing keeps this muscle tense to prevent or control distension of the cheeks. Expert wind players consider that the puffed-out cheeks of the wind-making cherubs on old maps show poor technique (17, p. 155).

The buccinator and incisive muscles are antagonists (9, p. 39) and play a part in establishing the horizontal position of the corners of the mouth. Lightoller (16, p. 32) believes, however, that this is a minor function of the buccinator, which for the most part remains free to perform its own functions between its lateral and medial attachments. He states that distention of the cheeks represents the normal and true resting length of the muscle fibers, the fibers at rest and undistended being longer than the distance between the points of attachment.

Levator Anguli Oris (Elevator of the Corner of the Mouth)

This muscle, sometimes referred to as the caninus, or canine, muscle because of its origin over the canine teeth, is more often named for its action in elevating the angle of the mouth. Arising just below the infraorbital foramen (an opening in the skull below the eye) this muscle extends downward and laterally, deep to the muscles that elevate the lip (Figures 7, 9). It is a flat, quadrilateral muscle, inserting into the modiolus. Some of the fibers merge with fibers of both lips, but most of them end in the skin and mucous membrane of the lower lip (29, p. 154).

The levator anguli oris elevates the corner of the mouth. Acting with the depressor anguli oris, it draws the angle of the mouth medially (12, p. 387). When acting with the muscles that elevate the lip, the furrow beside the nose (nasolabial sulcus) is accentuated.

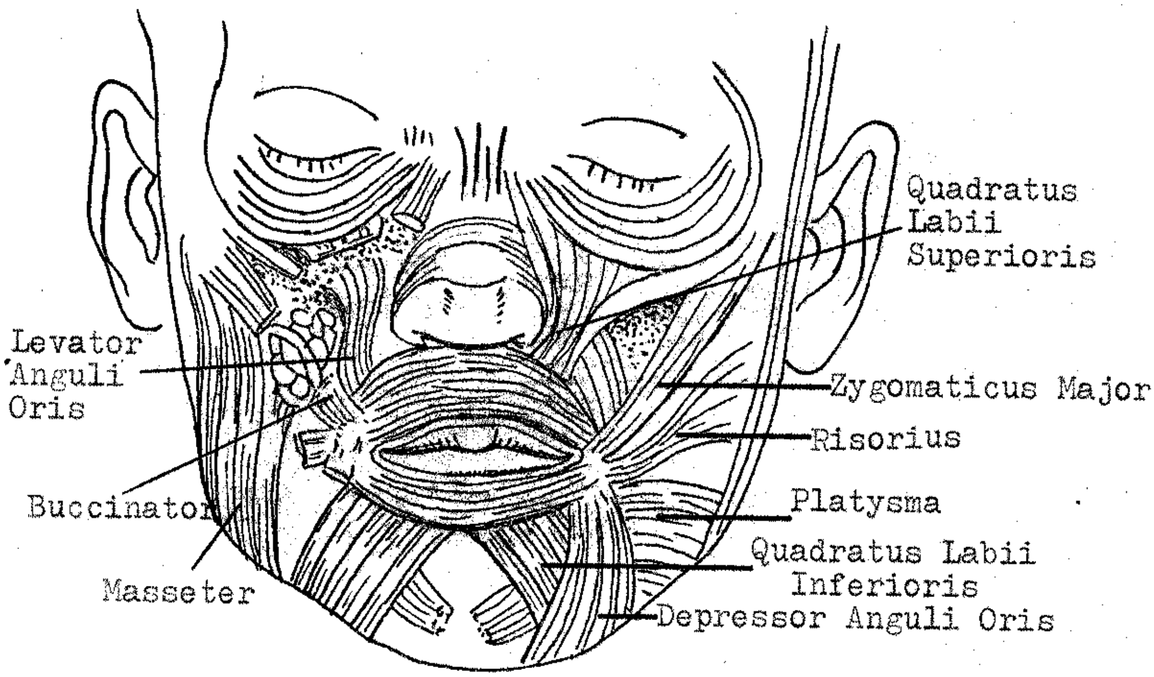

Fig. 9--The muscles of facial expression. Superficial layer on the right side of the figure; deep layer on the left side. (After Sicher.)

<u>Depressor Anguli Oris</u>
<u>(Depressor of the corner of the mouth)</u>

This muscle, sometimes called triangularis because of its shape (Figures 7, 9), is more often named for its action, depressing the angle of the mouth. Its fibers take origin from the oblique line of the mandible and, passing upward, converge at the angle of the mouth (31, p. 158). They blend with orbicularis oris and insert into the skin, many fibers entering the upper lip. The muscle is prominent and superficial. It is continuous, at its origin, with the platysma (12, p. 388), and, at its insertion in the modiolus, with risorius as well as with orbicularis oris. It crosses the muscle that depresses the lower lip (quadratus labii inferioris) and the buccinator (28, p. 24).

There are variations among authors in the description of this muscle. Fish (9, p. 43) states that it often has a double origin in bone at the lower border of the mandible. Lightoller (16, p. 17) describes the muscle as three-headed, including (1) a long head attaching to bone at the chin, (2) a lateral head extending as far outward as the first molar tooth, and (3) a buccal (cheek) head (actually a muscle more often named separately as risorius, described below).

The depressor anguli oris pulls the corners of the mouth and the upper lip downward, and is therefore the antagonist of the levator anguli oris and the zygomaticus major. Acting with the levator anguli oris, it draws the corner of the mouth medially.

Risorius (Grinning)

This is a thin, triangular wisp of muscle that arises from the superficial tissue over the masseter muscle and extends across the cheek, converging toward the modiolus so that the muscle gains in thickness as it courses laterally. Most of its fibers pass into and through the modiolus, partly interlacing with the fibers of adjacent muscles. The majority of the tendons end in the skin and mucous membrane just lateral to the corner of the mouth. Some bundles enter and end in the lower lip (29, p. 54).

The risorius is highly variable, often reduced to a few bundles widely separated from each other, or it may be missing entirely. It may be doubled, greatly enlarged, or blended with the platysma, which at the level of the corner of the mouth, turns into a horizontal course.

The risorius draws the corners of the mouth laterally. In spite of its name, it is not used to express pleasure, but instead, it gives rise to an expression of pain or a sardonic grin.

Zygomaticus Major (Zygoma = yoke)

This muscle is named for its origin on the outer surface of the zygoma (cheek bone). The name major or greater zygomatic is used to differentiate it from a smaller muscle which originates nearby, the zygomaticus minor. It is one of the most constant and best developed muscles of the middle face (29, p. 153). Arising from the zygomatic bone, this long, ribbon-shaped muscle descends obliquely to the modiolus, superficial to the masseter and buccinator muscles. It is frequently divided by the levator anguli oris into a superficial and deep part, the superficial fibers ending in a line extending the levator muscles of the upper lip laterally to the corner of the mouth. Many of the deep fibers end in the mucous membrane of the upper lip. Some bundles, however, may pass through the modiolus and reach the mucous membrane of the lower lip.

The zygomaticus major muscle pulls the corner of the mouth upward and laterally, as in laughing. When contracted greatly, it raises the cheek.

Quadratus Labii Superioris
(Square Muscle of the Upper Lip)

This muscle is actually composed of three separate muscles, which are usually treated as one due to the fusion of fibers in most cases to form a solid muscular plate. This plate may be visualized as extending from the midline below the nose laterally to the corner of the mouth (Figure 10). It arises from three attachments to bone, including (from the midline outward) origins at the root of the nose, under the eye, and on the cheek bone. Collectively the muscles contract to pull the upper lip upward, away from the lower lip. The three parts will be discussed separately.

The member arising from the root of the nose is a narrow band named for its action in elevating the upper lip and nasal wing (levator labii superioris alaeque nasi). As it descends toward the lips, it divides into two parts, one of which is attached to the skin of the wing of the nose, and the other to the upper lip in the neighborhood of

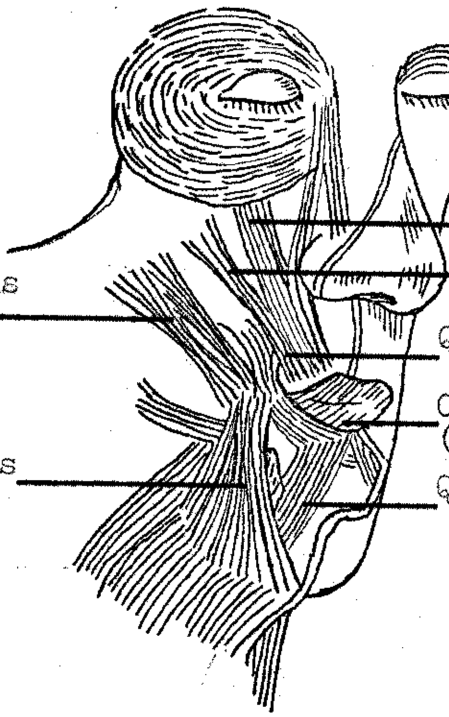

Fig. 10--Quadratus Labii Superioris, Zygomaticus Major, Levator Anguli Oris, Depressor Anguli Oris, Quadratus Labii Inferioris, Orbincularis Oris. (After Lightoller.)

the philtrum (the groove in the midline below the nose). It raises the wing of the nose and also that part of the upper lip just lateral to the midline.

The member arising from below the eye is also named for its action in elevating the upper lip (levator labii superioris). The fibers of this broad flat muscle descend to insert into the skin and outer portion of the upper lip. It raises and retracts the upper lip.

The third member is named for its origin on the surface of the zygoma (cheek bone). It is the longest and thinnest of the three divisions, and, to differentiate it from the greater zygomatic muscle, is called zygomaticus minor. It passes obliquely forward over the levator anguli oris and orbicularis oris muscle, and extends to a cutaneous and muscular insertion in the upperlip, medial to the corner of the mouth. Sicher (29, p. 152) reports that it is missing in about twenty per cent of the cadavers examined. As a rule, it is the weakest of the three muscles, and the most variable. It raises and retracts the upper lip.

Quadratus Labii Inferioris
(Square muscle of the lower lip)

Also named depressor labii inferioris because it acts to draw the lower lip downward away from the upper lip, this thin, quadrilateral muscle arises below the canine and bicuspid teeth from the base of the mandible and extends obliquely upward in a medial direction to the lower lip, through which its fiber bundles pass. The lower lateral part of the muscle is covered by the depressor anguli oris muscle. The most medial fibers may pass the midline, crossing the corresponding muscle fibers of the other side. The greater part of this muscle inserts in the skin of the lower lip, just lateral to the midline. Some of the fibers end in the skin of the chin; deep fibers find insertion in the mucous membrane of the lower lip.

This muscle is an antagonist of the mentalis (26, p. 397). It draws the lower lip directly downward and a little laterally. It also everts the lip slightly.

Mentalis (Mentum = chin)

This is a short, thick muscle that arises in an almost circular area above the protuberance of the chin, below the incisor teeth. From their origin the fibers of each mental muscle (left and right) diverge in their course toward the skin, some fibers interlacing with those of the muscle of the opposite side after crossing the midline. Only the most lateral fibers end in the skin of the same side. The superior fibers course upward and outward, looping around the lower border of the lip. The inferior fibers course downward and outward, the lowest fibers passing to the lower border of the mandible to end in the skin on the lower surface of the chin. The mentalis is superficial to the depressor of the lower lip (quadratus labii inferioris), varies in size, and generally is fused with the platysma (Figure 11).

The mentalis draws up the skin of the chin and assists in the protrusion of the lower lip. The actual position taken by the lower lip during mentalis contraction is dependent upon two factors: (1) the position and degree of contraction of the upper lip, and (2) the relative resistance of the lower lip and its depressor. If the upper lip is relaxed or pulled upward by the levators, the activity of the mentalis will push the lower lip directly upward. If the upper lip is firmly resistant, then the activity of the mentalis will lead to a very firm pressing of the lips together. If the lower lip is weakly resistant and the quadratus labii inferioris strongly resistant, then the activity of the mentalis will result in the lower lip being pushed forward as well as upward (16, p. 47).

Platysma (Flat Plate)

The platysma is a large, thin, quadrangular muscle covering most of the lateral and anterior regions of the neck. It extends from the chest upward superficially across the neck to the face. The fibers incline medially as they ascend and insert into the lower border of the mandible and into the skin and subcutaneous tissues of the lower part of the face and into the modiolus (Figure 11). Fibers may blend with depressor anguli oris, with the lower lip depressor (quadratus labii inferioris), or with the margin of orbicularis oris, and can sometimes be traced to the zygomaticus major or even to the margin of orbicularis oculi (eye). The muscle is highly variable, development being extensive in some cases, or it may be absent on one or both sides (16, p. 155).

The platysma retracts and depresses the corner of the mouth, elevates and wrinkles the skin of the neck. It can depress the mandible against resistance and move the skin of the chest and nipple slightly upward on the chest wall.

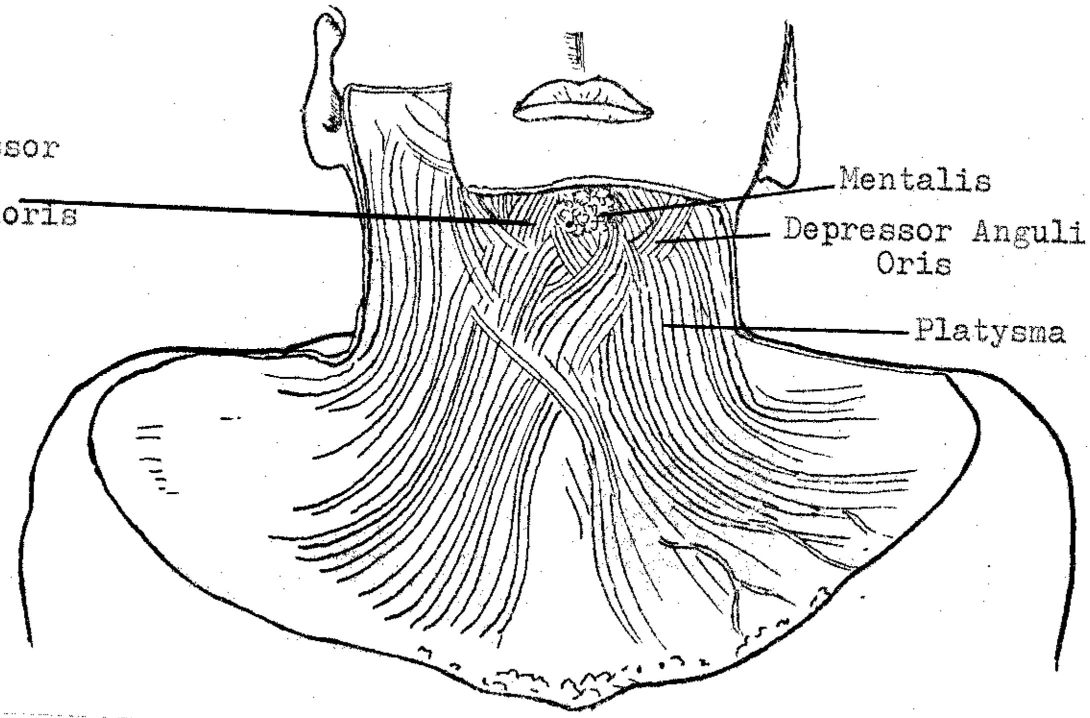

Fig. 11--Platysma and Mentalis. (After Anson.)

Innervation of Oro-facial Musculature

There are twelve pairs of nerves attached to the brain stem, all emerging through special openings in the skull, each pair assigned a number according to its location, front to back. The Seventh Cranial (facial) nerve supplies all the muscles of facial expression, as well as certain other muscles. On each side of the skull it spreads into six branches, four of which innervate the oro-facial musculature, as follows:

Zygomatic Branch--zygomaticus major, quadratus labii superioris, levator anguli oris

Buccal Branch--upper and lower orbicularis oris, incisive, buccinator, risorius, depressor anguli oris

Mandibular Branch--mentalis, quadratus labii inferioris

Cervical Branch--platysma

Summary of the Functions of the Oro-facial Muscles

Muscles directly closing the lips:

Orbicularis oris; compressor labii

Muscles assisting lip closure:

Mentalis; depressor anguli oris (which draws the upper lip downward); levator anguli oris (which draws the lower lip upward); platysma (which draws the corners back and downward)

Muscles that turn the red of the lip inward:

Compressor labii

Muscles drawing lips against teeth:

Buccinator; compressor labii

Muscles directly opening the lips:

Quadratus labii superioris; quadratus labii inferioris

Muscles that pull the mouth corners laterally:

Buccinator; risorius

Muscles that pull the mouth corners medially:

Incisive; levator anguli oris; depressor anguli oris

Muscles that pull the mouth corners upward and laterally:

Zygomaticus major

Muscles that pull the mouth corners downward and medially:

Depressor anguli oris

Muscles that pull the mouth corners downward and laterally:

Platysma

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CHAPTER III

ELECTROMYOGRAPHIC KINESIOLOGY OF FACIAL MUSCLES

In 1791 Luigi Galvani observed that electric current was produced by muscular contraction. This observation was confirmed in the twentieth century when techniques were developed for detecting and recording electrical discharges produced by contracting muscles. These techniques, pioneered in Europe in the 1930's, are known as electromyography, or EMG. [In this presentation, the nouns electromyography and electromyogram will be abbreviated to EMG, and the adjective electromyographic to emg, after Basmajian (1, p. 44).] The objective in EMG is to collect data concerning the electrical activity (action potentials) of individual motor units, such data to be interpreted for varying purposes including diagnostic, pathological, kinesiological, and other.

The detector of electrical activity is an electrode, of which there are two different types, surface and indwelling. Surface electrodes are simple silver discs placed on the surface of the skin. They are easy to use, but they lack precision in that the investigator cannot know exactly where the motor-unit-action potentials originate. Thus, unless the muscle is most superficial or is isolated from adjacent muscles, surface electrodes yield rather imprecise data (25, p. 19).

The indwelling electrodes (which are inserted into the muscle) include two varieties: needle, and fine wire. A serious disadvantage with the needle electrode is that muscle trauma may occur due to the necessity of leaving the needle in while the muscle is being exercised. The fine wire type overcomes this disadvantage, being exceedingly thin and flexible enough to follow any structural movement. Fine wire electrodes are implanted by means of a transporting hypodermic needle, and once implanted and the needle withdrawn, the subject has little or no proprioception of the electrode's presence. Therefore, the possibility of his altering his normal muscle behavior is minimal (25, p. 19). At the present time, this type of electrode approaches the ideal for detailed kinesiology (3, p. 32). Electrodes may be implanted anywhere in the muscle, the emg recording at any one point representing the activity in the rest of the muscle (15, p. 224).

Electrical activity picked up by the electrode is very small and must be amplified hundreds of times before recordings can be made. After amplification the signal is fed into an oscilloscope for transient visualization of the characteristic waveforms, to an inkwriter (in the case of less sophisticated equipment) for direct paper recording, and/or to a loudspeaker for auditory monitoring. Recent developments in technique include convenient methods for storing the information on magnetic tape, and for producing immediately readable, continuous-strip photographic printouts.

The electrical activity as seen on the oscilloscope or as printed out consists of spikes above and below an isoelectric line, representing reversal of polarization at the surface of the muscle fibers. Each spike is a summation of anywhere from a few to a great many signals arising from the random firing of motor units (3, p. 53). If muscle tension increases, the emg wave changes, tending to become greater in amplitude. The investigator is interested in the frequenty, amplitude, and duration of the spikes, and the timing and sequence of electrical discharges.

Electromyography provides the kinesiologist information which cannot be provided from anatomical observations. Studies based upon the latter, such as dissection of muscles, assume that since a muscle has a particular origin and insertion, it must then have a particular action. Such assumption is lacking in that it is concerned only with what a muscle can do or might do. "Electromyography is unique in revealing what a muscle actually does at any moment during various movements and postures. Moreover, it reveals objectively the fine interplay or coordination of muscles" (3, p. 22). This is possible through the use of multiple-channel apparatus, which provides simultaneous readings from several muscles.

The basic premise of electromyographic kinesiologic interpretation is that the noncontracting muscle puts out no voltages, and the contracting muscle has electrical activity roughly proportional to the tension in its muscle fibers. Such relationship does exist in fact, in the case of isometrically contracting muscles; but in isotonic contraction the situation is far more complex. The emg activity during isotonic contraction varies directly with load, velocity, and acceleration, and it varies inversely with length (7). As the angle of pull changes during movement, variable demands are made due to the change in mechanical advantage. Individual muscles do not act with constant force throughout the movement, and EMG reflects this logic (3, p. 141). The investigator must be content in knowing merely whether or not a particular muscle is involved in an activity, and to what extent.

Muscular activity is also related to muscular development. As a muscle is strengthened through a period of training and conditioning, electrical activity decreases. Devries (10, p. 21) showed that the rate of increase in electrical activity with increasing levels of isometric tension was lower in the muscles of well trained, than in poorly trained, athletes. With advanced training there is greater and greater efficiency and specificity of response (3, p. 97), resulting in less electrical discharge.

Various methods of analyzing and quantifying emg data have been devised. Perhaps the simplest system, adequate for most purposes, is that of Basmajian (3, p. 47), in which activity is described subjectively as nil, slight, moderate, or marked, based upon visual observation. Caution must be exercised in making these judgments, for complicating factors such as distance of the electrodes from the motor unit affect the recording (3, p. 14). The integrated output of muscles cannot be compared. Rather, the activity of a muscle at any moment can be compared only to the activity of that same muscle at other moments, and only during the same experiment.

Studies Involving Facial Muscles

Electromyographic studies of facial muscles generally have been clinical in nature and not concerned specifically with normal kinesiology. However, normal function of several facial muscles has been inferred in recent dental and speech studies which compared experimental and control groups. Muscles which have been under investigation are included below, with a brief description of the findings.

Buccinator

Using needle electrodes in the upper and lower parts of the muscle, de Sousa (9) studied the buccinator activity in twenty-five male students during the acts of puffing cheeks, blowing, whistling, compressing the lips, lateral retraction of the angle of the mouth (as in smiling), swallowing, suction, and chewing with full and empty mouth. The buccinator was constantly active in pulling the corners back and in compressing the lips. It was not active in puffing the cheeks, blowing, and whistling.

Blanton, et al (6), using fine wire electrodes in the center of the buccinator in twenty-two subjects with normal dentition, found the muscle markedly and consistently active during sucking, blowing, swallowing, masticating, pulling the lips against the teeth, and pulling the corners of the mouth laterally. The disagreement with de Sousa concerning activity in blowing is interesting. Perhaps differences in electrode type and/or location caused the different findings, or, the force exerted in blowing may have been a factor. This study, to be discussed later, confirmed that the buccinator could be either active or inactive during blowing, depending upon the nature of the activity and the intent of the subject. The findings of Blanton et al (6) suggest that the buccinator may be used at will in blowing, but the extent to which buccinator activity facilitates blowing was not determined.

Another interesting finding in the aforementioned study, Blanton et al, was that most subjects tended to puff out their cheeks while blowing through a straw, an act which elicited slight-to-moderate activity of the buccinator muscles. When subjects were then asked to maintain the cheeks taut while blowing, the result was an increase of activity to marked or very marked. Movements involving stretching the lips (pulling the lips laterally or pulling them against the teeth) elicited greater buccinator response than sucking (which necessitated puckering the lips).

Lundquist (20), using surface electrodes, studied the buccinator during chewing movements of six subjects with natural dentition and six with complete upper dentures and partial lower dentures. In unilateral chewing the electrical activity in all subjects was more pronounced on the working side than on the balancing side.

Tallgren (29), using surface electrodes, studied ten partially edentulous (toothless) subjects beginning shortly after loss of teeth and continuing during the period of adjustment to dentures. The findings showed the buccinator always active in smiling. Synchronized activity with upper orbicularis was interpreted as indicative that the buccinator and upper lip are functionally related. Also, less activity was shown during sucking, an observation which agrees with the findings of Blanton.

Depressor Anguli Oris

Leanderson *et al* (15) placed needle electrodes circularly around the lips at 5 mm intervals in an attempt to study facial muscle coordination during speech. From each electrode position, the activity during five consecutive readings of the same sentence was recorded. The findings suggest that in the production of bilabial consonants /p/, /b/, the depressor anguli oris pulls the corners of the mouth downward so that the upper lip becomes stretched and embraces the lower lip; that the mentalis pushes the lower lip upward, thereby aiding in the pressing of the lips together; and that both of these muscles then relax to permit the depressor labii inferioris to pull the lower lip downward for the release.

Mentalis

Leanderson *et al* (15) describe the mentalis action in the production of bilabial consonants /p/, /b/ as follows: it pushes the lower lip upward by pulling upward the skin at the point of the chin; it then relaxes during the release of the consonant to allow the depressor labii inferioris to act.

Basmajian (3, p. 334) gives the following statement concerning the findings of Hishikawa *et al* in a 1965 study in Japan: the study showed fairly continuous "tonic" activity of mentalis in man except during sleep, when it relaxes completely for short periods.

Baril (1, p. 544) investigated the mentalis in twenty-five thumb-and-finger-sucking subjects, using surface electrodes bilaterally. Twelve of the subjects had open-bite malocclusion (failure of the upper and lower teeth to meet when the jaw is closed). Eleven ofthese twelve subjects showed abnormally large contractions of mentalis. Baril concluded that this abnormal activity resulted from the fact that an open bite leaves a greater space to be sealed in swallowing, whistling, etc. The mentalis, therefore, in helping to seal the lower lip against the upper, has to work harder to fill the greater space involved. Baril suggests that the lower lip and mentalis function together synergistically.

Baril also reported marked activity in the upper orbicularis oris and mentalis during swallowing and sucking. In subjects with normal occlusion, the upper and lower lips and the mentalis exhibited distinct patterns of contraction characterized by good coordination, timing, and synchronization.

Tallgren's findings in the study mentioned earlier agree with those of Baril--synchronized activity of mentalis and lower orbicularis oris was demonstrated in most recordings of partially edentulous subjects, indicating a close functional relationship between these two muscles.

Depressor Labii Inferioris

Leanderson, et al (15) found that in the production of the bilabial consonants /p/, /b/, separation of the lips was produced by the depressor labii inferioris contracting as the mentalis and depressor anguli oris relaxed. In a later study (16) by the same experimenters in which emg activity in the upper and lower lips, levator labii superioris, depressor labii inferioris, depressor anguli oris, and mentalis was recorded simultaneously with speech, the following conclusions were reported: (1) muscle function during speech consists partly of a basic tonus or "speech posture," and partly of a manipulatory activity; (2) the initial position of the facial muscles is influenced by many factors--people smile, are sad, tense, relaxed, etc.; (3) postural activity is found in the levator and depressor labii, and manipulatory activity is found mainly in the orbicularis and depressor anguli oris.

Platysma

Basmajian (3, p. 334) gives the following statement concerning a study of this muscle made by de Sousa (1964), who investigated twenty men, using needle electrodes.

> Greatest activity was recorded in pulling the skin of the neck up, and the angle of the mouth down; widening the opening of the mouth elicited marked activity, but the natural opening of the mouth and jaws did not (3, p. 334).

Upper and Lower Orbicularis Oris

Lubker and Parris (19), using surface electrodes to measure labial emg activity, obtained simultaneous measures of intraoral air pressure, labial pressure, and labial emg activity from eighteen normal speakers during the production of bilabial stops [p], [b]. The labial gesture for these two consonants was shown to be essentially monotypic, requiring no more forceful labial contact or emg activity for one than the other. Intraoral pressure was greater for /p/ than /b/.

Scott (25), using fine-wire electrodes, implanted 1/4 inch distal to the mouth corners, recorded bilateral action potentials from the orbicularis oris in twenty stutterers and twenty non-stutterers during the pronouncing of the stimulus syllables /fa, va, pa, ba, u, i/. Dissynchronous neuromuscular activity between sides was observed in both groups. The phoneme /i/ showed little motor-unit action in both groups. Scott suggests that this may be due to the immobility of the lips during its production, or to the placement of the electrodes in superficial orbicularis oris fibers. When the wire electrodes were implanted more deeply, they apparently came in contact with either superficial fibers of risorius or deeper fibers of the buccinator muscles (both involved in retruding the corners of the mouth), for emg data were then recorded. Apparently, these two muscles aid in the production of the /i/ phoneme while the orbicularis oris tends to remain passive. When the wire electrodes were presumed to come in contact with fibers from either the risorius or buccinator muscles, a marked reduction in activity was recorded for the other five phonemes.

Baril (1, p. 549), using surface electrodes bilaterally, reported that the upper orbicularis oris muscle behaved as two separate muscles, right and left.

Tallgren (29) found evidence suggesting that the upper and lower lips do not act synergistically, the upper lip playing a more passive role than the lower in the function of the mouth. In partially edentulous individuals, the lower orbicularis oris and mentalis dominated the contraction pattern in yawning, sucking, smiling, and swallowing. The lower lip and mentalis appeared to have a close functional relationship, as did the upper lip and the buccinator.

No emg studies of facial muscles during brasswind performance could be found. Consequently, a number of such experiments were conducted at the Regional Rehabilitation Research and Training Center at Emory University, under the supervision of J. V. Basmajian, Director of the Center. A description of these studies may be found in Chapter V.

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CHAPTER IV

EXISTING THEORIES AND FACTS CONCERNING BRASSWIND EMBOUCHURE

A brasswind player must concern himself foremost with three aspects of musical tone production: pitch, loudness, and tone quality. Until he has these under some measure of control, he cannot attend adequately to other musical considerations such as rhythm, expression, and the myriad other factors involved in the performance of music. It seems appropriate, then, that a discussion of embouchure begin with the acoustical nature of brasswind performance, to which embouchure factors can then be related.

The brasswind performer produces sound by creating standing waves in the various length of tubing available to him. He accomplishes this by forcing a stream of air through his lips in such a manner that it pulsates, setting the air inside the instrument into vibratory motion. The exact nature of this phenomenon is not well understood, and needs critical examination. In fact, it is doubtful that any information concerning embouchure can be fully appreciated or evaluated until more is known of this phenomenon. Opinions vary among authors, some believing that the lips do not vibrate, some comparing them to vibrating strings or to vibrating double or single reeds. Taylor (101, p. 167) states that although the lips may act somewhat as a double reed, they differ in that they are never completely closed, but are set into vibration by a complicated edge-tone caused by the air rushing out between them.

Studies of lip vibration by Henderson (45, p. 59), Martin (62, p. 307), and Weast (114, p. 6) lead all these researchers to conclude that one lip vibrates, somewhat as a single reed. According to their findings, the upper lip is the significant vibrator, the lower lip acting as a relatively fixed facing. Action found in the lower lip was declared insignificant, interpreted as a reaction to the beatings of the upper lip against it (120, p. 338). In discussing the single reed concept, Weast suggested that the normal horizontal overbite of most players places the upper lip in a favored position to vibrate, the lower lip being held back and often overlapped by the upper. He also suggested that rarely, if ever, would a player have equal tension in the upper and lower lips, permitting equal response from both.

None of the above researchers conducted their experiments under performance conditions using a normal mouthpiece. Leno (54) was able to accomplish this with four trombonists as subjects, including two college students and two professional players. Leno used a plexiglass mouthpiece made by the Schilke Company of Chicago to the dimensions of the Bach model 6 1/2 AL. He employed high speed photography (920-1050 frames per second) to study players as they performed upon a Conn 88H trombone. He concluded that the actions of the lips are complex, not comparable to double reeds, single reeds, or vibrating strings. Rather, they are unique as generators of sound. Both lips were found to vibrate in all four subjects, the upper lip vibrations being more pronounced in three subjects, the lower lip vibrations more pronounced in one. Leno suggested that determining factors as to which lip vibrates more appeared to be the high or low placement of the mouthpiece and the alignment of the lips. These will be discussed in more detail later.

Leno showed that, in the four subjects under study, both lips actually touched at the beginning of their vibration. Further, he found that complete closure as a part of each vibration cycle produced better tone quality than did partial closure, the latter producing a tone described as "breathy." He was able to describe in considerable detail the actions of both lips at various times during each vibration, and the opening between the lips during their separation period.

Even though Leno's sample was small and confined to one instrument type, his work will be accepted in the present study as the most accurate description of lip vibrations in brasswind performance available to date, and the following findings from his work will be adopted:

1. Both lips vibrate in brasswind performance, and must completely close as part of the vibration cycle.

2. One lip will usually vibrate more than the other, this being related to mouthpiece placement and lip alignment.

3. The lips begin the vibration cycle from a closed position drawn together by muscular contraction.

4. Even for lower pitches the lips are turned inward somewhat and are pulled toward the teeth; with ascending pitch, muscular contraction intensifies.

5. Both lips vibrate at the frequency of the pitch produced on the instrument.

6. The width of the aperture between the lips, as well as the vertical opening, increases with descending pitch and with increasing loudness.

7. The vibrating vertical mass in each lip varies with frequency, the lower the frequency, the greater the vibrating vertical mass. A change in frequency of an octave (2 :1 ratio) shows approximately the same ratio change in vibrating vertical mass. A decrease in vertical mass for high pitches is apparently achieved by turning inward the red portion of the lips.

Leno's work provides insight into two of the primary considerations in brasswind performance: pitch and loudness. Unfortunately, he made no attempt to study lip vibrations in relation to timbre. His descriptions of the different actions of the lips lend support to this study that the mode of vibration of the lips has bearing upon the wave form or timbre produced. Perhaps a much higher framing rate in the photographic studies would have given information on this. No studies could be found investigating this aspect of performance, and it is necessary to turn at this point to the wealth of empirically derived information available from those who play and teach brasswind instruments.

Brasswind tones are usually characterized subjectively as dark, light, bright, mellow, thick, smokey, rich, full, round, thin, stuffy, dull, brilliant, open, "blatty," "breathy," and so on, each generation adding its own descriptive terms to the vocabulary. It is usually agreed that the instrument itself plays the primary role in determining tone quality, but the player may produce a wide range of timbre on any given instrument. He does this apparently by various manipulations of his lips, breath, mouthpiece, and oral chamber. These manipulations include fixing the lips at different tensions in various positions, setting the mouthpiece at various locations high or low on the lips, pressing the mouthpiece against the lips in various ways and in varying amounts, changing the size of the oral cavity by tongue and/or jaw movements, and forcing varying amounts of air at different pressures through the lips. In fixing the lips he may protrude them in varying amounts making them thicker; he may pull the corners back in varying amounts, making the lips thinner; he may move the lower jaw forward or backward so that the lips are at varying angles to one another; he may move the lower jaw upward to crowd the lips together or downward until they hardly touch at all and must be forced together by the mouthpiece. He may roll the red of one or both lips inward in varying amounts, or, may push them outward. Further, the lips may be made firm in differing ways, including many possible muscular activity patterns, and including muscle against muscle, muscle against the grip of the mouthpiece, and muscle against air pressure and flow. When one considers all the foregoing singly, and their many possible combinations, the complexity of timbre in tone production can be appreciated.

It is generally agreed that when the individual player thins his lips by drawing back the corners of the mouth, his tone becomes brighter. The opposite movement, thickening the lips by pulling the corners forward, causes the tone to become darker. If the latter is too pronounced, pushing too much of the lips into the mouthpiece, the tone becomes dull, choked, even nasal. If the lips are pushed together too tightly in the center, the tone becomes pinched, dull, and dead. Curling the red of the lips inward causes the tone to become thinner and brighter. Bright sounds are associated with a complex wave form at the source of sound (128, p. 20). The thinner the vibrating lips, the more complex the wave form (22, p. 236).

In summary, pitch is dependent upon the rate of lip vibration; loudness is dependent upon the amplitude of lip vibration, which in turn is dependent upon air pressure; and timbre is dependent upon the wave form which in turn is dependent upon the instrument itself and to a lesser extent various adjustments of the lips. As brasswind players have searched for the best ways to control these three aspects of tone production, many different schools of thought have emerged, and contradictory opinions by expert players and teachers have caused much confusion. It is not uncommon for a student to learn one technique from one teacher, and an opposite technique from another. Richtemeyer (82), in a survey of 118 professional players and teachers, concluded that teaching techniques are basically responsible for the majority of abnormal embouchures. Perhaps no one particular technique will satisfy the requirements of all players in all situations. If, on the other hand, there are a variety of techniques possible, the teacher must know more about embouchure than merely what has worked well for himself. Ideally he should understand all the elements of embouchure. The following sections represent an attempt to list all these elements, showing their function in embouchure, and presenting the variety of descriptions found in the literature. These elements will be organized as follows:

I. Lip Characteristics

- A. Lip Size
- B. Lip Thickness
- C. Amount of Lip Red
- D. Lip Strength
- E. Lip Texture
- F. Lip Elasticity
- G. Lip Sensitivity

II. Amount of Lip in the Mouthpiece

III. Mouthpiece Factors

A. Mouthpiece Placement
B. Mouthpiece Angle
C. Mouthpiece Pressure

IV. Corners of the Mouth (Modioli)

A. Movement of the Corners during Inhalation
B. Movement of the Corners during Exhalation
   1. Lateral Movement
   2. Vertical Movement
C. Tension in the Corners

V. Facial Muscle Activity

A. Buccinator (cheeks)
B. Upper Lip Levators
C. Lower Lip Depressors
D. Mentalis (chin)
E. Orbicularis Oris (lips)
F. Depressor of the Mouth Corner
G. Levator of the Mouth Corner
H. Platysma
I. Risorius
J. Zygomaticus Major
K. General Facial Tension

VI. Alignment Factors

A. Alignment of the Lip Opening Opposite the Teeth Opening
B. Alignment of the Lower Lip with the Upper Lip
   1. Jaw Alignment
   2. Mouthpiece Vertical Location

VII. Aperture Size

A. Teeth Aperture
B. Lip Aperture

VIII. Teeth Background and Support

A. Length of Front Teeth and Lips
B. Upper-Lower Front Teeth Alignment
C. Contour of the Front Arch
D. Front Teeth Slant
E. Uneven Front Teeth
F. Open-Bite
G. Vertical Overbite

H. Widely Spaced or Missing Teeth
I. Dentures
J. Opinions Concerning Teeth Background

IX. Miscellaneous Factors

A. Warm-up Routine
B. Wet Versus Dry Lips
C. Upstream Versus Downstream Playing
D. Endurance and Fatigue
E. Pedal and Altissimo Registers

I. Lip Characteristics

Attempts are often made in brasswind literature to describe lip characteristics, but semantic problems have led to confusion in defining them and assessing their significance. Importance is usually attached to such factors as strength, size, and texture, but apparently no attempt has been made to define clearly and evaluate carefully these characteristics. This lack will become apparent in the following discussions.

A. Lip Size

Lip size is usually discussed in terms of three dimensions: (1) vertical length of the lip as compared to the le length of the front teeth, (2) lip thickness in the naturally relaxed state, and (3) the amount of red integument showing. The optimum vertical length would appear to be one in which both lips are slightly longer than the front teeth, so that when the teeth are parted 1/8 inch to 1/4 inch, the lips will remain closed in their naturally relaxed state. The most common deficiency, apparently, is one in which the upper lip is considerably shorter than the upper teeth. This trait appears to have caused problems due to failure of the player to pull the upper lip downward into the proper position past the teeth edges. Conversely, short teeth and long lips have also presented problems, possibly due to lack of background support from the teeth, but this condition seems to be relatively rare.

B. Lip Thickness

Lip thickness has received considerable discussion in the literature due to the common belief held by early writers that thin lips are best suited to small mouthpieces, and large lips, to large mouthpieces. This belief is no longer accepted. Malek (59, p. 163), for example, found in a survey of fifty-two professional trumpet players that thin lips appeared no more desirable than thick, neither type being detrimental. Apparently, lip thickness alone is not an important factor in embouchure, but the subject needs further study. For example, thickness may be related to strength and range, but there is no evidence to support such theory.

C. Amount of Lip Red

The amount of lip red showing is a factor in lip thickness, but is treated separately for one important reason. There is virtually unanimous agreement in the literature that the mouthpiece should be so placed that the inside edge is above the red of the lip, <u>regardless</u> of the size of the lip red. The purpose is this requirement is not clear, but experience has obviously shown that mouthpiece placement in the red of the lips has led to poor performance results.

D. Lip Strength

Lip strength is another area of disagreement. Some writers state that strong muscles are required for brass-wind playing, others arguing that strength is not of great importance. For example, Noble (69, p. 54) and Weast (114, p. 9) state that strong facial muscles are required, especially with relation to endurance, loud playing, and high range. Baker (3), Kleinhammer (51, p. 25), and Stevens (95, p. 14), on the other hand, state that economy of muscle use is more important than strength. Baker (3) has found that the big problem in embouchure is overdevelopment. He states that great strength is not needed, that it may even be a handicap where flexibility is concerned. Rather, the player learns to isolate the proper muscles and not to use the others. Kleinhammer (51, p. 25) agrees, stating that trombonists use too many facial muscles too far away from the efficient function of the embouchure to be of tone-producing value. Stevens (95, p. 14) further supports this concept, stating that embouchure strength is not a sign of muscle strength, but rather a sign of using the right combination of muscles. No one has jet determined what muscles should be active in embouchure, nor to what extent.

E. Lip Texture

Texture as a term describing the lips is a somewhat ambiguous word, and, again, the problem of semantics arises. Some writers in using the term seem to mean hardness or suppleness of the red integument. Tull (111, p. 7) apparently thinks of it as density in stating that "some writers confuse lip size with density (texture)." With regard to hardness, writers often state that soft lips are compatible with low range and flexibility, and hard lips are more conducive to high range and endurance. Tull (111, p. 8) says that players with hard lips must work to make the lips more flexible, while the player with soft lips must place more emphasis on muscular development. Apparently, no method is available to make precise measurements of lip texture or hardness.

F. Lip Elasticity

The term elasticity is used apparently as an antonym to such terms as flabby or limp, and hard or rigid. The term refers to the quality of resilience or flexibility necessary for the lips to vibrate, and the proper state of elasticity is apparently achieved by correct muscular contraction and mouthpiece pressure in relation to air flow and pressure. One finds often in the literature statements to the effect that the lips must not be too rigid, nor too limp. There is apparently no way to assess objectively these qualities. Elasticity and texture are probably related--the softer the texture, the less the natural elasticity of the tissue.

G. Lip Sensitivity

Sensitivity refers to the awareness the player has during actual performance concerning his mouthpiece placement and pressure, lip position, tension, and lip relationship to air, via proprioceptive and exteroceptive receptors in the lips. One finds statements in the literature that lip sensitivity is important, that it is important to be able to reestablish yesterday's sensations, and that lip abuse diminishes sensitivity. Although this must certainly vary from person to person, and within the same person from time to time, there is apparently no way to measure this quality.

II. Amount of Lip in the Mouthpiece

There are two schools of thought concerning the amount of lip which should be kept inside the mouthpiece while playing. According to one, there is an optimum amount of lip for each player which, when found through trial and error, will accommodate all ranges. The player, then, never changes this amount of lip regardless of dynamics or range (Appendix). The other view is that the amount of lip in the mouthpiece changes in relation to range and dynamics (Appendix). Those who subscribe to the latter view differ in opinions as to when and how the amount is changed, Sexton stating that it is accomplished during breath inhalation and rests, Haynie stating that it is accomplished by contraction of the lips and tightening the mouth corners. White finds it possible to slide lip out of the mouthpiece while playing, and that this usually occurs when descending in range, but he states that it is not possible to slide more lip into the mouthpiece while playing, nor return lip to the mouthpiece which was allowed to slide out.

Stevens states that the amount of lip in the mouthpiece is not the critical issue; rather, it is the amount of lip exposed to air between the teeth edges, together with the tension in the lips. This amount is changed by jaw movement which opens or closes the teeth aperture; it is not accomplished by changing the outer contact of the mouthpiece.

III. Mouthpiece Factors

A. Mouthpiece Placement

There are three different facets of mouthpiece placement, and each deserves separate discussion: (1) approach, (2) placement, and (3) changes in placement during playing.

(1) Approach.--This might appear rather unimportant to the uninitiated. Actually, much has been written concerning this, and one entire school of playing (14) has arisen around an approach technique. This theory states that in bringing the mouthpiece toward the lips, the player may pull the lips

apart, roll them inward or outward, pull the corners up or down, hook the upper lip over the lower, do some combination of these, or hold the lips in their normal relaxed, closed position. Often the player is unaware of which of these he is doing, which will fit his playing best in terms of his physical characteristics, or what the consequences of each act are. As the mouthpiece reaches the lips, they should be touching and aligned properly vertically and horizontally opposite the teeth opening. The grip of the mouthpiece against the skin tends to hold the lips in the position they are in at the moment of contact. For this reason it is important that they be in the best possible position. To help keep the lips in proper position, Reinhardt (80, p. 231) advises the player to place, inhale, then play; never inhale, place, play. Caruso (14) goes even a step further, advising that for practice purposes the player place, inhale <u>through the nose</u>, then play. Hanson (41, p. 64) states that as the player is about to make placement, he should form the lips as if he were to play a high note, then make placement, thereby assuring that enough lip will be in the mouthpiece. Reinhardt (80, p. 250) recommends that the player approach the lips with the instrument in the exact playing angle. This sets the jaw as well as the embouchure. Grocock (39, p. 6) says that the mouthpiece should meet both lips at the same time.

(2) Placement.--In covering all facets of mouthpiece placement as discussed in the literature, two dimensions, lateral placement and vertical placement, must be related to the following factors: (a) instrument type, (b) timbre, (c) comfort, and (d) lip muscular freedom.

(a) Instrument type.--For many years recommendations concerning vertical placement were tied to instrument types: 1/3 upper lip for trumpet, 2/3 upper lip for French horn, 1/2 or higher placement for low brass. This idea has gradually changed, recommendations now being based on lip freedom, timbre, and individual differences. An exception to this is noted in the case of French horn, where almost unanimous agreement still prevails in favor of 2/3 upper setting (29, p. 22). Stevens (Appendix) recommends an approximately centered vertical placement for all instruments, using the lip aperture as the dividing line, with very slightly more lower lip than upper in the mouthpiece.

Regarding lateral placement, all agree that a centered placement is best for all instrument types, with exceptions made for individual differences in teeth structure. These are discussed in sections (c) and (d) below.

(b) Timbre.--It is generally agreed that a higher mouthpiece vertical placement makes for a darker, heavier tone. This tonal characteristic appears more in vogue in the United States today, particularly in ensemble work. The lighter, brighter tone is considered more soloistic. Lateral placement has not been discussed in relation to timbre.

(c) Comfort.--Some writers suggest that comfort is the most important consideration in mouthpiece placement. Bellamah (5, p. 7), for example, states that the groove or grip position where the mouthpiece feels most comfortable and responds best determines placement. Gibson (34, p. 20) recommends that the student be allowed to find his natural placement. Comfort has been discussed from two viewpoints: expiratory comfort and teeth comfort.

Expiratory comfort has to do with alignment of the mouthpiece opposite the largest opening between the upper and lower front teeth. This position will normally be in front of the two central incisors. Porter (76, p. 4) says that if the opening between the front teeth is larger on one side than the other, the mouthpiece is shifted toward the side with the larger opening.

Teeth comfort may be defined as freedom from pain, and proper support to the lips. The mouthpiece may push the lips against the sharp edge of a rotated or protruding tooth, causing discomfort, in which case the player will have to shift the placement or have dental correction.

A shift in lateral placement, if small, may not be detrimental. Lyon (57) states that he plays with the mouthpiece slightly to the left of center and considers this no problem. He believes that under these circumstances, attention must center upon retaining the lips in their natural resting position, not pulling them over to align them with the mouthpiece. In this case, because of the shifting of the mouthpiece to the left and retaining the natural position of the lips, he reports that he blows to the right of center of the mouthpiece throat.

(d) Lip muscle freedom.--The teeth support the lips by providing a sort of "lay" against which the mouthpiece presses the lips. One often hears in brasswind discussion that a comfortable playing "groove" in embouchure is advantageous. The player thereby has a quick reference point in mouthpiece placement which supposedly improves consistency in placement and, therefore, performance. This may be an oversimplification of a very complicated problem, which will be discussed in greater detail in Section VIII below. Such a groove may well be an advantage if lip and teeth alignment are compatible with it and if the lips are not pinned down in the groove as mouthpiece pressure increases for high range. Unfortunately, no accurate description of such a groove is available. On the other hand, Shiner (90) and Shiner (91) believe that an outward V shape formed by the upper central incisor teeth produces optimum muscular freedom and support. Students under their tutelage who do not have a natural V formation are advised to undergo orthodontic treatment to effect one. Mouthpiece placement is then made on the most forward projection of the teeth, a position which ordinarily corresponds to the center of the lips. This contact keeps the greatest pressure of the mouthpiece at the center, preventing any pinning down of the upper lip at the sides of the mouthpiece or isolation of the lip from muscular control. They do not consider bottom lip as being so critical.

Stevens recommends that in the case of irregular teeth the player should place the mouthpiece equally on the two most forward points of the bottom front teeth, bringing forward the lower jaw until the bottom teeth are verticallly alighed with the most protruded upper tooth, allowing the upper lip to absorb any irregularities present in the upper teeth.

Mouthpiece placement is also a factor in lip alighment and will be discussed in Section VI-B below.

3. Changes in placement while playing.--Once the player has placed the mouthpiece against the lips, the grip of the mouthpiece against the skin tends to hold the contact points constant until the mouthpiece is removed or shifted. However, it has been noted (Appendix) that the player can, without noticing it, pull some lip out of the mouthpiece by contraction of the labial tractors (upper lip levators, lower lip depressors). These muscles may easily overpower their antagonists, the lips; the grip of the mouthpiece, even with

great pressure, is not sufficient to hold the lips in position against the strong contraction of these muscles.

B. Mouthpiece Angle

The mouthpiece angle determines whether or not the instrument (trumpet or trombone) is held in a horizontal or slanting position and points straight ahead or off to one side. This matter is of secondary importance so far as embouchure *per se* is concerned. Rather, the angle formed by the mouthpiece and the supporting front teeth is of primary consideration. The mouthpiece should be placed at a right angle to a straight line drawn between the biting edges of the upper and lower front teeth, and should be pointed ahead in such a manner that the pressure is equal on both the left and right sides of the mouthpiece. The position of the instrument, then, would be dependent upon the angle of the head, the forward or backward position of the jaw, and the contour and slant of the front teeth. Farkas (29, p. 8) warns that if mouthpiece pressure is at an inclined angle to the flat slippery surfaces of the front teeth, the pressure will cause a sliding motion of the lips against the teeth. He advises that mouthpiece pressure be equalized over both lips, a position which would mean in most cases that the mouthpiece angle forms the right angle described above. Another comment, typical of many in the literature, recommends that if the upper teeth slant outward, the instrument will be pointed upward; if they slant inward, the instrument will be pointed downward. A great many brasswind teachers subscribe to a pivoting of the mouthpiece while changing registers in playing. Outwardly, this method would appear to be a change of mouthpiece angle. Actually, the pivot accompanies a movement of the jaw, and is necessary to maintain the ninety degree angle of the mouthpiece as described above. The findings of Haynie (42, p. 11) support this theory. Those teachers who do not subscribe to the pivot are opposed to any forward or backward movement of the jaw in playing (95, p. 37). The consistency of these two methods is apparent.

C. Mouthpiece Pressure

The pressure of the mouthpiece against the lips has been much discussed in the literature and from three different aspects: (1) amount, (2) distribution, and (3) timing.

(1) Amount.--Henderson (19, p. 61) found that an artist performer used one and three-fourths pounds of pressure in playing high C moderately loud, and over five pounds of pressure for the same pitch very loud. He found that a poor player used three and one-half pounds of pressure for high C moderately loud. He found that for an efficient player the mouthpiece and air pressure curves for any played series are parallel, and that the divergence of these curves is a measure of the degree of dependency a player puts upon

mouthpiece pressure as a substitute for muscular tension. Mouthpiece pressure was adjudged an undesirable substitute for muscular tension; the amount should always be slightly more than needed to keep air from escaping around the mouthpiece.

White (126) believes that not only are mouthpiece and air pressure curves parallel, but that the pressures are also approximately equal in efficient playing, with mouthpiece pressure being only slightly greater.

Haynie (42) and Bouhuys (9, p. 975) found that mouthpiece pressure increases with upper register performance and increased dynamics. Farkas (29, p. 16) states that as the player tires, he used more pressure. Thus, variable amounts of pressure are applied depending upon pitch, loudness, and possibly fatigue.

Subjective attempts to define the correct feeling of mouthpiece pressure have been of value. Stevens (96) says that the mouthpiece "must not go through the lips to the teeth." Reinhardt (80, p. 230) divides the embouchure into two parts, inner and outer, and writes that sufficient pressure must be used to make the two merge. According to him, too little pressure allows the mouthpiece to drift. Mendez (64, p. 22) says that there should be no imprint of the mouthpiece on the lips after playing.

Many writers warn that too much pressure is harmful to the lips, because it makes them less sensitive.

(2) Distribution of pressure.--Writers usually advise the player either to distribute the pressure equally to both lips, or to press slightly more on the lower lip. In no case was a statement found in favor of pressing more on the upper lip than the lower.

There is disagreement as to where the pressure is concentrated on each lip. Mueller (68, p. 5) writes of four points of distribution, two upper and two lower; Stevens (96) recommends three, one upper, two lower; and Shiner (91) recommends two, one above and one below.

(3) Timing.--Colin (19, p. 4) says that some players trap themselves by pressing against the lips a split second before the lips contract, especially when there is anxiety about an upcoming passage. Thieck (110, p. 121) agrees, advising the player to contract the muscles before increasing mouthpiece pressure, for contracted muscles better withstand mouthpiece pressure. Stevens (96) agrees with Colin, but disagrees slightly with Thieck. He believes that the player should not increase the mouthpiece pressure before increasing the air pressure, an act which he believes causes the muscular contraction. It appears that if the lips are weak or too relaxed, mouthpiece pressure causes the lips to be pressed against the teeth, a position which harms the lips and impairs the tone.

IV. Corners of the Mouth

A. Movement of the Corners While Inhaling

Brasswind teachers usually instruct their students to breathe through the corners of the mouth. Typical of the instructions is the comment by Sexton (Appendix): "The corners should be stretched back toward the ears, to allow much air to enter the mouth quickly."

White and Stevens (Appendix) disagree, stating that the corners should remain relaxed during inhalation, remaining motionless, and that the player should breathe by dropping the tongue and opening the jaw. The rationale behind this statement is that the player is better able to align his lips over and over if the corners remain in their normal relaxed position during inhalation. Haynie says to let nature decide what the corners do.

B. Movement of the Corners While Exhaling (Playing)

While producing tones, the player may move the corners laterally, or somewhat vertically at an angle upward or downward. Much has been written about this, with the usual differences of opinion.

(1) Lateral movement.--Lateral movement consists of pulling the corners backward or forward. Early writers recommended that the corners be pulled back as if smiling (which is in fact an upward and back movement), especially

when playing in the high register. This recommendation has been changed by nearly all authors today. Richtemeyer surveyed 118 professional players and teachers and found that the majority listed an extreme smiling position as an embouchure abnormalcy. Many teachers now recommend that the lips be drawn forward into a slight pucker when playing, arguing that the lips are therefore stronger and that the thicker lip provides a better cushion between the teeth and mouthpiece, resulting in less likelihood for lip damage. Also, the vibration of the thicker lip produces a darker tone than the thinner lip. Malek (59, p. 163) found that of fifty-two professional trumpeters interviewed, practically all recommended contracted rather than stretched lip. Peyron (74), in making a spectrum analysis of brass-wind tones, concluded that the "pucker" embouchure promotes better integration to the harmonic series than does the stretched or smile embouchure.

Other writers recommend that the corners during performance should remain in their basic, natural position, their position when relaxed (3, 6, 29, 42, 95, 126). This is sometimes referred to as a "puckered smile." Schuller (86, p. 20) says that no matter how relaxed or tense, the corners must not pull up, down, or out.

(2) Vertical movement.--No recommendation was found in the literature that the corners be raised during brasswind

performance, unless one interprets the smile mentioned above as an upward movement. There are writers, however, who recommend that the corners be pulled downward in playing. Tanner (100, p. 57), in talking with 100 trombone teachers at colleges and universities, found some who advise pulling the corners down. Sexton (Appendix) advises pulling them down, not back, for the upper range. Graham (37, p. 394) says that they must go down and in for ascending pitches. Tetzlaff (103, p. 368) says that while ascending, one should draw the corners down and exhale faster.

According to White and Stevens (Appendix), corner placement is based upon alignment of the lip aperture opposite the teeth aperture. If such alignment does not occur naturally with the corners in their relaxed position, the corners must move. White ads that should the player have any physical characteristic (jaw or teeth) that causes the player to push the upper lip up with the mouthpiece and out of alignment, the player would need to depress the corners of the mouth for high and loud playing.

C. Tension in the Corners

Recommendations in the literature concerning firmness in the corners vary from keeping them relatively loose to keeping them firm at all times. The consensus appears to favor keeping the corners firm, the exact tension being dependent upon loudness and range. Tension is greater for very low and very high tones than for tones in the middle range, and greater for loud than soft tones. However, there have been no studies which would indicate the amount of firmness involved.

Haynie (Appendix) describes the corners as firmly relaxed. Severinson (88) seems to agree, recommending that the corners be firm but comfortable so that the lips and vibrating area can remain fully relaxed. Farkas (29, p. 16) and Mendez (64, p. 32) state that if the player is performing correctly, the first signs of fatigue will occur in the corners.

There are some teachers who advocate that the player contract the corners against the teeth when playing. The reasons for this advice vary: to avoid puffed cheeks (Appendix); to gain a feeling of strength (Appendix); to avoid slack in both upper and lower lips (Appendix); to help achieve the total, balanced muscle activity in correct embouchure posture (Appendix).

V. Facial Muscle Activity

A. Buccinator (Cheeks)

There is confusion concerning the function of the cheek muscles in brasswind performance. Distension of cheeks while playing is considered a sign of poor technique by most players and teachers, although several professional players in the popular field perform in this manner. There is apparently no experimental evidence to indicate that the player who keeps his cheeks taut has any advantage over the player who allows his cheeks to puff.

The buccinator muscle contracts to hold the cheeks tightly against the teeth, or, if the lower jaw is dropped, it moves the cheeks between the upper and lower molars. If the muscle is relaxed, the slightest amount of intraoral air pressure will distend the cheeks. However, such distension does not stretch the cheek muscles, their fibers being longer than the distance between their attachments. For this reason, the muscle should function as well in the distended position as in the flat position. Whether or not the cheeks distend during performance, then, depends upon the intent of the player with regard to the amount of air pressure produced and the amount of resistance offered in the buccinator. Puffing the cheeks tends to relax the labial tractors, making it easier to hold the lips together. It also keeps the modiolus in the normal position, except for movement outward from the teeth. Unfortunately, it appears that players who distend their cheeks have never cared to defend their technique, nor to describe how they play. For the most part, they perform primarily popular music only, and are possibly more interested in playing than in analyzing their skill for teaching purposes.

On the other hand, much has been written in support of keeping the cheeks taut during performance. For example, Eby (28, p. 16) states that the cheeks should constantly hug the teeth and gums, lightly but not firmly. Haynie (Appendix) says that the cheeks should be firm in the low register, gradually getting firmer as range ascends, but staying as relaxed as possible for any given note. Sexton (Appendix) says that they should be firm throughout, for control of pitch level. Stevens (Appendix) says that the compression in the mouth chamber will determine tension, always being enough to prevent distension of the cheeks. White (Appendix) says they should be firm at all times, relative to range and loudness--the higher and/or louder the playing, i.e., the more the air pressure, the firmer the buccinator muscles will be.

The buccinator also pulls back the corners of the mouth during contraction if unresisted by the lips. Farkas (29, p. 12) advises the player to maintain a balance between the contraction of the cheeks and lips, so that neither the smile nor the pucker wins the struggle between the lip muscles and all the other facial muscles which radiate outward from the lips.

B. Upper Lip Levators (Quadratus Labii Superioris)

Some teachers recommend that these muscles should be tensed in brasswind performance, others arguing that they should remain relaxed. Winter (128, p. 21) writes that the upper lip should be braced upwards by a light pull from the levators, resulting in a slight flaring of the nostrils and two distinct lines curving down from the outside of the nose to the corners of the mouth. This idea is consistent with his concept of embouchure as a balance of tension between the lips and other facial muscles. Haynie (Appindix B) agrees, adding that the tension increases with ascending pitch.

Stevens and White (Appindix B), on the other hand, argue that the levators of the upper lip should remain completely relaxed at all times, since contraction of these muscles tends to pull the lips apart. According to this theory, the firmness needed in the lips for vibration is attained as the lips oppose the air flow, the greater the air pressure the greater the lip tension. White (126) emphasizes, however, that he is not sure that lip firmness or lip muscular tension is what is needed for vibration, increasing for ascending pitch. He believes that the increasing lip tension (especially upper lip) that actually occurs with ascending pitch is a relatively small ingredient accounting for the increasing rate of lip vibration for ascending. He believes that the more important factor is the reduction of the vibrating mass along with increased air pressure. Increased muscle activity is necessary to hold the lip position against this increased air, and should be much more in the muscles outside the lips (LAO, DAO, and others), and as little as possible in the lips themselves (especially the upper lip).

White and Stevens believe that tension in the levators adds an unnecessary extra burden, encouraging mouthpiece pressure as an aid in holding the lips in position. Sexton (Appendix) agrees that these muscles should be as relaxes as possible, but does not feel that it is possible to completely relax them in upper range.

White and Stevens believe that tension in the levators adds an unnecessary extra burden, encouraging mouthpiece pressure as an aid in holding the lips in position. Sexton (Appendix) agrees that these muscles should be as relaxed as possible, but does not feel that it is possible to completely relax them in upper range.

C. Lower Lip Depressors (Quadratus Labii Inferioris)

The lower lip depressors are not to be confused with the mentalis (chin) muscles. Some writers appear to confuse the lip depressor and mentalis muscles, referring to muscles that point the chin as chin muscles. In attempting to understand their descriptions, the assumption is made in this study that reference is made to the depressor muscles, not the mentalis (which perform the opposite function) when such writers recommend pulling the chin downward or keeping it flat and pointed. Some teachers recommend that the lower lip depressors should be tensed, others that they should be relaxed. Hanson (41, p. 62) and Farkas (29, p. 12) recommend that the chin muscles be pulled downward, avoiding rigidity. Moore (67, p. 6) apparently is recommending the same action in stating that the chin should be held flat. This view is consistent with the concept of balanced tension between the lips and other facial muscles. Noble (69, p. 54) recommends that the chin be pulled down by contracting the lip depressors and the depressors of the corners of the mouth. The purpose in this move is to keep the lips smooth and pliable inside the mouthpiece. The mentalis, which in contraction bunches up the chin, would have the opposite effect, wrinkling the lip and making it less pliable. Haynie (Appendix) says that the muscles should be tensed--the higher the pitch, the greater the tension.

In contrast to the above, Sexton (Appendix) says that the depressor labii muscles should be as relaxes as possible. Stevens (Appendix) says they should be relaxed so that a proper cushion can be maintained for the mouthpiece on the lower lip. White says they should be relaxed to allow the lips to remain closed, working only against air pressure.

D. Chin Muscles (Mentalis)

When the chin muscles contract, they raise the flesh of the chin, causing it to push upward against the lower lip and force it in an upward direction. These muscles are antagonistic to the depressor labii muscles, which usually relax as the mentalis contracts, although it is possible to contract both simultaneously. If the lower lip is resisted by the upper as the mentalis contracts, the two lips are brought firmly together. Under such circumstances the mentalis is an aid in closing the lips.

Some teachers advise keeping the chin muscles relaxed during performance; others advise contracting them. Farkas (29, p. 16) considers any pulling upward of the chin muscles a serious fault, and one of the more common faults observed in playing. This idea is consistent with his "tug-of-war" concept in which the tension of the lips is balanced by those facial muscles which antagonize the lips, and this technique would, of course, rule out the mentalis. Noble (69, p. 54) as indicated above, states that the mentalis must be relaxed in order to keep the lips smooth and pliable inside the mouthpiece. White (Appendix) says that the mentalis should be relaxed or it will tend to push the lips upward out of alighment with the teeth opening. However, he qualifies this somewhat by saying that one can feel some tension in this area of the face while playing, a concession which indicates that possibly the mentalis is not completely relaxed. He feels that it is wrong to emphasize this tension or deliberately to attempt to contract these muscles.

Stevens (Appendix) states that the mentalis should be always in a state of contraction, the degree being dependent upon intent and range. Eby (28, p. 17) seems to support this view, stating that in proceeding from the low to the high register, the line of the chin rises and then becomes firm and set.

E. Lips (Orbicularis Oris)

It was stated in Chapter II that the lips are by far the most complicated area in the oro-facial musculature. This complication will become even more apparent now as lip action in brasswind embouchure is discussed. As shown in Chapter II, the lips are not a unit anatomically, but they tend to function as one. Although each lip can act independently of the other, it is often more natural for each to mirrow the activity of the other.

The lips may perform four basic movements, singly or in any combination. These include (1) pulling the corners toward each other, (2) touching the lips together, (3) tightening the lips against the teeth, and (4) rolling the red of the lips inward. In tensing to perform (or attempting to perform) these movements, the lips may contract isometrically, isotonically, or a combination of the two; i.e., the lips may be held at their natural resting length while becoming firmer, or they may be pulled into various shapes and positions and held there while becoming firmer or softer as they interact with other muscles and with air pressure directed against them. These four fasic movements have been discussed at length in the literature, and only representative opinions will be given concerning them.

(1) Pulling the corners of the mouth toward each other.--This movement was discussed in Section IV above, majority opinion favoring the holding of the corners in their natural resting position. This position would require that the pull of the buccinator be equalled by the pull of the incisive muscles, both acting simultaneously. There is considerable opinion in favor of a lightly puckered condition. This position would require that the incisive muscles act first, or in a dominant role, until the corners are moved into this position, at which time the buccinator and incisive muscles would again equalize each other in their pull.

(2) Touching the lips together.--This position will be discussed in considerable detail in Section VII below, when lip and teeth apertures are described. Some players have stated that the lips must feel open when playing. This view is not surprising in view of Leno's finding (54, p. 27) that during the lip vibration cycle, the lips are apart thirty times as long as they are together. Most teachers, however, state that the lips must be kept close together, as if saying the letter /M/. Caution is given against squeezing the lips so tightly together that the tone becomes pinched or choked.

Playing difficulties in the high register are often attributed to inability of the performer to keep his lips touching. Reinhardt (80, p. 30) says that low and high tones are identical in that they are produced with the lips touching. The difference is in the amount of lip compression (pinching power) employed.

(3) Pulling the lips against the teeth.--The consensus from the literature favors pulling the lips against the teeth while playing, leaving some upper and lower lip free past the edges to vibrate. There is a variation in opinion as to just how tightly the lips should be pulled. Bellamah (6, p. 9) recommends that the muscles be held tightly against the teeth as the player ascends in pitch. Autrey (2, p. 10) disagrees, saying it is impossible to play with ease if the lips are stretched back tightly against the teeth. Hanson (41, p. 62) recommends that the lips be cushioned to a degree by puckering, but that they remain flat against the teeth and not protrude into the mouthpiece.

Colin (19, p. 267) does not agree that the lips should be pulled against the teeth. He states that air pockets between the teeth and the lips are advantageous in that they resist the mouthpiece pressing against the teeth, and thereby make the embouchure more responsive.

(4) Movement of the red of the lips inward/outward.--In considering this aspect of lip movement, lip-surface characteristics must be borne in mind. The lip surface is softer near the inner mucosa, becoming increasingly hard toward

the outer, normal skin. Thus, if the contact point is in the soft part of the lip, the vibrational mode is less complex, becoming more complex as contact approaches the vermilion border. Further, the muscular contraction necessary to turn the red inward apparently adds firmness to the lips in direct proportion to the amount of muscular activity.

It should be remembered that the labial tractors pull the red of the lips upward and outward in antagonism to the compressor labii and buccinator which close the lips and turn the red integument inward. Also, breath passing through the lips forces the lip red outward. The compressor labii and buccinator then must contract in opposition to breath pressure and to any possible activity in the labial tractors. Furthermore, the grip of the mouthpiece tends to hold the lips in a fixed position. It may be difficult if not impossible to turn the lips inward against the combined resistance of labial tractors, breath pressure, and mouthpiece grip. All these factors have an influence on the amount of tension in the lips, the firmer lips being conducive to high register and bright timbre. They also have great bearing upon lip resilience.

In the three basic lip movements just described, lips most naturally act together as one. However, when red of the lip is moved inward or outward, this statement is less true. The player may easily turn both lips inward, or may just as easily roll one in and leave the other in its natural position.

this latter case, the softer surface of one lip will contact the harder surface of the other, and one lip will be more contracted than the other. Mouthpiece placement and jaw placement also affect the lip contact point. These factors determine whether one or both lips vibrate, and which lip vibrates more. Pitch, timbre, and flexibility are all determined in part by these factors.

The literature is filled with recommendations concerning the red of the lips. Some representative statements appear below:

> For a fuller, rounder tone, the red of the lip must vibrate. Tuck the upper lip under to thin out the lip and permit the white are to vibrate more clearly and precisely. The lower lip should be flat and firm, not rolled (30, p. 300).

> The red of both lips should be allowed to turn outward in the low register, and inward slightly in the upper registers (Appendix).

> The red of the lips should not be turned outward in any register. Rather, it should be turned inward slightly (Appendix).

> The lower lip pulls in and upward as the player ascends, rolls down and outward as he descends. The upper lip remains in the original position (66, p. 358).

> In order to create the grip necessary to play in the high register, close the lips tightly, keep them parallel, and roll the red flesh in over the teeth (95, p. 162).

> The player may discover that the soft, inner red of the lips is more easily brought into vibration than the outer red, and will pucker in such way as to vibrate this area. The resulting tone, however, is not well defined. The lips should be "set" so as to keep this soft tissue away from the vibrating area (114).

F. Depressor of the Corner of the Mouth (Depressor Anguli Oris)

This is probably one of the more important muscles in embouchure, contracting in antagonism to the levator of the corner of the mouth to pull the lips together and make the corners firm. It also helps establish the vertical alignment of the corners, and therefore the alignment of the lips opposite the teeth aperture. Only one reference to this muscle could be found in the literature. Stevens (95, p. 25) states that the lip alignment is gently locked in place by this muscle. White (126) is presently engaged in an electromyographic study of this muscle with eighteen trumpet players.

G. Levator of the Corner of the Mouth (Levator Anguli Oris)

As the antagonist to the depressor anguli oris, the levator anguli oris is equally important in establishing the vertical alignment of the corners. Nothing could be found in the literature concerning this muscle, other than including it in listings of muscles. White (126) is studying this muscle also.

H. Platysma

Very little is known of the role this muscle plays in embouchure. Nothing could be found in the literature concerning it. In its role of pulling the corners downward and laterally, it thins out the lips and pulls the upper lip downward against the upper.

I. Risorius

This muscle is poorly developed or missing in many faces. Although mentioned often as the muscle responsible for pulling the mouth corners straight back laterally, it probably has little importance in embouchure.

J. Zygomaticus Major

This muscle is also mentioned very little in the literature. In its action of raising the corners and pulling them laterally, it could be troublesome to players with short upper lips. It probably has little use in embouchure, except for persons who have a long upper lip and short upper teeth.

K. General Facial Tension

Opinions vary concerning the amount of tension the player should feel in playing. Haynie (Appendix) says there should be a feeling of firmness in the low register, increasing as the pitch ascends, with a feeling of reserve as far as possible. Sexton says the feeling should be one of relaxation. Baker (3) emphasizes this. Stevens (Appendix) states that there must be both tension and relaxation.

White (Appendix) says there must be a general feeling of tension, concentrated more in the lower portion of the face, the amount determined by air pressure. Sexton reports that as he plays, he feels the tension in the lips more than in the face. Haynie feels that the tension spreads to include all facial muscles.

Kleinhammer (51, p. 23) writes that the muscles used in forming the embouchure are to be minimized in their number, as well as in their motion, for purposes of agility, flexibility, and efficiency. As stated earlier, he believes that most trombonists use too much facial muscle contraction too far away from the efficient function of the embouchure to be of tone-producing value. They not only work too hard, but distract from the sensitivity, ease, and finesse of the muscles that should be used exclusively in forming the embouchure.

Spaulding (86, p. 13) suggests that the player imagine he is playing an octave lower than he actually is playing, thereby keeping more relaxed and providing reserve to play higher.

Nagel (120, p. 173) says that most symphony players use large mouthpieces and horns and therefore must hold or set their embouchure more firmly than jazz players. Ciurczak (17, p. 51) says the student must always feel that each note he plays rides freely upon a strong column of air while the embouchure remains relaxed and relatively free of mouthpiece pressure.

Tetzlaff (109, p. 22) writes that one of the most difficult problems the brass player encounters is in relaxing those muscles not used in playing--to funnel energy only to those muscles which obtain results. In ascending there is a tendency for the smile to gain control.

Stevens (95, p. 45) states that the use of contradictory muscles is one of the most prevalent fundamental problems he has found.

"If the lip aperture is correct and no sound comes, either there is too much tension in the lips and not enough air pressure, or too much air pressure and not enough lip tension" (95, p. 60).

"Change in aperture size does not mean added lip tension. If this were true, soft playing, which requires a small aperture, would mean low tension. But soft tones are produced with less quantity of air, too little to activate a rigid, highly contracted lip. Loud tones require a great work load from the embouchure" (114, p. 8).

VI. Alignment

There are two aspects of alignment in embouchure: alignment of the lips opposite the teeth (horizontal alignment) and alignment of the lower lip with the upper lip (vertical alignment). These will be discussed separately.

A. Alignment of the Lips Opposite the Teeth

There appears to be considerable agreement among brass-wind teachers that the opening between the lips should be well aligned opposite the opening between the teeth. This is one of the important recommendations in the pivot system of playing (80, p. 236), and it is constantly stressed in the Costello system (95). Stevens (Appendix) states that there must be an equal amount of upper and lower lip opposite the teeth aperture, and that where an upper front tooth is longer than the others, the longer tooth will establish the boundary line. Further, "at no time should the bottom lip facing be shorter in length than the top lip reed within the mouthpiece" (95, p. 56). According to his theory, the lips must form a straight line between the corners of the mouth, a position which may necessitate pulling the corners vertically.

The purpose in alignment is to keep the lips in position to receive air, and free to vibrate under all playing circumstances. Poor alignment may result in the impeding of lip vibrations as the mouthpiece pushes the lips against the teeth. This is critical in upper register playing, and in playing softly (Appendix).

Stevens (Appendix) says that alighment is maintained by fixing the corners properly and by not using the muscles in the upper half of the face. White (Appendix) cautions that outward-slanting teeth create a problem in alignment, mouthpiece pressure tending to cause the upper lip to ride the upward slant of the teeth and thereby move upward out of position. Under the pivot system (80, p. 236) the player uses the mouthpiece to push or pull the lips into position.

B. Alignment of the Lower Lip With the Upper Lip

Opinions vary widely regarding alignment of the upper and lower lips, some favoring an even alignment, others a receded position of the lower lip. In no instance was there found a recommendation that the lower lip protrude beyond the upper. Some reasons given in support of the various opinions follow.

> The red portion of the upper lip should very slightly overlap the lower lip, as the upper lip vibrates more than the lower lip (41, p. 62).
>
> To play the high register, form a small aperture by placing the lower lip up and under the upper lip. Keep this setting for the low register, relaxing (106, p. 22).
>
> The lower teeth should recede approximately 1/8 inch, thereby bringing the lower lip back, making room for the lips to vibrate (190).
>
> The even alignment produces a fuller upper register than does the clamping effect of the overbite (114, p. 36).
>
> The air column must continue in a straight line through the mouth, lips, and finally the horn. This is done by an even alignment of the lips (29, p. 7).
>
> Do not allow one lip to overlap the other. The lips must be evenly aligned so that both lips can receive an equitable distribution of weight of the mouthpiece (Appendix).
>
> The position of the bottom lip determines which part of the top lip vibrates, for it will vibrate wherever the bottom lip creates a facing or base (95, p. 42). (Note: Stevens does not say which part of the

lip should vibrate, but since he advocates even alignment, with the red of both lips tucked under, he obviously believes that the contact point should be in the outer red of both lips. If the lower jaw recedes, the contact point would be more toward the inner red of the upper lip.)

Lip alignment is determined by two factors: (1) lip alignment of the lower teeth with the upper and (2) placement of the mouthpiece on the lips. Teeth alignment, in turn, is determined by the location of the lower jaw in relation to the upper jaw while playing. The player may move his jaw forward, or to a very slight degree backward, changing jaw relationship, and thereby changing teeth alignment. Since the teeth form the backdrop for the lips, teeth alignment affects lip alignment and lip proximity.

Mouthpiece placement also affects lip alignment. A low placement brings the pressure of the mouthpiece nearer the vibrating edge of the upper lip, shortens the vertical length of the lip inside the mouthpiece, and holds the lip close to the teeth, while at the same time the lower lip is proportionately lengthened vertically and given more room to move horizontally with the flow of air. Conversely, a high placement of the mouthpiece shortens the vertical length of the lower lip, while the pressure of the mouthpiece inhibits lower lip movement. The upper lip then has more freedom to move horizontally with the flow of the air. This will be discussed in more detail under Section IX-C below, Upstream vs Downstream playing.

Lip alignment may be important, then, as a determiner of contact point between the lips and a determiner of direction of air flow into the instrument. It is not known which of these is the more critical, or whether both, in fact, are critical.

Haynie (Appendix) states that the lower jaw is most forward for the low register, gradually receding as the player ascends, being careful not to recede too much too soon. He further states that it would be advantageous to keep the teeth alignment even throughout the range, for stability of total embouchure. Sexton (Appendix), however, states that the normal person cannot align the teeth vertically in the top range because of undue strain on the lower jaw. White and Stevens (Appendix) believe, however, that if the teeth can be aligned in the low register, the alignment can be preserved throughout the upper range.

VII. Aperture Size

A. Teeth Aperture

The upper and lower front teeth must be parted in brasswind performance to allow for proper flow of air and to permit part of the tissue of one or both lips to oscillate without interference. Most authors do not suggest any given size opening, other than to recommend that the opening be smaller for high range than low.

Stevens (95, p. 27) has arrived at a very exacting formula with regard to teeth aperture. He says that the opening between the front teeth must be computed from a basic opening of 1/4 inch, the teeth alignment being even. For moderately loud playing in the middle range, the opening is approximately 1/4 inch. The opening may increase by 1/16 inch for low register and/or loud dynamics, and may decrease by 1/16 inch for upper register and/or soft dynamics. In a crescendo from MF-FF on the same pitch, the jaw drops 1/4 of the original aperture size, i.e., 1/16 inch. To decrescendo MF-PP, the jaw closes 1/4 of the original aperture size, i.e., 1/16 inch. To ascend in pitch during a crescendo, the aperture should remain constant. To ascend in pitch without a crescendo, the aperture should close slightly. The 1/4 inch aperture, plus the additional 1/8 inch of play (1/16 inch more open, 1/16 inch closed) provides the openings necessary for all dynamic levels throughout the total range of the instrument, four octaves or even more (95).

Shiner (90) also has arrived at an exact formula. He recommends that the opening between the upper and lower front teeth be 1/8 inch and that the jaw be 1/8 inch receded. This approximates the 1/4 inch opening recommended by Stevens, but brings the lips into contact in a different alignment.

Amstutz (1, p. 110) showed through a videofluorographic study that teeth aperture decreases as pitch ascends, and increases as pitch descends, the amount varying between subjects. Meidt (63) found that four of the five French horn players in his study decreased the teeth aperture for high notes, but that one subject increased it. Research for this study revealed one student who opened the teeth in ascending. He appeared to be working very hard in the high register, and his endurance was poor.

B. Lip Aperture

Lip aperture was discussed briefly under Section V-E above.

It is generally agreed that the lips must touch to vibrate. Leno (54, p. 75) showed further that as part of the vibration cycle, complete closure of the lips is required for best tone quality.

According to Reinhardt (80, p. 230) and Eby (28, p. 11) the lips are never apart except as air forces them open. Hanson (41, p. 64) states that low tones can be played either with the lips close or spread open, but that high tones can only be played when the lips are close. Henderson (45, p. 60) states that the lower lip controls pitch by squeezing against the upper lip to increase frequency (the upper lip resisting this action and becoming stiffer), and by restricting the vibratory movement more to that part of the lip closest to the opening between the lips.

Lip aperture is probably dependent upon teeth aperture, mouthpiece placement, mouthpiece pressure, air pressure, and facial muscle contraction. As the upper and lower front teeth are moved apart by a downward motion of the jaw, the lips are pulled apart (or not squeezed together as much); and conversely, as the lower jaw closes, the teeth and lips are moved closer together. If the mouthpiece is placed while the lips are apart, it will tend to hold them in the parted position, or if closed, in the closed position. As mouthpiece pressure increases, the lips are flattened and spread out, coming closer together. The interplay of facial muscles may tend to pull the lips together or apart, as discussed in Section V above.

Jenkins (48, p. 60) says that two factors preventing free lip vibration are excessive mouthpiece pressure and squeezing the lips too tightly together. Conversely, Tetzlaff (102, p. 24) says that perhaps the greatest deficiency in embouchure is failure to keep enough lip inside the mouthpiece to vibrate easily.

Farkas (29, p. 41) writes that the highest, softest note one can play is the result of the smallest possible lip aperture. The lowest, loudest note will require the largest lip aperture. A perfectly calculated crescendo during an ascending scale could conceivably be produced with no change in size of the lip aperture.

VIII. Teeth Background and Support

The exact function of teeth in brasswind embouchure is not well understood. Wide variations in teeth structure and location may be found among players even at the professional level, making it difficult to establish norms conducive to good performance. A number of studies relating to this problem have been made, from which general descriptions of teeth arrangements favorable and unfavorable to embouchure have been deduced. Unfortunately, these descriptions have had little impact upon brasswind pedagogy, beginning players in school bands still are being selected primarily on the basis of musical talent, shortage of a particular instrument in an instrumental program, or personal preferences of the player, with little thought given to physical requirements.

The role of teeth in brasswind playing might be compared somewhat loosely to that of the mouthpiece lay in clarinet tone production, where the distance traveled by the vibrating reed is determined by the size of the opening in the lay, lip placement and pressure, and air pressure. In brasswind performance, the distance traveled by the vibrating lips probably is determined by the size of the opening between the upper and lower front teeth, the slant of the teeth, lip tension, mouthpiece size, placement and pressure, and air pressure. The analogy is not a particularly close one, however, in that the vibrating clarinet reed touches the fixed lay during the closed part of the cycle, whereas the vibrating lips touch each other during the closed part of their cycle. Also, the clarinet reed is approximately the same length as the lay, while the lips must extend vertically past the front teeth edges to vibrate properly.

Discussions of teeth formation related to brasswind embouchure have centered on playing comfort. For example, if a sharp tooth edge causes pain during performance, the player is advised to undergo dental correction or to shift the mouthpiece to a more comfortable place, but this new position may result in a performance deficiency. However, in recent years other relationships of teeth to embouchure have been propounded and will be discussed below.

A. Length of Teeth Compared to Lip Length

It is generally agreed that to vibrate properly, the lips must extend past the teeth edges. If the lips and teeth are the same length or if the lips are slightly longer that the teeth, the player can easily close the lips in proper alignment in front of the parted teeth. If the upper lip is short, the player must pull it down past the teeth edges by muscular contraction and/or mouthpiece push-pull. If the player uses proper muscular contraction, the situation will tend to improve itself over a period of time, the short lip being lengthened through practice (97, p. 21).

Porter (77, p. 40) states that when the upper teeth are shorter than the upper lip, the teeth offer too little support for the embouchure, causing difficulty in the upper range. Cheney (16, p. 451) found this situation in a large percentage of brass instrumentalists who were unable to adjust well to embouchure. In this situation, the player must elevate the lip through muscular contraction and/or mouthpiece push-pull.

More emphasis has been placed upon the length of the upper lip than the lower lip, probably due to the greater mobility of the lower lip and the fact that most players consider the upper lip the primary vibrator.

Porter (77, p. 24) says that small irregularities in tooth length, such as an elongated front tooth, do not seem to cause any difficulty. Stevens (Appendix) states that in such cases, the long front tooth becomes the gauge in comparing lip and teeth lengths, and in determining the opening between the teeth.

B. Alignment of Lower Front Teeth With Upper

A great deal has been written about teeth alignment and the accompanying jaw movements necessary for proper alignment in brasswind embouchure. Alignment is important in that it determines to a great extent the position of the lips as they touch each other. This was mentioned above in Section VI-B, lip alignment, but deserves elaboration.

In discussing the relationship of the upper front teeth to the lower, dentists use the term <u>overjet</u> to refer to the projection of the upper incisors forward beyond their antagonists. There is no term in dental vocabulary which applies in exactly the same way to the reverse situation, projection of the lower incisors forward beyond the upper incisors. The term <u>underjet</u> will be coined for his purpose.

Consensus appears to favor an even alignment of the biting edges of the upper and lower front teeth, at least during performance in the middle and low registers. However, in upper-register performance, majority opinion appears to favor pulling the lower jaw back and up as the pitch ascends. Since the incisors should aupport the upper and lower lips with equal pressure, pulling the jaw back removes support, and the instrument must be pivoted downward to keep the pressure equalized, and particularly to avoid excessive pressure against the upper lip. Stevens (Appendix) argues against a change of alignment during register changes, and against any pivoting of the instrument. He states that the even alignment can be and should be maintained through all ranges.

Malek (59, p. 163) found in a survey of fifty-two professional players that only five had a slightly receded jaw and one, a slightly protruded jaw, with the jaw in a state of repose. None had extreme jaw recession or protrusion. Cheney (16) found in a study of sixty-two semiprofessional players at the University of Michigan, that difficulties noted were most often among players with more than normal overjet. This was especially true of players of the smaller brass instruments, where the smaller mouthpiece allowed less room for variation. The greater the overjet relationship of the upper and lower jaws, the poorer the adjustment. An extreme underjet situation was not found in his study, but he appeared confident that such situations would make brass instrument playing very difficult. Six musicians with a receded jaw complained that they were unable to shift the jaw forward to properly align the teeth.

Stevens (Appendix) feels that a slight underjet is no deficiency. Believing, as he does, that the upper lip is the primary vibrator and that more than one half of the pressure of the mouthpiece should be against the lower lip, the forward position of the lower incisors does not pose a problem to him. Conversely, Shiner (91) feels that a slight overjet is no deficiency, and does not suggest that the jaw be brought forward to align the teeth. Since the majority of players have a slight overjet, he advises playing with the jaw in its normal resting position except for dropping it to allow for proper teeth opening. In this playing position, mouthpiece pressure is equalized on the lips by pivoting the instrument.

Haynie (42, p. 9) found that the majority of subjects in his videofluorographic study thrust the jaw forward to accommodate the low register, and receded the jaw to play the upper register. He states (Appendix) that it would be advantageous if the teeth alignment could be vertical throughout the range for stability of the embouchure. Sexton (Appendix) does not believe that the average person can align the teeth vertically in the top range because of undue strain on the lower jaw. Stevens, on the other hand, insists that all students align the jaw vertically throughout the playing range. Porter (77) points out that the lower jaw can be moved forward considerably from its point of rest, but can be moved backward only slightly. Probably those players who find it uncomfortable to bring the jaw forward enough to align the teeth, could stretch the jaw muscles through practice so that the normal resting position of the jaw would be more forward. This might upset other functional relationships of the jaw, however. If it could be determined that for certain playing characteristics, the even alignment of the teeth throughout the playing range were advantageous, probably the best solution for those persons with serious deficiencies would be to undergo dental correction. In the case of the player with considerable underjet, this would be the only solution, since the jaw cannot be retruded from its resting position more than one-half cusp of the lower molar teeth (44, p. 1).

C. Contour of the Front Teeth Arch

The contour of the front teeth arch has received little attention in the literature. Shiner (90) and Shiner (91) recommend that the upper two central incisors form a slight outward V, or wedge shape, so that the greater amount of mouthpiece weight will be in the center of the upper lip. According to this theory, the player thereby would be able to avoid pinning the lips at the lateral points of mouthpiece contact, creating better muscular control of the lips inside the mouthpiece. Students whose natural front teeth arch depart from this wedge shape are advised to undergo orthodontic treatment (36). Results in such cases have been dramatic, offering strong support for the V shape in the upper central incisors. As to the lower teeth, a slightly rounded arch is considered desirable.

Haynie and White (Appendix) also have observed that the wedge shape appears advantageous. Sexton (Appendix), on the other hand, considers a flat contour in front more desirable. Haynie states that a flat formation of the upper central incisors encourages playing to one side for an anchor place to prevent mouthpiece slipping. Stevens (95, p. 59) does not recommend any particular arch form, but suggests that teeth which match each other and have no unusual high spots are ideal. He recommends placing the mouthpiece weight equally on the two most forward points of the lower teeth, thereby freeing the upper lip from excessive pressure of the mouthpiece.

D. Front Teeth Slant

There is general agreement that the slope of the front teeth should be vertical, not slanting inward or outward. There is much in the literature indicating that slanting teeth often create problems, although under certain conditions they may help decrease other deficiencies.

Outward-slanting upper teeth cause problems for two reasons: (1) it becomes more difficult in most cases to align the teeth, the more the slant, the greater the distance the jaw must move; and (2) mouthpiece pressure may cause the upper lip to "ride up" the inclined plane, forcing the lips apart. Haynie (Appendix) says that the outward slant encourages playing low on the upper lip and a backward pivot on high notes.

Inward-slanting teeth, on the other hand, have apparently caused less trouble, forthey are seldom discussed in the literature. Since the problems mentioned in the preceding paragraph would be reversed, it seems that inward slanting teeth might be advantageous, it being easier to align the teeth, and mouthpiece pressure tending to force the lips together. However, Sexton (Appendix) says that he has had nothing but problems with such players, and Haynie

(Appendix) has found that the mouthpiece tends to slip downward under this condition. Hanson (41, p. 6) says that teeth which slant inward are a disadvantage because the player then has a tendency to allow the lips to curl inward past the teeth edges. Stevens says that even in the case of inward-slanting teeth, the mouthpiece will tend to ride the upper lip upward. He recommends that the instrument bell be lowered in such a case until the mouthpiece points at a right angle to the slanting upper teeth. Obviously the degree of slant is of primary concern; the greater the slant, the more difficult will be the required adjustment.

Very little has been written about the slant of the lower teeth, possibly due to the widespread belief that the upper lip is the primary vibrator, the lower acting somewhat as a facing. The slant of the lower teeth is a factor in the ease with which upper and lower incisal edges can be aligned. Also, it would seem likely that the problem of the lip riding the inclined plane would be equal in either case.

In situations where one or two of the upper (or lower) front teeth slant one direction, while the others are vertical or slant in the opposite direction, no general statement can be made. This situation will be discussed in more detail in the following sections.

Cheney (16) found that protruding upper front teeth were troublesome to all brass players who exhibited this condition in his study. However, he found that retrusion of all upper incisors did not present a problem. Rather, in the case of players with a receded jaw, this proved advantageous, since the amount of jaw movement needed for adjustment was reduced.

E. Uneven Front Teeth

An uneven condition in the front teeth is usually due to three factors, singly, or in various combinations: tooth rotation; tooth slant; and crowding. In the rotated condition, one edge of a tooth is turned toward the lip. If located opposite the rim of the mouthpiece, discomfort often results, and often the player in such cases finds it necessary to shift the mouthpiece laterally, with the result that the mouthpiece no longer rests in the center of the lips. If the uneven tooth is located opposite the mouthpiece opening rather than the rim, there is less likelihood of poor adjustment.

In the case of the single slanting front tooth, if the slant is outward and is opposite the mouthpiece rim, discomfort may result, depending upon the amount of the slant. If the slant is inward, the player may experience discomfort from adjacent tooth edges, may feel a lack of tooth support to the lips, and/or may be forced to place the mouthpiece unevenly against the lips.

The slant of the teeth may result in anterior crossbite, where one or more upper front teeth turn inward, crossing the lower, or where one or more lower front teeth turn outward, crossing the upper. This can cause problems in teeth alignment as well as in tooth evenness.

In the crowded condition, one or more teeth may be rotated, or may overlap adjacent ones, causing discomfort if the mouthpiece, as a result, must be brought into contact with a sharp tooth edge or must be placed unevenly against the teeth.

It is impossible to generalize concerning the above as related to success in adjusting to brasswind embouchure. Many fine players have teeth which do not approach normal dentition, and Cheney (16, p. 454) concludes that uneven front teeth will be the direct cause of poor adaptation for only a small number of individuals who display it. More often, problems result from the combination of uneven teeth with a protruded or retruded jaw. Also, the problem is more acute with players of small-mouthpiece instruments.

Cheney (16, p. 454) found that of thirty-six individuals with crowding of the upper front teeth, only fourteen adjusted poorly, and of these, only five attributed the problems directly to the crowding. Of forty individuals showing crowding of the lower front teeth, only twelve adjusted poorly, three complaining of the irregularity as the direct cause.

Malek (59, p. 163) found that of fifty-two professional trumpet players in his study, twenty had even teeth, twenty-seven slightly uneven, and five very uneven. Lamp (52) found no relationship between tooth unevenness and successful performance on brass instruments.

Cheney reported (16, p. 540) that among the subjects in his study, where a single upper central or lateral incisor was turned inward so that it crossed its lower opponent, adjustment of the small brass mouthpiece against the lip opposite the crossed tooth was difficult.

Stevens (95, p. 26) states that if the teeth formation is irregular, the player should find the two most forward points of the bottom teeth and distribute the mouthpiece weight equally on these points. Research in this study has found this workable only in some cases. For example, where the plane formed by the two forward points of the lower teeth cause the mouthpiece to be pointed off to one side, and the formation of the upper teeth require that it be pointed to the opposite side, adjustment has been poor.

F. Open Bite

In open bite there is space between the upper and lower front teeth when the jaw is closed. Apparently, open bite in an amount less than 1/4 inch causes no problem. Cheney (16, p. 455) found one cornet player with 3/4 inch open bite who tried unsuccessfully for three years to master the cornet, then tried a larger mouthpiece instrument, the trombone, also unsuccessfully. Failure was attributed to lack of teeth support for the lips.

G. Vertical Overbite

Vertical overbite is the reverse situation to open bite. The upper teeth extend downward past the lower teeth edges toward the lower gums. Cheney (16, p. 488) found this condition in nearly all of the 100 individuals examined. An overbite of up to 1/3 the length of the front teeth is considered normal. Overbites in excess of this amount are troublesome. The combination of a receded jaw and deep overbite is particularly troublesome.

H. Widely-spaced Teeth and Missing Teeth

Cheney (16, p. 448) found that all players with extreme spacing between the front teeth experienced difficulties with embouchure. All complained of discomfort and early tiring during playing. Presence of mild spacing seemed of little consequence. Cheney believes that the loss of a single front tooth could affect embouchure in the same manner as the crossbite of a single incisor.

Weast (114, p. 57) believes that missing teeth usually cause loss of efficiency due to loss of underlying support to the muscles. Porter (77, p. 46) states that gaps in the jaws due to missing teeth may allow the buccinator muscle to distend in an uncontrollable manner. He attributes this to the missing girders (side teeth) necessary for the support of the embouchure musculature.

I. Dentures

Kessler (50, p. 1,304) found among professional trumpet players some who were wearing full dentures, and some who reported playing as well as before losing their natural teeth. Hruby (47, p. 7) found pitch range a factor concerning the difficulty experienced by performers with full upper dentures. Little or no trouble resulted in middle or low register performance, but the high pressure of air necessary for upper register performance tended to dislodge full dentures. No trouble was found in the case of partial dentures, which were anchored securely to natural teeth.

Recent developments in prosthetic dentistry placing dentures in bone may provide a solution to problems involving dentures.

J. Opinions Concerning the Importance of Teeth Background

Studies relating teeth to success in performance have produced varying results. Lamp (52, p. 1,235), in a study of 151 subjects, reported no correlation between tooth evenness and performance on brass instruments. Cheney (16), in a study of sixty-two semiprofessional players, found that the combination of a receded jaw, short lip, and protruding upper front teeth was detrimental to brass instrument playing. Further, he reported that crowding and rotation of the front teeth, protrusion of the upper incisors, and crossbite of one or more of the front teeth caused difficulty in adjustment.

Malek (59, p. 163) found among fifty-two professional trumpet players, five with very uneven teeth, a discovery which would tend to support the findings of Lamp. Whitaker (124, p. 424) believes that evenness of teeth is not important. He supports this statement by saying that one of his best trumpet students "has teeth that look like they were put in by a shotgun atten paces." Tull (111) believes that tooth irregularities may be advantageous in producing security and consistency in mouthpiece placement by providing an anchor spot.

Obviously there is need for further research into this aspect of brasswind performance.

IX. Miscellaneaous

A. Warm-up Routine

It is generally agreed that some type of warm-up period is necessary for good performance. It is also accepted that the nature of the warm-up will vary among individual players, some requiring very little, others needing several hours (114, p. 14). Further, it is agreed that warm-up varies from day to day for the individual according to the amount and type of playing he has been doing. Even the hour of the day has an influence (100, p. 54).

There is wide variation of opinion concerning the warm-up routine. Spaulding (94, p. 188) recommends warming up in the high register first. He believes that this allows the lips to "seat" properly while they are fresh, and that five minutes of combined high register and pedal note playing equals thirty minutes of the conventional warm-up. Warm-up in the low register first seats the lips for low register work, according to his theory. Stevens (95, p. 80) also recommends that the player avoid low register warm-up. According to his theory, this encourages a loose, flabby lip. Further, he says that warm-up should not include loud playing in the middle or low registers, for these result in too open a lip aperture. Starting tones should be at moderate volume in or above the staff, slurring upward as far as possible. The player should be concerned with "activating muscle memory by simulating the upper register playing formation."

Weast (114, p. 14) and Ernest Williams (127) recommend that warm-up routines emphasize the low register first and then extend to the high register. Baker (3) recommends a warming-down routine at the end of a performance, if possible, to avoid stiffness the next day.

B. Wet vs Dry Lips

Although the lip is never completely dry in brasswind playing, due to the moisture in the breath, much has been written concerning the importance of keeping the lips moist or relatively dry. The consensus favors keeping the lips wet, although some players claim they can brace against the mouthpiece better if the lips are dry to the point of being sticky (29, p. 35). Mendez (64, p. 27) says that wet lips vibrate more easily than dry lips.

C. Upstream vs Downstream Playing

The terms upstream and downstream in brasswind playing refer to the direction of air past the lips into the mouthpiece, in an upward or downward direction. If the lower lip extends outward past the upper, the air is directed upward; and if the upper lips extend outward past the lower, the air is directed downward. Factors influencing this include the position of the lower front teeth in relation to the upper, and the placement of the mouthpiece on the lips. Whether the direction of the air stream is important of itself, or whether it is merely a symptom of the teeth relationships and mouthpiece placement is not known.

There is disagreement among writers concerning the up or down direction of the air, but agreement concerning directing the air toward the mouthpiece rim. The higher the tone to be played, the nearer the rim of the mouthpiece the air is to be directed, whether up or down. In the middle register, the air is directed toward the center of the mouthpiece. Consensus appears to favor downstream playing, although there are notable exceptions. Stevens (Appendix) favors bringing the jaw forward and directing the air up for the upper register.

D. Endurance and Fatigue

Discussions of endurance center on breath support, mouthpiece pressure, relaxation during performance, and proper spacing of practice. Insufficient breath support apparently results in increased mouthpiece pressure, a condition which causes tiring. The more tired the player becomes, the greater the tendency to increase mouthpiece pressure. A wide mouthpiece rim promotes endurance at the expense of flexibility (123, p. 173). The more narrow the mouthpiece rim, the more quickly the lips tire, since the mouthpiece weight is distributed over a more narrow area.

The player who learns to relax at every possible opportunity while playing increases his endurance. According to Noble (69, p. 55), a player should seize every opportunity to relieve mouthpiece pressure, re-circulate the blood, relax the muscles, and conserve strength when playing moderately loud and in the middle register so that he has the strength needed when register or loud playing is required.

Farkas (29, p. 16) says that fatigue, when it comes, should be felt in the corners of the mouth, not at the point where the lips touch the mouthpiece.

E. Pedal and Altissimo Registers

There is considerable disagreement concerning the advisability of playing in the extreme low and high registers of brass instruments. Consensus seems to favor avoiding both these registers on trumpet, and the extreme high register on the other instruments, but there are notable exceptions.

McBeth (58) states that pedal tones are the very foundation of the Maggio system for trumpet. The pedal note embouchure is then retained in the upper register. Spaulding (94, p. 13) says that pedal tones stimulate blood circulation in the lips, rebuild lip tissue, and condition the lips for the upper register. Stevens (95), however, says that practicing low tones does not develop the ability to play the high tones. He believes that the pupil should first learn the high tones, and then relax to produce the low register. He does not recommend any practice in the pedal register for trumpet players.

Weast (114, p. 15) says that pedal notes can be of value in that they relax and stimulate the embouchure, but overuse of this register may cause excessive looseness of the lips and loss of control. Bloomquist (8) states that pedal tones seem to be helpful in developing the upper register in that the relaxation learned should carry over into the high register.

Chapter Summary

An attempt has been made in this chapter to list and discuss briefly all possible factors which enter into brass-wind embouchure. A comprehensive survey of literature together with personal interviews and correspondence produced a considerable body of information, which was organized under large headings for discussion. The complexity of brasswind embouchure should now be apparent, and it is understandable that so many varying and conflicting opinions prevail.

Research covering all aspects of embouchure is needed. Particularly lacking is any description of the playing characteristics produced by a particular embouchure, including pitch range, power, tone quality, endurance, flexibility, and control. When these are finally opened to scientific inquiry, it may be found that a single embouchure posture and pattern of facial muscle activity will prove more efficient than all of the others. The term <u>efficient</u> here refers to an embouchure posture which will produce the widest possible pitch range, with dynamic control, minimum mouthpiece pressure, flexibility, control, endurance, and characteristic timbre. It does not necessarily imply that such posture is superior to all others. Differing physical characteristics and individual player preferences with regard to timbre and style would have to be considered in final value judgments. The player who departed from such ideal posture would sacrifice to some extent the advantages offered by it. He might limit his playing, for example, to a more narrow pitch range in order to produce a particular timbre, or in order to accommodate his playing to a physical deficiency. These thoughts will be developed in Chapter VI.

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CHAPTER V

ISLEY-BASMAJIAN ELECTROMYOGRAPHIC STUDIES OF FACIAL MUSCLES

A review of electromyographic literature, discussed in Chapter III, produced considerable information which might be related to the present study. However, it was found that much additional information was needed and that no emg studies of facial muscle activity during brasswind performance had been made. Consequently, such studies were conducted at the Regional Rehabilitation Research and Training Center at Atlanta, Georgia, under supervision of J.V. Basmajian, Director of the Center.

During the first experiment an investigation was made concerning the possibility of using surface electrodes in all the studies rather than the more complicated indwelling electrodes. Beckman miniature electrodes were placed over the center of the left buccinator muscle, and fine-wire electrodes were placed over the same area to determine if emg potential detected by the two electrode types might be correlated. The results were negative in part. Activity detected by the indwelling electrodes was confirmed well enough by the surface electrodes; however, the surface electrodes detected emg potentials at times when no activity was registered by the indwelling electrodes.

A later attempt to correlate readings from the two electrode types was also negative. With indwelling electrodes in the lower lip, and surface electrodes over the quadratus labii inferioris, no descrimination in activity recorded from the two sources could be made. It was decided, therefore, that surface electrodes would not produce the information desired, and that indwelling electrodes were to be used in all the experiments.

Description of Equipment Used

Equipment used included the following:

Electrodes--Electrodes consisted of two Evanohm liquid nylon insulated wires made by Driver Harris, .0011 inch thick, with the tips bared and bent back to make one bipolar electrode. Insertion into each muscle was via a 27 gauge hypodermic needle. The complete assembly was dry sterilized for one hour at a temperature of 130 degrees Centigrade.

Connectors--Electrodes were connected to spring-tempered brass wire connectors fashioned after Basmajian, Forrest, and Shine. The spring connectors thus connected the subject to the input cables of four low-level preamplifiers.

Preamplifiers--Preamplifiers consisted of four LA042 Argonaut Differential Preamplifiers from Argonaut Associate Incorporated, Beaverton, Oregon.

Power Supply--LPS040 Argonaut Power Supply.

Monitoring Equipment--All electric potential signals were monitored by an audio amplifier connected to an eight-inch loudspeaker and/or a four-beam Type 564B Tektroniz Storage Oscilloscope.

Recording and Storage--An Ampex SP700 4-channel tape recorder or a Hewlett-Packard Model 3955-C 14-channel magnetic tape recording system was used to record and store the electromyographic signal.

Printing--After the experiments were completed, the data stored on the magnetic tapes were transferred to Kodak Linograph Direct Print bromide paper by means of an ultraviolet recorder, Honeywell 1508 Visicorder, at a speed of 25 millimeters/second.

Muscles Investigated

Exploratory studies were made of the following muscles using indwelling fine wire electrodes:

Orbicularis Oris Superioris--Electrodes were inserted with a forward thrust through the mucosa, two centimeters to the right of the midline, at the level of the vermillion border.

Orbicularis Oris Inferioris--same description as orbicularis oris superioris.

Buccinator--In all experiments except two, electrodes were inserted through the mucosa at the level of the corner of the mouth. The transporting needle entered opposite the first molar tooth, and was thrust posteriorly to end approximately opposite the second molar tooth. In two later experiments one subject was retested with electrodes in the upper and lower fibers, as far posterior as possible, opposite the third molar tooth.

Platysma--Electrodes were inserted three centimeters anterior to the angle of the mandible and one centimeter superior, in loose platysma fibers crossing over the mandible.

Zgomaticus Major--Electrodes were inserted through the skin, under the left cheek.

Mentalis--Electrodes were inserted one centimeter to the right of the midline, one and one-half centimeters superior to the level of the mandible.

Levator Anguli Oris--Electrodes were inserted through the mucosa, one-half inch vertically upward opposite the gum of the right upper canine tooth, at an angle slightly forward.

Quadratus Labii Superioris--Only one part of this muscle was investigated, the levator labii superioris alaeque nasi. Electrodes were inserted just left of the nose, in the belly of the muscle.

Quadratus Labii Inferioris--Electrodes were inserted through the mucosa, next to the root of the left lateral incisor, two centimeters from the midline.

Depressor Anguli Oris--Electrodes were inserted through the skin on the left side, in the middle of the belly of the muscle.

Muscles Not Investivated

Risorius

Quadratus Labii Superioris (Levator Labii and Zygomaticus Minor parts)

Incisive

Compressor Labii

There appears to be no way that these muscles can be investigated with certainty using present techniques and equipment.

Description of Subjects

Subjects for the experiments included the following, listed by number for identification in the Tables to follow:

Subject No. 1--the author, a subject in six experiments.

Subject No. 2--teacher of trumpet at the university level, performing trumpeter, a subject for three experiments.

Subject No. 3--sophomore trumpet major, 1 experiment.

Subject No. 4--sophomore trumpet major, 1 experiment.

Subject No. 5--freshman trumpet major, 1 experiment.

Subject No. 6--junior clarinet major, enrolled in a brass methods class, 1 experiment.

Subject No. 7--professional trumpet player in the popular field, 1 experiment.

Subject No. 8--professional trumpet player in the classical field, 1 experiment.

Procedure

Each subject was placed in a semi-reclined chair for the experiment. Four connectors were fastened to the subject's clothing, as near as possible to that part of the face where electrodes were to be inserted. After the equipment was connected and a proper ground attached to the subject, electrodes were inserted in the muscles and attached to the appropriate connectors. Feedback from the oscilloscope was used as an indication of proper location of the electrodes. Often several insertions were made before the electrodes were judged to be located properly. All electrodes were inserted by J.V. Basmajian.

During the early experiments many technical problems arose. Among these were 60-cycle interference, movement artifact, and electrode slippage. Some experiments ran as long as three hours, leading to considerable subject fatigue. It was decided that a maximum of four bipolar electrodes could be used simultaneously in the experiments using present techniques. The addition of even one bipolar electrode would have magnified the technical problems beyond the endurance of the subjects.

No subject was permitted to see the oscilloscope while the experiment was in progress. Each subject was asked to perform certain facial contortions such as smiling, frowning, puffing the cheeks, and pursing the lips, and then to produce certain tones on a brasswind instrument. Data were stored on tape and later printed out for analysis. Results were tabulated and examined for answers to the following questions:

1. What is the amount of emg potential in a particular facial muscle durging performance of a given task?

2. Whatare the order and timing of facial muscle activity during performance of a given task?

3. Is there inter-subject and/or intra-subject variability in emg potential in facial muscles during performance of a given task?

4. Do the data in these experiments confirm the conclusions found in the literature?

Results

The amount of emg potential in specific facial muscles during performance of certain facial tasks is shown in Tables I - V. Tables I - II show the amount of emg potential registered by each individual subject during the performance of facial contortions. Table III shows the emg potential registered by each subject during brasswind performance. A summary of the emg readings from these three tables is presented in Tables IV - V by individual muscle. A black space in a table indicates that no data were available. Such absence of data was the result of electrode slippage or movement artifact. Six subjects performed the various facial contortions, and eight performed upon brasswind instruments.

Abbreviations used in the tables include

OOS--orbicularis oris superioris (upper lip)

OOI--orbicularis oris inferioris (lower lip)

BUC--buccinator (cheek)

QLS--quadratus labii superioris (upper lip levators)

QLI--quadratus labii inferioris (lower lip depressors)

LAO--levator anguli oris (levator of the mouth corner)

DAO--depressor anguli oris (depressor of the mouth corner)

PLT--platysma

MEN--mentalis (chin)

ZYG--zygomaticus major

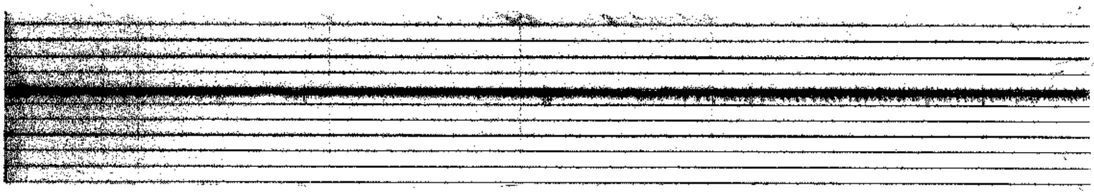
Electromyographic activity was evaluated according to the following code devised by J.V. Basmajian.

0 = nil activity

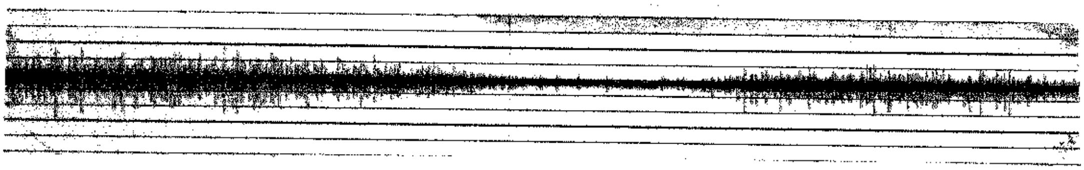
1 = slight activity

2 = moderate activity

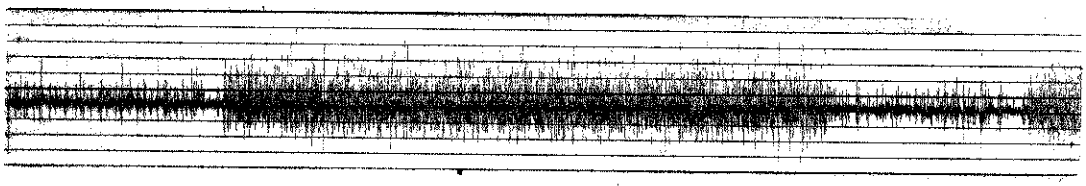
3 = marked activity



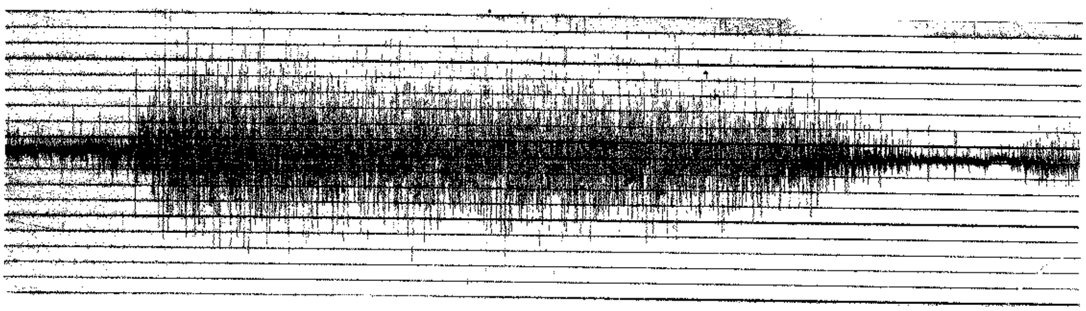
Nil Activity



Slight Activity



Moderate Activity



Marked Activity

Fig. 12--Examples of the Electromyograms

The above examples are recordings of activity in the orbicularis oris superioris muscle during facial contortions.

Table I (see page 161) contains all the data recorded from subject number one during six experiments. The columns are organized in such a manner that all emg readings from a particular muscle during the performance of a given task are adjacent to each other for ease of reference. For example, in Table I it will be observed that the orbicularis oris superioris (upper lip) was among the muscles studied in four experiments. While performing tasks one and two, puffing the cheeks, data were obtained in three of the four experiments. Movement artifact was the cause of the one failure. In the three experiments recorded, there was nil activity in the upper lip during task one, and a variation from slight to marked activity during the performance of task two. The variation in activity during task two may be interpreted as inter-subject variability, or may have been due to variation in electrode placement.

It will be noticed further in Table I that emg potential from the orbicularis oris inferioris muscle (lower lip) was recorded in three experiments, the buccinator in five, the depressor anguli oris in two, and the other muscles in one. An examination of the Table shows that in repeated studies of the same muscle, there is often wide inter-subject variation. This is interpreted to mean that there is more than one way to perform a task, and the subject's understanding of the task and his skill in performing it are important factors in determining the muscular activity involved.

Table II (see page 163) includes data recorded from subjects two through six during the performance of facial contortions. Wide intra-subject variation will be noticed. For example, in task one, puffing the cheeks lightly, subject two registered marked activity in the upper lip, subject four registered moderate activity, and subjects five and six registered nil activity.

Table III (see page 165) presents the emg potentials recorded from all subjects during brasswind performance. It will be noticed that data were recorded more than once from subjects one and two. In task number thirty-six for example, emg potential from the upper lip was recorded during four experiments involving subject number one, and two involving subject number two. The inter-subject variation in each subject supports the conclusion stated earlier that the subject's understanding of a task and skill in performing it are factors determining muscular activity.

Intra-subject variability can be observed also in this table. For example, in task thirty-four subject four shows moderate activity in the quadratus labii superioris, subject five shows slight activity, and subject six shows nil activity.

Tables IV and V, which present a summary of the data from Tables I - III, show at a glance the wide intra-subject variability during performance of the majority of the tasks. For example, in Table IV, task one, five subjects recorded nil activity in the upper lip, one recorded moderate activity and one recorded marked activity. This variability can be noticed in the majority of muscles where data were recorded from more than one experiment. However, there are exceptions. For example, in Table IV, task one, it will be seen that all subjects recorded nil activity in the buccinator, quadratus labii superioris, quadratus labii inferioris, and platysma muscles. Such agreement is rare, however, particularly in those muscles that were investigated several times. The data tend to indicate wide inter-subject and intra-subject variation in the amount of emg potential in individual muscles during the performance of the tasks.

TABLE I

SUBJECT NUMBER 1 ELECTROMYOGRAPHIC READINGS DURING FACIAL CONTORTIONS*

Task	OOS	OOS	OOS	OOS	OOI	OOI	OOI	BUC M	BUC U	BUC U	BUC L	BUC L	LAO	DAO	DAO	MEN	QLS	ZYG
1. Puff cheeks gently	0	0	0		1	0	1	0	0	0	0	0	0	0	1	1		
2. Repeat, forcefully	1	3	3		3	2	3	1	1		1	2	1	0	2	2	1	1
3. Pull mouth corners straight back, gently	0	0	0	1	0	0	1	3	2		1	1	0	0	1	1	0	0
4. Repeat, forcefully	1	0	1	1	0	0	1	2	2		2	1	0	2	3	2	1	1
5. Pull mouth corners down gently, pursing lips gently	1	3	1	2	3	1	2	0	0	1	1	0	1	0	2	2	1	0
6. Repeat, forcefully	1	3	1	3	3	2	3	0	1	2	2	1	2	3	3	3	1	0
7. Pull mouth corners back and down gently		0		0		0	0		0	0	0	0	0	1	2	1		
8. Repeat, forcefully		0		0		0	1		0	0	1	1	0	2	3	2		
9. Gentle smile, lips together	0	0	0	0	1	0	1	2	1		0	1	0	0	1	1	0	1
10. Wide, forced smile	1	0	1	1	1	0	1	3	2	1	1	3	0	0	1	2	3	3
11. Purse lips gently	2	3	1	2	3	3	3	0	0	0	0	0	0	3	2	2	1	0
12. Repeat, forcefully	3	3	2	3	3	3	3	0		2		2		3		3	2	0
13. Tense QLS aleque nasi gently	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0
14. Repeat, forcefully	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	1	3	1
15. Tense levator labii gently	0	0	1	0	1	0	0	1	1	3	0	1	0	0	1	1	2	1
16. Repeat, forcefully	1	0	1	0	2	0	1	2	1	3	0	0	0	0	1	1	3	2
17. Tense levator anguli oris gently	0	0	1	0	1	0	1	2	1	3	0	1	0	0	1	1	1	1
18. Repeat, forcefully	1	1	1	2	2	1	3	3	1	2	1	2	0	2	2	3	3	2
19. Tense depressor anguli oris gently, lower lip down	0	0	1	2		0	3		0	0	0	0	0	1	1	1	1	0
20. Repeat, forcefully	0	0	1	2		0	3		1	1	0	1	0	2	2	3	1	0
21. Tense depressor anguli oris gently, lower lip in place	0	3	1	2		1	1		1	0	1	1	0	0	2	2	1	0
22. Repeat, forcefully	0	3	1	3		2	2		1	0	3	2	0	3	3	3	1	0

TABLE I--continued

Task	OOS	OOS	OOS	OOS	OOI	OOI	OOI	BUC M	BUC U	BUC U	BUC L	BUC L	LAO	DAO	DAO	MEN	QLS	ZYG
23. Tense quadratus labii inferioris gently, lower lip down	0	0	0	0		0	1		0	0	0	0	0	1	1	3	0	0
24. Repeat, forcefully	0	0	0	2		1	2		0	1	1	1	0	2	3	3	0	0
25. Tense quadratus labii inferioris gently, lower lip in place	1	0	0	0	0	1	2	0	0	0	0	0	0	1	2	1	0	0
26. Repeat, forcefully	2	2	2	1	1	2	3	2	1	1	1	1	0	3	3	3	1	2
27. Contract mentalis gently, lips together	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	3	0	0
28. Repeat, forcefully	0	2	0	2	3	2	3	0		1	2	2	0	3	3	3	0	0
29. Curl red of lips on top of teeth gently	0	1	1	2	3	1	1	2	0	0	1	0	0	0	0	1	1	0
30. Repeat, forcefully	0	2	1	2	3	2	3	2	2	2	2	1	0	0	3	2	2	1
31. Curl red of lips past teeth edges gently	0	2	0	1	2	1	1	0	2	2	2	1	0	0	2	1	1	1

*0 = nil emg activity; 1 = slight; 2 = moderate; 3 = marked. BUC-M = middle of buccinator; BUC-U = upper buccinator, BUC-L = lower buccinator.

TABLE II

SUBJECTS 2, 3, 4, 5, 6 ELECTROMYOGRAPHIC READINGS DURING FACIAL CONTORTIONS*

Task	Subject No. 2							Sub. No. 3			Sub. No. 4				Sub. No. 5				Sub. No. 6			
	OOS	OOI	OOI	BUC	LAO	DAO	PLT	OOI	BUC	PLT	OOS	OOI	QLS	QLI	OOS	OOI	QLS	QLI	OOS	OOI	QLS	QLI
1. Puff cheeks gently	3	1	3	0	1	0	0	1	0	0	2	1	0	0	0	0	0	0	0	2	0	0
2. Repeat, forcefully	3	3	3	1	1	1	2	3	0	1	3	3	1	1	3	2	2	0	3	3	0	0
3. Pull mouth corners straight back gently	1	0	0	2	0	1	1	1	1	1	1	1	0	3	2	2	3	0	0	0	0	2
4. Repeat, forcefully	1	3	1	3	1	2	2	2	3	3	3	2	1	3	2	2	3	0	0	1	0	3
5. Pull mouth corners down gently, pursing lips gently	2	2	1	0	0	2	2	3	2	1	2	2	0		1	1	1	0	2	3	0	1
6. Repeat, forcefully	3	3	3	2	0	2	3	3	3	2	3	3	1	2	2	2	2	0	3	3	0	1
7. Pull mouth corners back and down gently								0	2	2					0	0	1	0	0	1	0	2
8. Repeat, forcefully								2	3	3									1	3	0	1
9. Gentle smile, lips together	1	1	0	0	0	0	0	0	0	0	0	0	0	2	1	1	3	0	0	0	0	2
10. Wide, forced smile	1	1	1	3	0	1	0	1	2	1	0		0	3	1	1	3	0	0	1	0	3
11. Purse lips gently	3	3	2	0	1	2	1	2	0	0	2	1	0		2	1	1	0	1	2	0	1
12. Repeat, forcefully	3	3	3	2	1	2	2	3	2	1	3	3	0	1	3	3	2	0	3	3	0	2
13. Tense QLS alequae nasi gently	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	1	1	0
14. Repeat, forcefully	0	3	0	0	0		0	3	0	1	1	2	3	2	0	0	1	2	1	2	2	0
15. Tense levator labii gently	0	0	0	0	0	0	0	1	0	0	1	2	2	2	0	0	1	0	0	1	0	0
16. Repeat, forcefully	0	0	0	0	0	0	0	1	0	0	1	2	3	3	1	0	2	2	1	1	3	3
17. Tense levator anguli oris gently	0	0	0	0	1	1	0	2	1	1	1	1	1	2	3	2	2	0	3	3	2	3
18. Repeat, forcefully		0		0	2	2		3	2	2					3	3	3	1	3	3	3	3

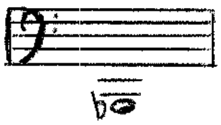
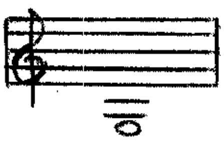
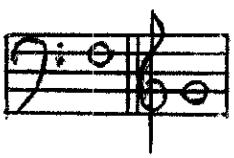
TABLE II--continued

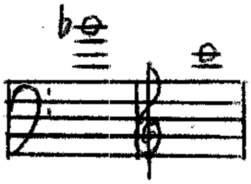
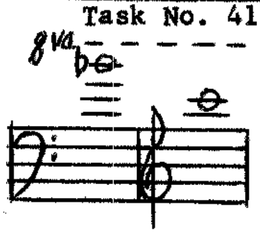
Task	Subject No. 2							Sub. No. 3			Sub. No. 4				Sub. No. 5				Sub. No. 6			
	OOS	OOI	OOI	BUC	LAO	DAO	PLT	OOI	BUC	PLT	OOS	OOI	QLS	QLI	OOS	OOI	QLS	QLI	OOS	OOI	QLS	QLI
19. Tense depressor anguli oris gently, lower lip down					0	1		2	1	3	1		0	3	2	1	2	0	2	2	0	3
20. Repeat, forcefully					0	2		1	1	3	2	2	0	3	2	2	2	1	3	3	0	3
21. Tense depressor anguli oris gently, lower lip in place					0	2		2	1	2	2	1	0	1	2	2	1	0	2	3	0	1
22. Repeat, forcefully					1	2		3	2	3	3	2	1	3	2	2	2	0	3	3	0	2
23. Tense quadratus labii inferioris, gently, lower lip down					0	0		2	1	2	0		0	2	1	1	3	2	2	2	0	3
24. Repeat, forcefully					0	1		2	2	3	1		1	3	1	1	3	3	2	2	0	3
25. Tense quadratus labii inferioris gently, lower lip in place	0	3	0	3	0	1	0	3	2	2	2		0	2	1	1	3	2	3	3	0	3
26. Repeat, forcefully	0	3	0	3	1	2	0	3	3	3	3	2	1	3	1	1	3	3	3	3	0	3
27. Contract mentalis gently, lips together	0	1	0	2	0	2	0	3	1	1	2	2	0	0	0	1	1	0	3	3	0	1
28. Repeat, forcefully	2	3	1	3	0	2	3	3	2	1	3	3	1	1	1	2	2	0	3	3	0	2
29. Curl red of lips on top of teeth gently	3	2	3	2	1	1	3	1	1	1	2	1	0	1	3	1	1	1	2	3	0	3
30. Repeat, forcefully	3	3	3	3	1	2	2	3	3	2	3	2	1	3	3	2	1	2	2	3	0	3
31. Curl red of lips past teeth edges gently	3	2	3	2	1	1	3	3	2	2	3		1	3	3	2	0	0	2	3	0	0

*0 = nil emg activity; 1 = slight; 2 = moderate; 3 = marked, BUC-M = middle of buccinator; BUC-U = upper; BUC-L = lower.

TABLE III

ALL SUBJECTS ELECTROMYOGRAPHIC READING DURING BRASSWIND PERFORMANCE

		1st Subject*	2nd Subject	3rd Sub.	4th Sub.	5th Sub.	6th Sub.	7th Sub.	8th Sub.
Task No. 32	OOS	0,3							
	OOI	1							
	BUC								
	QLS								
	QLI								
	LAO								
	DAO	0							
	PLT								
	MEN	2							
	ZYG								
Task No. 33	OOS		2		3			1	2
	OOI		1		2			1	3
	BUC		2						
	QLS				2				
	QLI								
	LAO							2	3
	DAO							2	2
	PLT		2						
	MEN								
	ZYG								
Task No. 34	OOS	2,2	3,2		3	1	1	1	2
	OOI	3,2,	2,3,1,2,	1	3	1	2	2	3
	BUC	2,1,2	1,2	1					
	QLS	1			2	1	0		
	QLI				2	0	3		
	LAO		2					2	3
	DAO		2					1	2
	PLT		1,3,	0					
	MEN	2							
	ZYG	2							
Task No. 35	OOS	2,1,2,3	2		3	1	2	1	2
	OOI	1,2,2	1,2	2	3	1	3	1	3
	BUC	2,1,2		2					
	QLS	1			1	1	0		
	QLI				2	0	3		
	LAO		2					2	3
	DAO	1	2					1	2
	PLT		2,2	1					
	MEN	2							
	ZYG	1							
Task No. 36	OOS	2,1,2,3	2,3		3	1	2	2	2
	OOI	1,2,2	2,3,2	2	3	1	3	1	2
	BUC	2,1,2	2,3	3					
	QLS	1			1	2	0		
	QLI				3	0	3		
	LAO		3					3	3
	DAO	2	3					2	2
	PLT		2,3	2					
	MEN	2							
	ZYG	1							

		1st Subject*	2nd Subject	3rd Sub.	4th Sub.	5th Sub.	6th Sub.	7th Sub.	8th Sub.
Task No. 37	OOS	3,1,2,3	3		3	2		3	2
	OOI	1,2,2	3,3,3	2	3	1		2	3
	BUC	2,2,3	3,2	3					
	QLS	1			1	2			
	QLI				2	0			
	LAO		3					3	3
	DAO	3	3					2	2
	PLT		2	1					
	MEN	2							
	ZYG	1							
Task No. 38	OOS	3,1,3,3	3		3	3		3	3
	OOI	2,3,2	3,3	3	3	3		2	3
	BUC	3,2,3	3,2	3					
	QLS	1			2	2			
	QLI				2	0			
	LAO		3					3	3
	DAO	3	3					2	3
	PLT		3	2					
	MEN	3							
	ZYG	2							
Task No. 39	OOS		3		3	3		3	3
	OOI		3	3	3	3		3	3
	BUC		2	3					
	QLS				2	1			
	QLI				2	1			
	LAO		3					3	3
	DAO		3					2	3
	PLT		3	3					
	MEN								
	ZYG								
Task No. 40	OOS	3,1,3	3			3		3	
	OOI	2,3,3	3	3		3			
	BUC	3,2,3	2	3					
	QLS	1				1			
	QLI					1			
	LAO							3	
	DAO	3						2	
	PLT		3	3					
	MEN	3							
	ZYG	2							
Task No. 41	OOS	1				2		3	
	OOI	1				2		2	
	BUC								
	QLS					2			
	QLI					1			
	LAO							3	
	DAO	3						2	
	PLT								
	MEN	3							
	ZYG								

*Subject No. 1 performed on trombone; all others performed on trumpet.

TABLE IV

SUMMARY OF ELECTROMYOGRAPHIC READINGS DURING FACIAL CONTORTIONS*

Task	OOS	OOI	BUC	ZYG	LAO	DAO	QLS	QLI	MEN	PLT
1. Puff cheeks gently	5(0)1(2) 1(3)	2(0)5(1) 1(2)1(3)	7(0)		1(0)1(1)	2(0)1(1)	3(0)	3(0)	1(1)	2(0)
2. Repeat, forcefully	1(1)6(3)	2(2)7(3)	1(0)4(1) 1(2)	1(1)	2(1)	1(0)1(1)1(2)	1(0)2(1)1(2)	2(0)1(1)	1(2)	1(1)1(2)
3. Pull mouth corners straight back gently	4(0)3(1) 1(2)	5(0)3(1) 1(2)	3(1)2(2) 1(3)	1(0)	2(0)	1(0)2(1)	3(0)1(3)	1(0)1(2)1(3)	1(1)	2(1)
4. Repeat, forcefully	1(2)1(3) 2(0)4(1)	2(0)3(1) 3(2)1(3)	1(1)3(2) 2(3)	1(1)	1(0)1(1)	2(2)1(3)	1(0)2(1)1(3)	1(0)2(3)	1(2)	1(2)1(3)
5. Pull corners down gently, pursing lips gently	3(1)4(2) 1(3)	3(1)3(2) 3(3)	4(0)2(1) 1(2)	1(0)	1(0)1(1)	1(0)2(2)	2(0)2(1)	1(0)1(1)	1(2)	1(1)1(2)
6. Repeat, forcefully	2(1)1(2) 5(3)	2(2)7(3)	1(0)2(1) 3(2)1(3)	1(0)	1(0)1(2)	1(2)2(3)	1(0)2(1)1(2)	1(0)1(1)1(2)	1(3)	1(2)1(3)
7. Pull corners back and down, gently	4(0)	4(0)1(1)	4(0)1(2)		1(0)	1(1)1(2)	1(0)1(1)	1(0)1(2)	1(1)	1(2)
8. Repeat, forcefully	2(0)1(1)	1(0)1(1) 1(2)1(3)	2(0)2(1) 1(3)		1(0)	1(2)1(3)	1(0)	1(1)	1(2)	1(3)
9. Gentle smile, lips together	6(0)1(1)	5(0)4(1)	3(0)2(1) 1(2)	1(1)	2(0)	2(0)1(1)	3(0)1(3)	1(0)2(2)	1(1)	2(0)
10. Wide, forced smile	3(0)5(1)	1(0)7(1)	2(1)2(2) 3(3)	1(3)	2(0)	1(0)2(1)	2(0)2(3)	1(0)2(3)	1(2)	1(0)1(1)
11. Purse lips gently	2(1)4(2) 2(3)	2(1)3(2) 4(3)	7(0)	1(0)	1(0)1(1)	2(2)1(3)	2(1)2(0)	1(0)1(1)	1(2)	1(0)1(1)

TABLE IV--continued

Task	OOS	OOI	BUC	ZYG	LAO	DAO	QLS	QLI	MEN	PLT
12. Repeat, forcefully	1(2)7(3)	9(3)	1(0)4(2)	1(0)	1(0)1(1)	1(2)1(3)	2(0)2(2)	1(0)1(1)1(2)	1(3)	1(1)1(2)
13. Tense QLS aleque nasi gently	8(0)	7(0)2(1)	7(0)	1(0)	2(0)	3(0)	2(1)2(2)	3(0)	1(0)	2(0)
14. Repeat, forcefully	4(0)4(1) 1(3)	4(0)3(2) 2(3)	7(0)	1(1)	2(0)	2(0)	1(1)1(2)2(3)	1(0)2(2)	1(1)	1(0)1(1)
15. Tense levator labii gently	4(0)4(1)	5(0)3(1) 1(2)	3(0)3(1) 1(3)	1(1)	2(0)	2(0)	1(0)1(1)2(2)	3(0)1(2)	1(1)	2(0)
16. Repeat, forcefully	3(0)5(1)	4(0)3(1) 2(2)	4(0)1(1) 1(2)1(3)	1(2)	2(0)	2(0)1(1)	1(2)3(3)	1(2)2(3)	1(1)	2(0)
17. Tense Lao gently	4(0)2(1) 2(3)	3(0)3(1) 2(2)1(3)	2(0)3(1) 1(2)1(3)	1(1)	1(0)1(1)	1(0)2(1)	2(1)2(2)	1(0)1(2)1(3)	1(1)	1(0)1(1)
18. Repeat, forcefully	3(1)1(2) 3(3)	1(0)1(1) 1(2)4(3)	1(0)2(1) 3(2)1(3)	1(2)	1(0)1(2)	3(2)	3(3)	1(1)1(3)	1(3)	1(2)
19. Tense DAO gently, lower lip down	2(0)2(1) 3(2)	1(0)1(1) 2(2)1(3)	4(0)1(1)	1(0)	2(0)	3(1)	2(0)1(1)1(2)	1(0)2(3)	1(1)	1(3)
20. Repeat, forcefully	2(0)1(1) 1(3)	1(0)1(1) 2(2)2(3)	1(0)4(1)	1(0)	2(0)	3(2)	2(0)1(1)1(2)	1(1)2(3)	1(3)	1(3)
21. Tense DAO gently, lower lip in place	1(0)1(1) 4(2)1(3)	3(1)2(2) 1(3)	1(0)4(1)	1(0)	2(0)	1(0)2(2)	2(0)2(1)	1(0)2(1)	1(2)	1(2)
22. Repeat, forcefully	1(0)1(1) 1(2)4(3)	4(2)2(3)	1(0)1(1) 2(2)1(3)	1(0)	1(0)1(1)	1(2)2(3)	1(0)2(1)1(2)	1(0)1(2)1(3)	1(3)	1(3)
23. Tense QLI gently, lower lip down	5(0)1(1) 1(2)	1(0)2(1) 2(2)	4(0)1(1)	1(0)	2(0)	1(0)2(1)	3(0)1(3)	2(2)1(3)	1(3)	1(2)

TABLE IV--continued

Task	OOS	OOI	BUC	ZYG	LAO	DAO	QLS	QLI	MEN	PLT
24. Repeat, forcefully	3(0)2(1) 2(2)	2(1)3(2)	1(0)3(1) 1(2)	1(0)	2(0)	1(1)1(2)1(3)	3(0)1(3)	3(3)	1(3)	1(3)
25. Tense QLI gently, lower lip in place	4(0)2(1) 1(2)1(3)	2(0)2(1) 1(2)3(3)	5(0)1(2) 1(3)	1(0)	2(0)	2(1)1(2)	3(0)1(3)	2(2)1(3)	1(1)	1(0)1(2)
26. Repeat, forcefully	1(0)2(1) 3(2)2(3)	1(0)2(1) 2(2)4(3)	4(1)1(2) 2(3)	1(2)	1(0)1(1)	1(2)2(3)	1(0)2(1)1(3)	3(3)	1(3)	1(0)1(3)
27. Contract mentalis gnetly, lips together	6(0)1(2) 1(3)	3(0)3(1) 1(2)2(3)	5(0)1(1) 1(2)	1(0)	2(0)	1(0)1(1)1(2)	3(0)1(1)	2(0)1(1)	1(3)	1(0)1(1)
28. Repeat, forcefully	2(3) 2(0)1(1)	6(3) 1(1)2(2)	3(2)1(3) 1(0)1(1)	1(0)	2(0)	1(2)3(3)	2(0)1(1)1(2)	1(0)1(1)1(2)	1(3)	1(1)1(3)
29. Curl red of lips on top of teeth gently	1(0)2(1) 3(2)2(3)	4(1)2(2) 3(3)	4(1)2(1) 1(2)	1(0)	1(0)1(1)	2(0)1(1)	2(0)2(1)	2(1)1(3)	1(1)	1(1)1(3)
30. Repeat, forcefully	1(0)1(1) 3(2)3(3)	3(2)6(3)	1(1)4(2) 2(3)	1(1)	1(0)1(1)	1(0)1(2)1(3)	1(0)2(1)1(2)	1(2)2(3)	1(2)	2(2)
31. Curl red of lips past teeth edges gently	2(0)1(1) 3(3)2(2)	2(1)3(2) 3(3)	1(0)1(1) 5(2)	1(1)	1(0)1(1)	1(0)1(1)1(2)	1(0)2(1)	2(0)1(3)	1(1)	1(2)1(3)

*Numbers outside the parenthesis indicate the number of subjects showing a given emg activity. Numbers following in parenthesis indicate the amount of emg activity, (0) indicating nil activity, (1) indicating slight, (2), moderate, and (3), marked.

TABLE V

SUMMARY OF ELECTROMYOGRAPHIC READINGS DURING BRASSWIND PERFORMANCE*

	Task 32	Task 33	Task 34	Task 35	Task 36	Task 37	Task 38 8va	Task 39	Task 40	Task 41
OOS	1(0)1(3)	1(1)2(2)1(3)	3(1)4(2)2(3)	3(1)5(2)2(3)	2(1)6(2)5(3)	1(1)3(2)5(3)	1(1)8(3)	5(3)	1(1)5(3)	1(1)1(2)1(3)
OOI	1(1)	2(1)1(2)1(3)	4(1)4(2)4(3)	4(1)4(2)3(3)	3(1)6(2)3(3)	2(1)4(2)5(3)	3(2)7(3)	6(3)	1(2)5(3)	1(1)2(2)
BUC		1(2)	3(1)3(2)	2(1)3(2)	1(1)3(2)2(3)	3(2)3(3)	2(2)4(3)	1(2)1(3)	2(2)3(3)	
QLS		1(2)	1(0)2(1)1(2)	1(0)3(1)	1(0)2(1)1(2)	2(1)1(2)	1(1)2(2)	1(1)1(2)	2(1)	1(2)
QLI		1(2)1(3)	1(0)1(1)1(2)	1(0)1(2)1(3)	1(0)2(3)	1(0)1(2)	1(0)1(2)	1(1)1(2)	1(1)	1(1)
LAO		2(2)	2(2)1(3)	2(2)1(3)	3(3)	3(3)	3(3)	3(3)	1(3)	1(3)
DAO	1(0)	1(2)	1(1)2(2)	2(1)2(2)	3(2)1(3)	2(2)2(3)	1(2)3(3)	1(2)2(3)	1(2)1(3)	1(2)
PLT			1(0)1(1)1(3)	1(1)2(3)	2(2)1(3)	1(1)1(2)	1(2)1(3)	2(3)	2(3)	
MEN	1(2)		1(2)	1(2)	1(2)	1(2)	1(3)		1(3)	
ZYG			1(2)	1(1)	1(1)	1(1)	1(2)		1(2)	

*Bass clef notes were played on trombone, treble clef notes on trumpet. Numbers outside the parentheses indicate the number of subjects recording a given emg potential; numbers inside the parentheses indicate the amount of emg activity as follows: 0 = nil, 1 = slight, 2 = moderate, 3 = marked.

The order and timing of muscular activity also varied from subject to subject, and within the same subject. There was no evidence in these experiments to indicate that one mode of performance of a task was superior to another.

Comparison of the findings in this study to those in related literature was complicated by the publication of several important related studies. Although the experiments of this study had been completed before the discovery of several of these important related studies, these studies are discussed in Chapter III, along with other related literature. Findings in these recently published studies dictated that one additional experiment be conducted to seek information concerning questions generated. Such an experiment was made, the author as subject. In the interest of time, and in order to address the experiment to as many of the questions as possible, immediate feedback from the oscilloscope was available to the subject. No recordings of the data were made. The information derived from this final experiment is presented in the following section.

Buccinator (Electrodes in the Middle, Upper, And Lower Parts of the Left Buccinator)

1. When the left modiolus was retracted laterally there was marked activity in various parts of the left buccinator. The amount of activity in one part was somewhat independent of activity in the other parts. For example,

the subject could draw the modiolus back laterally in such a manner that more activity was noted in the upper and lower parts than in the center. If he so willed, he could repeat the action in such a manner that more activity was noted in the center than in the other two parts.

2. When the right modiolus was pulled back laterally while relaxing the left side of the face, there was no activity in the left buccinator, indicating that the two buccinators can perform unilaterally. This finding agrees with Lundquist as stated in Chapter III.

3. In smiling, whether gentle or forced, the buccinator was always active. The subject could find no way in which he could move the corners of his mouth back laterally without buccinator activity. This finding agrees with all sources referred to in Chapter III.

4. In puckering the lips, it was possible to avoid buccinator activity when no attempt was made to turn the lip red inward. However, the subject could find no way to turn the lip red inward during puckering without buccinator activity.

5. The levator anguli oris and buccinator appear to be closely related. Any facial movement which involved activity in the levator anguli oris showed marked buccinator activity.

6. With the lower lip pulled downward, the subject could tense the depressor labii inferioris without buccinator activity. However, any attempt to hold the lower lip in

place while tensing the depressor labii resulted in marked buccinator activity.

7. It was possible to contract the mentalis without buccinator activity when the lower lip was allowed to be pushed upward freely. When the lips resisted the upward push of the mentalis, there was marked buccinator activity.

8. In puffing the cheeks the subject could keep the buccinator relaxed, or could produce slight-to marked activity according to his intent. This finding clarifies the disagreement between de Sousa and Blanton, as discussed in Chapter III, and confirms the conslusion of Blanton that the buccinator may be used at will in blowing.

9. With visual and aural feedback it was possible to cancel previously learned patterns of activity and train new ones.

Mentalis and Quadratus Labii Inferioris (Electrodes Inserted in the Two Muscles as Described Earlier.)

1. The subject could elicit varying amounts of activity in the mentalis without activity in the quadratus labii inferioris. However, any activity whatever in the quadratus labii inferioris was accompanied by at least moderate activity in the mentalis.

2. The subject was unable to avoid activity in the mentalis except when the entire face was completely relaxed. The muscle was very easily excited.

3. In playing the trombone the mentalis was always

active, but the activity was never marked. Activity increased from slight in the pedal register to moderate in the *altissimo* The quadratus labii inferioris was not active except in the *altissimo* register when activity was slight.

Zygomaticus Major (Electrodes Placed As Previously Described)

1. When the subject grimaced or smiled, there was marked activity in the zygomaticus major.

2. When the corners were pulled back and down and the upper part of the face remained relaxed, there was no activity in the zygomaticus major.

Evaluation of Data

The data obtained in this study show wide inter-subject and intra-subject variation and suggest that an individual may perform in many different ways tasks involving facial muscles. The particular neuromuscular pattern employed and the amount of activity in individual muscles are dependent in part upon the intent of the individual, his understanding or interpretation of a task, and his aptitude and skill in performing it. When one considers the many muscles involved in facial dynamics and the fine control possible over each muscle, including control of individual motor units within a muscle, the wide variation in activity noted is not surprising.

CHAPTER VI

A THEORY OF BRASSWIND EMBOUCHURE

The complexity and variability of facial musculature and facial muscle activity have been discussed. Also, many different opinions concerning brasswind embouchure have been presented. The wide variations noted in each instance seem to preclude generalization that one particular facial type, facial/jaw muscle posture, or performance mode is more suitable than another for brasswind performance. The question "Is one embouchure type and performance mode best for all players?" cannot be answered, for it is doubtful that any single embouchure is highly compatible with every possible musical end. However, it is here proposed that one basic facial/jaw muscle posture and pattern of muscular activity is most efficient in brasswind performance. A description of this embouchure has been developed and will be presented and discussed.

The adjective <u>efficient</u>, as applied to embouchure, is defined as the production of musical tone with minimal expenditure of facial/jaw muscle energy consistent with the ends to be achieved. These ends include performance which encompasses the widest possible range of pitch and dynamics, with maximum control and with timbre normally considered characteristic of the instrument. No implication is made that this most efficient embouchure is suitable for every conceivable musical purpose; an individual player might intentionally depart from it, sacrificing physical advantage for musical ends. Furthermore, it appears that some players may not be able to accommodate themselves comfortably to such an embouchure formation for physiological reasons.

From the evidence presented in the preceding chapters, it is postulated that the following basic embouchure is the most efficient possible for all players. The description is in two parts: (A) optimum facial muscle posture, jaw posture, and mouthpiece placement; and (B) optimum patterns of muscular activity. The embouchure will be described first in its entirity. The supporting rationale will be presented later.

A. Optimum Facial Muscle Posture, Jaw Posture, Mouthpiece Placement

   1. The lower jaw is so positioned that the incisal teeth edges are vertically aligned throughout the entire range of the instrument.

   2. The lower jaw is so positioned that one quarter inch average or basic aperture exists between the upper and lower incisal teeth edge, the aperture size changing very slightly as a function of pitch and loudness.

   3. The modioli are positioned vertically and horizontally as follows:

      a. Vertically, the modioli remain in their natural resting position, exceptions made as necessary to touch the lips together opposite the center of the teeth aperture.

      b. Horizontally, the modioli remain in their natural resting position, or are moved somewhat medially from this position.

   4. The upper and lower lips touch opposite the

center of the teeth aperture, inverting as they touch so that the outer red of one lip touches the outer red of the other.

5. The lips are positioned in front of the teeth aperture, not inward past the teeth edges.

6. The mouthpiece is placed vertically and horizontally as follows:

   a. Vertically, the mouthpiece bite is placed above the red lip line. The ratio of upper lip to lower inside the mouthpiece varies among instrument types, and is not considered here as a factor in efficiency.

   b. Horizontally, the mouthpiece is centered opposite the largest part of the incisal aperture.

7. Mouthpiece pressure is distributed more to the lower lip than upper. The greatest amount of pressure, on each lip separately, is at the midline.

8. Postural changes during performance include:

   a. changing the size of the teeth aperture

   b. changing the amount of red lip inversion slightly.

B. Optimum Patterns of Muscular Activity

Patterns of muscular activity involved in most efficient embouchure include the following jaw muscle and facial muscle actions:

1. The mylohyoid and digastric muscles contract slightly to open the jaw, the force of gravity aiding this movement.

2. Simultaneously with the preceding, the jaw is moved as necessary to align vertically the incisal teeth edges. Forward movement is made by contracting the lateral pterygoids; posterior movement is made by contracting posterior fibers of the temporalis muscle. There is no activity in any of the other jaw muscles, nor any facial muscles, as the jaw moves into position.

3. The modioli are fixed vertically and horizontally by the following muscles:

   a. Vertically, the modioli are fixed bilaterally by the levator anguli oris (LAO) muscles and their antagonists, the depressor anguli oris (CAO). If the position, DAO will contract first, resisted later by LAO in proportion to intraoral air pressure and any necessary changes in lip aperture. If the corners are to be raised, the reverse is true.

   b. Horizontally, the modioli are positioned bilaterally by the incisive muscles, aided by LAO and DAO, opposed by the antagonist buccinator muscles. If the modioli are to remain in their natural resting position, the combined medial pull of the incisive, LAO and DAO muscles, must equal that of the simultaneous lateral pull of the buccinator muscles. The buccinators contract in relation to intraoral air pressure and lip compression, which are constantly changing during performance.

      If the modioli are to be positioned medially, the incisive muscles contract first, opposed only by the natural turgor of the facial tissue being moved; then the buccinators contract as intraoral air pressure is introduced, the amount of contraction being dependent upon the air and lip compression involved. The combined force of contraction in the incisive, LAO and DAO muscles must slightly exceed that of the buccinators.

4. The zygomaticus major and platysma muscles and the labial tractors (quadratus labii superioris and quadratus labii inferioris muscles) remain relaxed at all times.

5. The mentalis is slightly to moderately active involuntarily; there is no voluntary use of this muscle.

6. The lips touch and invert by combined action of the buccinator and compressor labii muscles, assisted by LAO and DAO.

7. Contraction necessary to maintain jaw and facial muscle posture while playing is minimal, increasing in the facial muscles directly with tonal

frequency and intensity. Contraction in the lateral pterygoids varies with the amount of pressure exerted against the lower jaw by the mouthpiece.

8. Postural changes during actual performance involve the following muscular actions:

   a. An increase in teeth aperture size is made by increased isotonic contraction in the mylohyoid and digastric muscles. A decrease in teeth aperture size is made by decreasing the activity in these same muscles. It is possible that closing the jaw slightly also involves activity in the masseter and/or temporalis muscles. However, it appears reasonable to expect that, for most persons, the natural elasticity of the tissue stretched in opening the jaw will be sufficiety to close it as the mylohyoid and digastric muscles relax.

   b. An increase in red lip inversion is achieved by increased activity in the compressor labii and buccinator muscles. To decrease the amount of inversion, activity in these muscles is lessened.

Rationale

The rationale for the above description was developed from empirical sources and research findings presented in the preceding chapters and the appendix.

A. Posture and Mouthpiece Placement

1. Vertical alignment of the incisal teeth--In Chapter Four considerable empirical evidence was presented indicating that high vibrational frequencies in the lips during brasswind performance are most easily produced by touching the firmer, outer, red surfaces of the lips together. The argument in favor of vertical teeth alignment is based upon the premise

that this is true--that touching outer-lip-red of one lip against outer-lip-red of the other is more efficient for upper register performance. This premise will be discussed later, when optimum lip position is discussed.

Touching outer-lip-reds is facilitated by vertical alignment of the incisal teeth edges, since the teeth form the backdrop toward which the lips are pushed by mouthpiece contact. If the lower teeth edges are positioned posteriorly to the upper, the soft-inner-red of the upper lip will vibrate against the firmer-outer-red of the lower lip as the lips are inverted for the upper register. This is perhaps the more common mode of performance among brasswind players, the resultant tone tending to be somewhat mellow and dark. The jaw opens and moves forward for the low register, closes and recedes, for the upper. As the jaw recedes, lip contact shifts toward the inner red of the upper lip, and the embouchure becomes less efficient in producing high vibrational frequencies.

In cases where the lower incisal teeth edges are situated anteriorly to the upper in normal occlusion, the problem of aligning the teeth edges is often less acute. The relaxed opening of the jaw follows an arc which carries the lower incisal teeth in a downward and posterior direction. A player with a slight underjet would possibly not have to make any adjustment of the jaw posteriorly to align the teeth.

A large amount of underjet presents an alignment problem which the player can do very little to correct. Fortunately, this situation is apparently uncommon among the population as a whole. The lower jaw cannot be retruded in most cases more than one-half molar tooth cusp. Excessive underjet would necessitate considerable inversion of the lower lip, carrying it across the lower incisors. The problems thereby created are to be discussed later.

Vertical alignment of the incisal teeth, then, is necessary if outer-lip-reds are to touch properly.

2. Teeth Aperture Size.--The 1/4 inch incisal aperture is selected as optimum, based upon the work of Leno and Stevens, discussed in Chapter Four. When the lips contact each other opposite the center of the teeth aperture, a larger aperture will result in a greater amount of each lip being free to vibrate. The size of the incisal opening, then, influences the amount of vibrating lip-vertical-mass, which in turn affects lip vibrational frequency and amplitude. Given a constant pressure of air and constant lip elasticity, a smaller incisal opening will result in a smaller amount of vibrating lip-vertical-mass, and consequently, a smaller amplitude and a greater frequency of vibration. Conversely, within the same context of constant air pressure and lip elasticity, a larger incisal opening permits a greater amount of vibrating lip vertical-mass, resulting in a greater amplitude and lower frequency of lip vibration.

The size of the teeth opening, to be optimal, should permit the minimum amount of vibrating-vertical-mass which will produce the frequency, intensity, and timbre desired. This size is not known. Stevens (Appendix), in training many players to use a 1/4 inch aperture as an average, has found that only a slight change in size (a maximum of 1/16th inch more open or closed) accommodates an exceptionally wide range of frequencies and intensities. This 1/4 inch opening is accepted here as optimum for several reasons. First, it has proven in practice to be a workable opening.

Second, it is a forgiving aperture in terms of player error. The larger the aperture, the less critical is the margin of error with regard to aligning both lips in front of the teeth aperture. For example, a player whose lip alignment moves slightly above or below the center of the incisal opening will experience no interference in lip vibrations if the teeth aperture is large enough. However, if the aperture is too small and the same error in alignment is made, the lips will vibrate too closely to the biting edges of the teeth, especially as the lips are rolled inward and compressed for upper register performance. With the 1/4 inch opening, there is 1/8th inch upper and lower lip past the teeth edges when the lips are properly centered. Allowing 1/16th inch closure of the teeth for higher and softer tones, there remains 3/16th inch upper lip past the teeth edges. This appears to be a reasonable minimum for a forgiving aperture.

As a third reason, the maximal aperture must be chosen on the basis of minimal jaw movement from the natural position of repose. The greater the jaw movement, the greater is the strain placed on the temporomandibular joint. This is especially critical for players with excessive overbite and/or overjet. A combination of forward jaw motion and large opening will probably be tiring for nearly everyone and impossible for some. Stevens (Appendix) has found in training the 1/4 inch aperture that it appears to be a reasonable goal for nearly all who have tried it. Those players who experience initially a slight strain in the temporomandibular joint may reduce such strain by keeping all the jaw muscles relaxed except the prime movers. Over a period of time, the muscles involved will tend to accommodate themselves to the new lengths required. However, the player with extreme overbite and/or overjet will, in some instances, have to accept a compromise or undergo dental treatment.

The 1/4 inch average incisal opening is accepted, then, for three reasons: (1) it has proven in practice to be a workable opening; (2) it approximates a minimum forgiving aperture; and (3) it approximates a maximum for most players as to strain on the temporomandibular joint.

3. Modioli: Horizontal and Vertical Positions.--According to the postulate stated earlier, the modioli are to remain in their natural resting position, or move slightly

medially. This is based upon the principle, stated in Chapter Two, that muscles perform more efficiently when at their resting length or slightly shorter.

If the modioli are drawn laterally from their resting position, the incisive muscles are correspondingly stretched and weakened. In such condition, there will be a tendency for lateral movement to increase as the buccinators contract to hold against the greater air pressure needed for upper register performance. The lips are correspondingly stretched and weakened. Considerable opinion was stated in Chapter Four against widening the mouth corners when approaching the upper register.

On the other hand, if the modioli are drawn medially from their resting position, the incisive muscles will be correspondingly shortened and will perform at maximum efficiency against the lateral pull of the buccinators. The slightly contracted lips will be in a strengthened position. Furthermore, the buccinators will not be less efficient, since there is slack in the fibers making up these muscles. In addition, the LAO and DAO muscles will be shortened, and will perform more efficiently in closing the lips.

The vertical location of the modioli should be opposite an imaginary line drawn laterally across the center of the incisal aperture. This postulate is based upon the premise that the lips must touch opposite the center of the aperture. As the lips contract to touch properly and resist the flow of air, they tend to form a straight line between the modioli. If this line is to be opposite the center of the incisal opening, the modioli must be on the same line.

4. Lips touching and inverted opposite center of teeth aperture.--With the recommended 1/4 inch aperture, there is minimal margin of error allowed in lip alignment. If the lips touch above or below center, they approach the teeth edges, and the inversion necessary for upper register performance pulls the vibrating tissue toward the teeth, interfering with the vibrations. If the lips remain centered, the lips can invert without such interference.

Lip inversion remains something of a mystery, no scientific studies having been made concerning optimum points of lip contact. The findings of Leno, discussed in Chapter Four, indicated that the lips turn inward as they touch, the amount increasing as frequency of vibration increases. Explanation as to why the lips invert must be left to conjecture. The author believes that inversion has to do with lip elasticity--the greater the frequency of vibration, the greater the elastic strength required. Lip elasticity appears to involve two considerations: (1) the natural elasticity of the lips in their relaxes state; and (2) variations in elasticity as a result of muscular contraction.

The natural elasticity of the relaxed lips is probably adequate for production of vibrations over a narrow range of frequencies and intensities. However, it is doubtful that a player could perform with the lips completely relaxed, even though he may feel that they are. The slightest contraction in the muscles which close the lips brings tension to the lips, since these muscles make up a considerable part of the substance of the lips. As these muscles contract, they become firmer, increasing in elastic strength. The player is concerned with establishing the exact state of elasticity best suited to his playing requirement. Efficiency dictates that this be done with the least possible muscular activity.

The lips are brought into contact by contraction of the following muscles: buccinator, compressor labii, LAO, and DAO. All four are involved in embouchure posture, and all four apparently perform efficiently when the lips are in their natural resting position, or slightly inverted. Conversely, when the lips turn outward in protrusion, the compressor muscles are relaxed, at least momentarily, and are pulled from the position where they perform more efficiently. If all four muscles are to perform most efficiently, then, the lips must be in their natural resting position, or slightly inverted.

Much has been said about the desirability of touching the outer-red of the lips together so that the firmer part of the lips touch, as opposed to touching the softer mucosa of one lip to any part of the other. It has been found that touching the outer-red of both lips to each other facilitates upper register performance, and the assumption has been made that lip surface characteristics are therefore a factor in tone quality and pitch range. There is no scientific evidence to support this. It may well be that the increase in elasticity brought about by lip inversion is more important than lip surface characteristics. However, it seems probable that bringing tissue which is naturally more elastic into the vibrational scheme, makes it less necessary to build elasticity through muscular contraction. If this is true, touching outer-reds is desirable for reasons of efficiency.

The optimum mode of lip contact in brasswind embouchure, therefore, is lips inverted slightly, the outer-red of both lips touching opposite the center of the incisal opening.

5. Lips touching anterior to the incisal opening.--Brasswind specialists warn against allowing the lips to extend inward past the teeth edges. The reasons for this are not clear, but it is apparent that this position produces poor performance results. It can only be presumed that the excessive inversion involved causes too great a build-up of elasticity, resulting in a lack of resiliency in the lips. Also, the location of the lips across the teeth edges probably causes interference in lip vibration.

6. Mouthpiece placement: vertical and horizontal.--There appears to be unanimous agreement among brasswind specialists that the mouthpiece inner rim edge must be placed above the

red border of the upper lip. The reasons, again, are not clear. The explanation usually given is that placement on the red invariably produces poor results. It seems reasonable to assume that placement in the red interferes with proper inversion of the upper lip. In such a case, the inner mucosa of this lip would likely be brought into the vibrational scheme. This would make for ease in playing the middle and low registers, but would cause difficulty in upper register performance. The author has observed that players who practice this placement use excessive mouthpiece pressure, probably due in part to loss of muscular control within the lips. The lips are abused by such practice, resulting in loss of sensitivity, control and endurance.

The ratio of upper lip to lower is determined by mouthpiece placement. This ratio as a factor in efficiency has not been covered in the literature. French horn players practice two-thirds upper lip placement, and some trumpet players practice the opposite, placing one-third of the mouthpiece on the upper lip. The exact ratio is selected more on the basis of desired timbre and physical comfort than on efficiency. Probably from the standpoint of efficiency alone, there is an optimum placement on each lip, not too close and not too far from the vibrating lip edges--close enough to give adequate support, and not too close to interfere with upper lip vibrations. Therefore, in low register performance, where increased vibrating-vertical-mass is necessary, high placement would be more efficient. Conversely, in the upper register, a somewhat lower placement would be more efficient, providing mouthpiece support to reduce the amount of vibrating-vertical-mass. However, changing placement for the various registers does not work well in practice since there is often no opportunity to do so as the player moves from one register to another. The player therefore finds a compromise placement that works well in all registers. For the majority of players, a centered placement, as an average, would appear to be best with regard to overall efficiency.

7. Mouthpiece pressure at the midline.--Considerable opinion was presented in Chapter Four favoring an outward V shape of the upper central incisors as the most desirable teeth background. The reason given was that the greatest pressure of the mouthpiece thereby will be at, or near, the midline where many of the transverse fibers of the lip meet and interdigitate. With the most forward point of the teeth located at the midline, and with the mouthpiece pointed straight ahead, the pressure of the mouthpiece will be lessened at the lateral points of contact on the lips, making for greater control of muscle fibers between their points of attachment. Excessive lateral pressure pins the upper lip inside the mouthpiece and tends to isolate it from the muscle

fibers outside the mouthpiece. This results in loss of muscular control, and where pressure is excessive, loss of sensitivity.

It seems reasonable to assume that any formation of the upper front teeth which results in a slight forward projection at, or near, the midline, may be equated with the V shape just mentioned. For example, one upper central incisor overlapping the other could result in such condition. Or one central incisor located slightly forward of the other could produce essentially the same effect. The important consideration seems to be location of the main weight of mouthpiece pressure at a single point, near the midline.

Pressure against the bottom lip does not appear to be quite so critical, perhaps because the upper lip is usually the primary vibrator. Optimum control in this lip is probably achieved in the same manner as described above. However, it appears that such control is secondary in this case to another consideration. It seems preferable to have a firm anchor against two lower teeth because this satisfies a need for security, and helps to make placement more consistent from one time to the next.

8. Postural changes during performance.--There are only two postural changes made during performance: teeth aperture size and red-lip inversion. All other aspects of posture

have been selected for maximum efficiency throughout the entire range of the instrument and do not change.

Teeth aperture size directly influences the amount of lip vibrating-vertical-mass. The larger the aperture (given constant air pressure and lip elasticity), the larger the amount of vibrating-mass, and conversely. If the aperture remains constant, changes in vibrating-mass and amplitude of vibration are made through air pressure and muscular activity changes. It takes an apparently unproducible amount of air pressure and considerable increase in muscular activity to play in the upper register if the teeth aperture is too large. There is an optimum aperture for every lip vibrational frequency and amplitude, and the player quite easily moves the jaw vertically to accommodate such an aperture. The difficulty comes in learning these exact openings and producing them with consistency.

With regard to changes in lip inversion during performance, the amount of inversion is related to register--the higher the register, the greater the amount of inversion. The author has found that these changes need only be slight. Too much inversion results in the lips becoming frozen with contraction, and consequent loss of resilience. It then becomes very difficult to produce any lip vibrations.

B. Optimum Patterns of Muscular Activity

1. Muscles opening the jaw.--In ordinary mastication, gravity is the force which opens the jaw. However, it is unlikely that gravity alone will produce the 1/4 inch incisal opening recommended in brasswind playing. The mylohoid muscle and the anterior bellies of the digastric muscle contract when forceful depression of the jaw is needed. Probably these muscles are used to a very slight extent in brasswind performance, the greater the jaw opening, the greater their contraction. There is no activity in the muscles that close the jaw, except as the jaw is manipulated slightly to make a smaller incisal opening.

2. Muscles moving the jaw forward and backward.--It was shown in Chapter Two that forward movement of the jaw is accomplished by the contracting lateral pterygoids, and backward movement by posterior fibers of temporalis. To reduce strain on the temporomandibular joint, it is essential that only the prime movers in either case contract. The amount of contraction will then be dependent only upon the distance the jaw is to be moved, muscular activity varying directly with this distance. Also, activity in the lateral pterygoids will vary somewhat with mouthpiece pressure against the lower incisal teeth or gums. This pressure tends to push the jaw

posteriorly in opposition to the lateral pterygoids. The greater such pressure, the greater the resistance which must be offered by these muscles.

A player with considerable overjet will have to move the jaw farther than other players, and strain on the tempero-mandibular joint will be greater. It is of importance, for reasons stated above, that there be no activity in the antagonist muscles.

The player with underjet in excess of one-half molar tooth cusp will likely be unable to align his teeth vertically, since posterior movement of the jaw is quite limited, as discussed in Chapter Four.

3. Modioli: horizontal and vertical placement.--Muscles which act horizontally on the modioli are the risorius and buccinator, and their antagonists, the incisive, DAO and LAO muscles. The risorius muscles account for little of the substance of the lips and contract to pull the modioli laterally, stretching the lips. Their contraction places an unnecessary burden on the incisive, DAO, and LAO muscles, which have to hold the modioli against the lateral pull of the buccinator. For this reason the risorius should be relaxed.

The buccinator muscles must contract to compress the lips and to keep the cheeks taut. In so doing, the modioli will be pulled laterally unless opposed by an equal force from the incisive, DAO and LAO muscles.

If the modioli are to remain in their natural position, the incisive muscles must contract isometrically at the same instant the buccinator contracts, the force of contraction in the two muscles being equal. The activity in the buccinator will vary directly with intraoral air pressure, and the activity in the incisive muscles will vary directly with that of the buccinator.

If the modioli are to be positioned medially, the incisive muscles will contract first, opposed only by the natural elasticity of the facial muscle tissue being moved. The activity will then increase directly with that of the buccinator.

If the buccinator is allowed to pull the modioli laterally, the incisive muscles are stretched and must work harder than would have been necessary at their resting length or shorter. In this condition, the greater the contraction of the buccinator, the greater the disadvantage of the incisive muscles, DAO and LAO, with the result that the buccinator becomes dominant. The incisive muscles cannot balance the pull as the buccinator contracts increasingly for the upper register, and the modioli are moved laterally even farther.

If the modioli are in their natural resting position, the incisive, buccinator, LAO and DAO muscles can perform with maximum efficiency. If the modioli are medial to their natural resting position, the same is true. The incisive, LAO and DAO muscles are correspondingly shortened, remaining at maximum efficiency. The buccinator fibers are not correspondingly lengthened since they have slack due to the fibers being longer than the distance between attachments. Also, many buccinator fibers do not pass through the modiolus. Therefore, the buccinators can perform with equal efficiency whether the modioli are in their natural positions, or moved laterally or medially.

The muscles which establish the vertical placement of the modioli in brasswind embouchure are the levator anguli oris and depressor anguli oris. The zygomaticus major and platysma muscles, which move the modioli in a vertical-lateral direction, are not to be used.

As discussed earlier, the modioli must be located so that the lips (which in contracting tend to form a straight line between the corners) touch opposite the center of the teeth aperture. For the majority of persons this location will be the natural resting position of the modioli. In such a case the LAO and DAO muscles, which aid in closing the lips, contract simultaneously and with equal tension, the amount being directly related to intraoral air pressure. Their contraction tends to pull the corners medially, thereby working in harmony with the incisive muscles.

Where the modioli must be moved downward for correct alignment, DAO contracts first against the natural elasticity of the facial tissue. LAO and DAO then contract in direct relation to intraoral air pressure to close the lips. If the modioli are to be moved upward, LAO contracts first.

Players with very long upper and/or lower incisors and correspondingly short vertical lip length must be careful that the modioli remain properly located as the lips are made to touch. For example, as the player with long upper incisors and short upper lip attempts to bring the lip downward past the teeth edges, the tendency will be for the modioli to ride upward, meeting the lip part way. Care must be taken to insure that this does not occur.

4. Zygomaticus major, platysma, and labial tractors.--The zygomaticus major and platysma muscles and the labial tractors must remain relaxed at all times, since they tend to pull the modioli laterally and pull the lips apart. The zygomaticus contracts to pull the modioli back and up, thinning the lips and pulling them out of alignment opposite the teeth aperture. The platysma does just the opposite, pulling the corners back and down. Working together these muscles join forces with the buccinator in pulling the modioli laterally. This adds to the burden of the incisive, LAO and DAO muscles in holding the modioli in place.

As stated earlier, the greater the work-load to be performed by the prime movers, the more relaxed must be their antagonists. The work-load in brasswind embouchure is in holding the lip alignment, and in touching and inverting the lips against the flow of air. Only those muscles which perform this task should be used if efficiency is to be maximum.

The labial tractors pull the lips apart and turn the lip-red outward. For the reasons previously stated, these antagonists of the lips must be relaxed.

5. Mentalis.--The mentalis contracts to pull the flesh of the chin upward, and in so doing, it causes the lower lip to be forced upward. If the lower lip is relaxed, mentalis contraction causes it to be forced outward and upward past the upper lip. However, if the lower lip is contracted, it is forced against the upper lip, closing the lips and tending to push the upper lip in an upward direction. The mentalis is never quiescent when any of the facial muscles are active, so it is impossible to keep this muscle completely relaxed in brasswind performance. However, no conscious attempt should be made to use the muscle. Rather, it should be kept as relaxed as possible. If the depressor labii muscles are inactive, the slight involuntary contraction of the mentalis will aid in closing the lips without causing undue upward motion.

6. Lips touching and inverted.--The muscles which close the lips, and invert and compress them, are the buccinator, compressor labii, LAO and DAO. It is important that the

sensation of control in touching and inverting the lips come from the modioli, not from the peripheral part of the lip near the midline. There are two reasons for this. First, by curling the lips inward from the corners, the contact points of the lips outside the mouthpiece are sealed against the loss of intraoral air which could escape around the mouthpiece. Secondly, the lips are not likely to be pressed as tightly together at the center as when control is emphasized at the midline. Excessive contraction in the center could freeze the lips and choke the tone. There is also the likelihood that control from the periphery at the midline will cause lip inversion to carry past the teeth edges into the oral chamber. Just why this latter is true may never be known, since the intricate interlacement of fibers within the lips makes scientific investigation difficult, if not impossible. But experience has shown that unless the student is taught in the beginning to curl from the corners, the probability is great that he will over-emphasize contraction at the midline.

7. Minimal contraction.--Once the posture is established, it should be maintained by the minimal contraction necessary to change the teeth aperture and to hold the lips in position against intraoral air pressure. This involves only those muscles which hold the jaw and modioli in position, and which close, compress, and invert the lips. The

facial muscles work only against the flow of air; contraction is a function of intraoral air pressure and teeth aperture size.

Tension should be felt slightly more in the lower part of the face than in the upper in approaching the higher register. Increased tension in the lower part of the buccinator causes a slightly firmer lower lip, providing a secure facing for the upper lip. Increased tension in DAO pulls the upper lip more closely to the lower as the teeth close slightly, thereby offsetting any tendency for the modioli to ride up as the teeth are closed. Tension in the upper part of the face, on the other hand, would tend to harden the upper lip too much for efficient lip vibration and encourage a riding up of the modioli as the teeth close.

9. Postural changes during performance.--There are no postural changes during performance other than changes in teeth aperture size and lip inversion. These have been discussed in relation to vibrating-lip-vertical-mass. An increase in the size of the teeth aperture and a decrease in lip inversion, within the context of a constant pressure of air, permit a greater amount of lip-vertical-mass to vibrate, and conversely. These changes can be made with ease if only prime movers are used, and if the lip setting, alignment, and mouthpiece placement are correct. Some examples of aperture and lip inversion changes during performance follow:

a. In an ascending passage during a decrescendo, the player maintains the same intraoral air pressure, closes the teeth aperture no more than 1/16th inch from the normal 1/4 inch posture and makes no change in lip inversion, keeping the lips as relaxed as possible as the teeth close. Lip vibrational frequency will increase and the amplitude will decrease in proportion to the change in aperture.

b. In an ascending passage during a crescendo, the player maintains the same teeth aperture, increasing intraoral air pressure throughout the ascent. The red of the lips will invert very slightly, but the player will have no proprioception of this change. It will feel more as if he is holding the lips in their same position as he ascends.

c. In an ascending passage without change in intensity, there will be an increase in air pressure and a decrease in teeth opening. In this instance there probably will be only a small change in lip inversion.

Summary

In this chapter a theory has been set forth favoring one particular facial/jaw muscle posture and pattern of muscular activity as the most efficient embouchure made for all brasswind players. This posture and activity pattern were described, and a supporting rational was presented.

CHAPTER SEVEN

IMPLICATIONS FOR BRASSWIND PEDAGOGY

A theory has been advanced that a single embouchure mode is most efficient in brasswind performance. Further, this optimum embouchure has been described in detail. Assuming the validity of this theory, the implications for brasswind teaching are considerable, and are presented in the following four major categories: (1) advisement concerning the selection of brasswind instruments, or a particular brasswind instrument, as a performing medium; (2) methods for teaching the beginning brasswind player; (3) methods for maintaining and developing optimum embouchure through advancing of performance; and (4) remedial methods for brasswind players who have developed a less efficient embouchure.

Persons considering brasswind instruments as a performing medium should be advised at the outset concerning their possible success. Such advice should be given not only on the basis of musical aptitude and the playing opportunities a given instrument affords, but also upon natural physical adaptability for a particular instrument. The latter often has been overlooked, probably because little has been known about embouchure. If the embouchure posture described in Chapter Six is accepted as optimum, it seems reasonable to assume that the more closely the natural jaw and facial conformations of a prospective player approximate this posture, the more easily the player will be able to develop it. Conversely, the more widely the natural conformations depart from this posture, the more likely a compromise in embouchure will be necessary. Any compromise would mean some departure from optimum posture, and the greater such departure, the greater the limitations to be experienced in playing. For example, a person with outward-slanting teeth and receded jaw may find it impossible or too much of a strain to align the teeth edges as required in optimum embouchure. This person should be fully aware of the options open to him: orthodontic treatment if he wishes to have the best possible advantage in embouchure; limited upper range if he wishes to play with his natural deficiency. He should know that if he chooses the latter, he may well be able to meet all requirements for performing a great amount of excellent solo literature, performing in secondary school and amateur ensembles, and performing professionally in both the "legit" and popular fields so long as his performance goals are consistent with his natural limitation. If he accepts his limitations, he will not waste time experimenting with various embouchure modes in an attempt to develop a technique which is not possible for him.

A description of common deviations from the norm of optimum embouchure is beyond the intent of this chapter. It must be the responsibility of brasswind pedagogists to know efficiency factors in embouchure, and the limitations to be expected when a particular deviation exists. Study is needed to establish norms of performance at all levels of playing ability, based upon the playing characteristics associated with optimum embouchure and various deviate modes.

The second major implication for brasswind pedagogy concerns methodology for training optimum embouchure at the beginning level of performance. It is here that proper technique can be taught most efficiently. Probably the most crucial moment in embouchure development is when the mouthpiece is touched to the lips for the first time. With proper training, the majority of students should be able to learn correct posture and muscular activity patterns regardless of age; and through the playing of appropriate musical exercises, they should develop such posture and activity patterns as their natural embouchure mode.

An examination of method books for beginners in common use shows that much is left to chance or to individual interpretation in the early training of embouchure. General instructions usually found concern only mouthpiece placement and lip formation. It is assumed that the player will find his best natural embouchure on his own. In addition, the early playing exercises center on the low mid-range of the instrument where one embouchure mode is probably as satisfactory as another. It is possible to play well in this range using techniques that are not suitable for upper register performance. Within the limitations of range, timbre, flexibility, power, and endurance required in these methods, and later for secondary school performance, many different embouchure modes are possible. Psychological factors (incentive, musical aptitude) and physiological factors (general body strength, breath management) may camouflage embouchure deficiencies, especially at this level. Methods for teaching beginners must be modified, then, if the optimum embouchure is to be trained from the start. The following procedures are suggested, incorporating the principles set forth in Chapter Six.

1. Principles of breathing in playing a brass instrument must be stressed from the start, since once the player has finally mastered embouchure technique, he relies almost entirely upon breath management and thinks very little about embouchure. Deep breathing, abdominal support, relaxed throat, quiet chest and shoulders must all be developed purposefully, and may not be taken for granted. Exercises which develop proper concepts in breathing and breath support should be practiced daily until they become habitual.

2. Embouchure posture should be taught before the student is allowed to work on his instrument. This includes

a. Teeth parted approximately 1/4 inch, incisal edges aligned vertically. The student can check himself on this by using a small stick, such as that used in stirring coffee, trimmed as necessary to the right size. Inserting the stick between the teeth and tilting it up and down by moving the jaw forward and backward, he can get feedback concerning correct opening and alignment. If the student experiences discomfort, he must be instructed to relax the jaw as much as possible, and practice for a short time at first, gradually increasing the time as comfort permits.

b. Lips touching lightly opposite the center of the teeth opening. The student can get feedback concerning proper lip-to-teeth alignment by touching the tip of the tongue against the inside of the lips.

c. Modioli in their natural resting position. Feedback is obtained by touching the modioli with the fingertips while forming the embouchure.

d. Red of both lips turned inward slightly. The student is instructed to start this movement from the corners, gradually curling inward toward the midline, being certain that the lip-red does not cross the teeth edges.

e. Muscles in the chin and beside the nose are relaxed. Feedback is obtained by touching these areas with the fingertips as the embouchure is formed. Any movement or firming of facial tissue indicates muscular activity.

3. Once the posture has been established in a relaxed, comfortable manner, breath is passed through the lips. Checks are made by the student with the fingers and tongue to assure that the posture has not been disturbed. Air flow is increased and the student continues checking, being certain that the posture is maintained as the lips hold against increased air pressure. Proper breathing and breath support are constantly checked.

4. Tonguing is introduced, making certain that the posture is not disturbed. Particular attention should be given the lower jaw, which should not move with the tongue.

5. After all of the above has been comfortably established, mouthpiece placement is introduced. This is a crucial moment in the early training of technique, and instructions should be specific to each individual. In the case of the smaller mouthpieces where the rim is placed opposite the incisal teeth, placement should be on the most forward point of the upper teeth, and the most forward two points of the lower teeth. In all cases the bite must be above the upper lip-red. Vertical placement should be approximately equal on both lips except for horn, where 2/3 upper and 1/3 lower lip are recommended, making a slight sacrifice in efficiency to achieve characteristic timbre. After placement is made, the student forces air through the mouthpiece without any attempt to vibrate the lips, checking constantly to see that correct posture is maintained and that facial muscle activity appears to be nil. Air is increased, so that the lips begin vibrating. If the lips are touching properly and inversion is maintained, the first vibrations will be at a rather high frequency. If they are not, the student continues working with the mouthpiece alone for a full, free vibration, and is cautioned against tensing and pressing for the high frequency. As the posture

stabilizes and the lip inversion holds against the flow of air, the frequency will rise.

6. Once the student produces a full tone on the mouthpiece at a relatively high frequency with consistency, he is permitted to take his instrument for the first time and is taught how to assemble and hold it.

7. Finally, the student is introduced to the playing of exercises especially written for this method. These exercises will differ from traditional beginning exercises in that the middle range of the instrument will be fully explored first, with occasional playing in the upper register. The low register will be avoided during the early weeks of playing, for the following reason: students find that this register can be played immediately if they remove a small amount of lip from the mouthpiece or make other undesirable adjustments or deviations from the optimum embouchure posture. This will cause difficulty in developing the altissimo register, where more lip in the mouthpiece is needed.

Frequent checks must be made to assure that correct posture is being maintained and that there is a minimum of tension in the facial muscles. Also, constant checks on breathing and breath support must be made, and reminders made about tonguing.

Once proper embouchure, breath support, and tonguing are correctly and securely established, other aspects of technique and musicianship normally covered by beginners can be introduced. This marks the first time that the brasswind players may join with other instrumentalists in playing ensemble pieces, approximately one month after the beginning program has started. Beginning brasswind students must be taught, therefore, in a separate class from ther instrumentalists for at least their first month of study. As they begin playing in full band and orchestra, they continue meeting separately at least once each week to have embouchure checked and to develop range beyond that normally required in beginning band or orchestra music. By the end of the year, these students will be aware of all registers, pedal through altissimo, will know the proper procedures to use in attempting these registers, and in many instances, will have succeeded in playing far beyond the ranges required in secondary school band and orchestra performance.

Care must be taken that the beginning student not press the mouthpiece too hard against the lips in playing high tones and that he not allow lip to slide out of the mouthpiece as he plays in the low register. Constant checks must be made throughout the year to be certain that proper imbouchure posture is maintained and that improper muscles are not brought into play. Extremely loud playing should be avoided during the first year if it appears that it causes the student to remove lip from the mouthpiece. Coordination and ease of playing over a wide pitch range must be stressed as important goals.

The third implication for brasswind pedagogy concerns the methodology involved in maintaining optimum embouchure after it has been established as the player concentrates upon developing overall technique. In present methodology little, if any, mention is made concerning embouchure after the student has begun playing. Emphasis centers upon developing general musicianship, and playing demands are only moderate as related to upper register performance. In such a situation, it is possible that a student will slip into a less efficient embouchure mode and yet perform with ease all of his musical assignments. To prevent this, it will be necessary to use supplementary materials which present to the student the full range of the instrument and which emphasize the desirability of developing this range even though it does not appear in his ensemble and solo experiences. If the player is reminded occasionally of the elements of embouchure, is encouraged to check himself carefully against any deviations from correct posture and muscular activity, and is assigned exercises which he cannot play with ease unless he uses correct embouchure, he will be less likely to slip into poor habits. Further, his embouchure will continue to develop; and when he is confronted with music which exploits the outer limits of the instrument, he will be more prepared to play it.

There is no such supplementary material readily available today; it will be up to the individual instructor to develop his own. If the demand for material of this nature becomes great enough, it is likely that it will become available.

The fourth implication for brasswind pedagogy relates to remedial methods for brasswind players, who have already established an embouchure mode which deviates from the most efficient one described. In this case, habits developed over many years, in some instances, must be broken and new ones developed. Such modification in technique may come at a very inconvenient time, especially for those players in responsible positions in musical organizations. The author, in order to gain insight into this problem, conducted an informal study with eighteen college brasswind majors who were holding important positions in band and orchestra and who were interested in improving their embouchure. The subjects included trumpet, trombone, and tuba majors. All were able to adjust with comparative ease to the embouchure while concentrating on nothing but jaw position and proper muscular activity. They were further able to incorporate the new embouchure rather well at times, although inconsistently, in the playing of special exercises which emphasize upper register performance. All students found that they could occasionally play very well over a wide range, whereas at other times, they could barely play at all. Few were able to incorporate this technique immediately into their ordinary playing assignments. It appeared that much time would be needed to change old habits.

The trumpet players met with less success than players of other instruments as they changed embouchure mode. Their problems appeared to be related to lack of muscular relaxation. Apparently, these players had become accustomed to keeping their facial muscles overly firm during performance over the years and were unable to relax sufficiently. There were moments, however, when all realized the satisfaction of playing with ease in the altissimo register. All students appeared convinced that the new embouchure had merit and wanted to continue working at it, even though time would be lost thereby from their regular study.

Remedial work may take either of two forms. The first, probably the quickest, involves a sudden change to the new embouchure, attempting to erase at once the old habits. This would mean that the player would become at least momentarily a beginning student and would have to drop all responsibilities of performance during the change. For a period of at least one year, and perhaps considerably longer, the new habits would be developed until they were stable. The player would lose time thereby from the regular study of exercises, etudes, studies, solos, etc., that might have been expected of him. His reward for this would be the development of a technique which would enable him to perform eventually at a more advanced level than he could have attained on his old embouchure.

The second approach involves a very gradual development of the new embouchure while the player continues to perform on the old one. In this case the player would play daily upon two different embouchures, practicing special exercises on the new one, and then practicing regular playing assignments on the old. At some point he would begin using the new embouchure on a limited basis in his playing, and gradually discard the old. This would probably take much longer than the first approach; but it would allow the player to proceed with his regular performance schedule. The amount of time and difficulty involved in this approach is not known. The preliminary investigation mentioned above indicates that for most players the gradual change causes only minor difficulty. It might be noted that in this informal experiment, the players with the poorest embouchure made the change more quickly and with more ease than those students with a somewhat better, previously developed embouchure mode. This was especially true of trumpet players; the better the player, the more troublesome the changeover.

The four implications discussed in this chapter must be given further study. Some of the questions needing scientific investigation are as follows:

1. Are there any adverse physiological effects

resulting from having all students conform as closely as possible to the posture described? If so, what are they, and what are the characteristics of students who experience them?

2. Will the young student respond in a positive way to the beginning approach described? Can he be motivated by an approach which stresses physical development at the outset rather than the customary, and more pleasant, experience of playing tunes immediately?

3. What will be the playing characteristics of students taught by this method as countrasted with those taught in the traditional way? This would include a description of tone quality, range, mouthpiece pressure, endurance, flexibility, etc., at various times, at the beginning, intermediate, and advanced levels of performance.

4. What is the most desirable method of changing from another embouchure mode to the optimum?

5. What musical exercises are suitable for use in developing most efficient embouchure and maintaining it through all levels of performance?

APPENDIX

QUESTIONNAIRE AND ANSWERS CONCERNING TWO OPPOSING METHODS OF TEACHING BRASSWIND EMBOUCHURE

Definition of Special Terms Used in the Questionnaire

Trumpet Pedal Register--All notes downward from written F# below the treble staff.

Trumpet Low Register--Written F# below the treble staff upward through second line G.

Trumpet Middle Register--Written G# second line treble staff upward through G, top of staff.

Trumpet High Register--Written G# top of treble staff upward through G, four ledger lines above the staff.

Trumpet *Altissimo* Register--All notes upward from written G, four ledger lines above the treble staff.

Legit--The slang word *legit* is common in musical jargon, and it is used in the questionnaire intentionally for want of a better term. It is an antonym for the word *popular* as applied to art, and refers to classic works of of music as distinguished from popular music.

Two Opposing Methods of Teaching Brasswind Embouchure

Method 1. Emphasis is on the development of embouchure in the low, middle, and high registers. Flexibility, power, and control in these registers are stressed in relation to artistic performance of standard literature. The altissimo and pedal registers are recognized and are considered desirable, but they are believed to be representative of innate ability, not required nor expected of all students.

Method 2. Emphasis is on the development of embouchure in the high and altissimo registers first for all students. This method is grounded in the premise that the embouchure in the middle, low, and pedal registers can be developed later without radical departure from the embouchure used in the high and altissimo registers. Emphasis is placed on power, ease, and control in the high register first, with mechanical considerations taking precedence over musical considerations in the beginning. As mechanical considerations are mastered, musical considerations are then stressed.

Respondents to Questionnaire

John J. Haynie, Professor of Music, performer and teacher of trumpet, North Texas State University, Denton, Texas, representing method one.

Haskell O. Sexton, Professor of Music, performer and teacher of trumpet, University of Illinois, Urbana, Illinois, representing method one.

Roy Stevens, performer and teacher of trumpet, Stevens-Costello Embouchure Clinic, New York, New York, embouchure specialist, author of Embouchure Self Analysis and the Stevens-Costello Triple C Embouchure Technique, representing method two.

Elmer R. White, Associate Professor of Music, performer and teacher of trumpet, Appalachian State University, Boone, North Carolina, representing method two.

Questionnaire and Answers

A. Description of students working under your tutelage

1. What level student--beginner through advanced conservatory/college through professional--comes to you for study?

Haynie: Beginner, rare; occasional high school student; some college freshmen and sophomores; basically, graduate students, senior undergraduate, and a few junior undergraduates.

Sexton: Medium ability through advanced conservatory/college.

Stevens: Beginning through professional, mostly professional. Most do not come to learn to play the instrument, mechanically speaking. Ninety-nine per cent come to work solely on embouchure--how to apply it to their mechanics.

White: The students who come to me to study are mostly undergraduate college students.

2. Are students under your tutelage more interested in legit or popular performance?

   Haynie: Legit.

   Sexton: Legit.

   Stevens: From both areas. They are already functioning in their chosen area.

   White: I have students who are interested primarily in legit playing, students interested primarily in popular playing, and students interested in both.

3. What are the ultimate goals of your students, generally? (Teaching in public schools, colleges, professional playing, what type of playing?)

   Haynie: Teaching in college, first choice. Next choice, teaching in public schools. Professional playing is of interest to some, but they are smart enough to realize that such opportunities are limited. Some do become professional players if the breaks allow--the right place at the right time.

   Sexton: Teaching in public schools, colleges.

   Stevens: To become a lead player, or better lead players; professional playing.

White: Most of my students will pursue public school teaching careers. Some students have ambitions toward college teaching careers, and others toward professional playing careers, in both legit and popular fields.

4. How long do students normally study under your tutelage?

Haynie: From two to six years, with four being an average. Some drop after one year, probably out of music.

Sexton: Two to four years.

Stevens: An average of three years. If they last the first eight weeks, they last for at least three years. Those who have studied longer have established reputations for their embouchures.

White: Most students study with me for four years.

5. When a student has completed study with you, is he more suited to the legit or popular field?

Haynie: The majority are more suited to the legit side. Those who become professional players do so in the popular field, usually leaving before completing the program. Those completing the program are suited to legit playing.

Sexton: Legit.

Stevens: 1. The student has never completed study.

Even the most advanced come back for periodic check-ups. 2. The student is suited to either field. 3. Students include a principal player in the Metropolitan Opera Orchestra, and lead players in the popular field.

White: I allow the student to determine his own emphasis to some extent. In all cases the primary emphasis is on legit playing, but time is taken, if the student wishes, to study jazz interpretation, etc. In my own playing the emphasis is on legit playing, but I have done, and continue to do both.

B. Work in the altissimo register.

1. Do you stress development of the altissimo register?

Haynie: No.

Sexton: No.

Stevens: We start with it.

White: My students work in the altissimo register, not necessarily for the purpose of making this register usable musically, but as an exercise for embouchure development.

2. What percentage of your students, approximately, work to develop the altissimo register?

Haynie: Perhaps ten per cent work on it and are not discouraged from doing so.

Sexton: None.

Stevens: All.

White: Virtually all students work to some extent in the altissimo register.

3. What percentage of your students actually develop a usable altissimo register?

Haynie: Five per cent or less. They could do it before coming to me.

Sexton: None.

Stevens: All have it as a usable upper register. It is relative to the individual player's mechanical development, which is dependent on his insight and ability to coordinate what he knows will play.

White: All of my students learn to produce tones in the altissimo register; however, only those who are inclined toward playing popular music, e.g. stage band, etc., would have reason to use the register and therefore work toward any control of this register.

4. In your opinion, is there such a thing as being naturally suited to play the altissimo register?

Haynie: Yes.

Sexton: Possibly, but I have had such little interest in it I have not explored it.

Stevens: Yes. If the natural formation suits the principles that are involved in physical law, the pupil does not necessarily have to know those principles. It would be better if he did know, for he would have more assurance in the sharp-shooting or placement of tones.

White: Any player can learn to produce a good sound in the <u>altissimo</u> register, although because of certain factors, e.g. teeth formation, some students develop it more easily or quickly than others.

4a. If so, what are physiological characteristics of players so endowed?

Haynie: Most have a normal looking embouchure, use excessive pressure, play very loudly, and have a very strong facial musculature to withstand the excessive pressure. Some have undesirable characteristics: excessive expansion of the neck, puffing cheeks, mouthpiece low on the upper lip, and head ducked.

Sexton: (No comment.)

Stevens: 1. The ability to retain a parallel jaw position to the top teeth edges, establishing a firm background for the bottom lip facing and the top lip reed. 2. A minimum of teeth irregularities. 3. An easy alignment of the lips between the teeth aperture, equally spaced.

White: Wedge-shaped upper front incisors are an asset as is the lack of an excessively pronounced distoclusion. A pronounced distoclusion in conjunction with upper front incisors that slant outward (buck-teeth) makes development of the register more difficult.

4b. What are psychological characteristics of players naturally suited to playing altissimo?

Haynie: High note players are braggadocios. There is a physical thrill to playing high notes, and listeners like to hear them.

Sexton: (No comment.)

Stevens: Whatever the psychological barriers are prior to the development of the upper register, they cease to exist after a mental connection, understanding, and sense experience have been established.

White: I do not believe there are any psychological characteristics which would affect the development of the altissimo register any more than any other aspect of trumpet playing.

5. Were all your students who successfully developed the altissimo register naturally suited to this register?

Haynie: No.

Sexton: (No comment.)

Stevens: No. Physical deficiencies had to be overcome to conform with the principles.

White: All of my students develop this register so they all must be well enough suited.

6. Do you stress <u>fortissimo</u> playing in the <u>altissimo</u> register?

Haynie: No.

Sexton: (No comment.)

Stevens: Yes. It is part of the physical law.

White: Yes.

7. Do you stress <u>pianissimo</u> playing in the <u>altissimo</u> register?

Haynie: No.

Sexton: (No comment.)

Stevens: Yes. It is also a part of physical law.

White: Not on the B^b soprano trumpet.

8. Do you stress control of slurs and articulations through a wide range of dynamics in the <u>altissimo</u> register?

Haynie: No, but if I did stress the <u>altissimo</u>, I would emphasize this just like the high register.

Sexton: (No comment.)

Stevens: Yes, very much; almost exclusively for the early stages.

White: Not on the B^b soprano trumpet. <u>Pianissimo</u> playing and/or articulation practice in the _altissimo_ register is really not feasible, and probably not possible for most mortals, on the B^b trumpet. If the student is advanced enough and so inclined, this sort of work might be done on the B^b piccolo trumpet.

C. Embouchure.

1. Corners of the mouth.

a. What is the action of the corners of the mouth during inhalation? Why?

Haynie: Firm, but not tight. I agree with Farkas concerning the "tug-of-war" between facial muscles. The corners are relaxed for lower notes, and tighten up in ascending to high notes. During inhalation, let nature decide what the corners do.

Sexton: Corners stretched back toward the ears, to allow much air to enter the mouth quickly.

Stevens: Relaxation, separation of lips minus tu-ee (pulling the corners back and up). Intake must be silent--no sipping. It is this position that permits the player to bring his lips together from the corners to the outer rim of the mouthpiece and establish playing formation with a minimum of tension. The release of air and its force will determine the playing tension. The tension may increase or decrease from the original playing formation based on the intent of the player. It is the fixed corners in their relaxed position that permits the player to correctly align his lips over and over.

White: The corners of the mouth should remain virtually motionless during inhalation so as not to disturb the embouchure setting and mouthpiece placement. A completely silent breath can be taken if the throat is kept open, the tongue dropped to the bottom of the mouth, and the jaw opened slightly. The muscles of the embouchure must be relaxed to allow the mouthpiece placement to remain fixed as the jaw is lowered slightly. As this is done, the corners will move downward almost imperceptably.

b. What is the placement of the corners of the mouth vertically and horizontally while performing in the various registers low to altissimo? Why?

Haynie: There is nothing that can be done to change the natural inclination of the corners up or down. I suspect that if a player's corners naturally turn up, such a person plays the "smile" system. The corners of most players turn down. Keep the basic, natural position--the natural position when relaxed.

Horizontally, the movement must be minimal. Be aware of contraction, keeping a normal appearance, the position when relaxed. This is true in all registers. There appears to be movement in some fine players. It is a very individual matter, some appearing to move the corners forward, some backward. Keep motion to a minimum.

Sexton: Corners drawn down, not back for upper range, for purposes of strength in embouchure.

Stevens: It is the same, taking into account the relative change of muscular tensions. The corners in normal resting position with the teeth 1/4 inch apart and aligned vertically (even bite) is the correct position unless there is a deformity.

White: The horizontal and vertical position of the corners of the mouth should be, for most players, the same as in a natural state of repose. Assuming that the teeth are vertically aligned, the corners should remain in virtually the same position for all registers, i.e. vertically aligned with the teeth aperture and in natural width. A player with very fleshy lips may need to widen the corners slightly. Any jaw position, e.g. a receded jaw, or teeth structure, e.g.

outward slanting upper front incisors in conjunction with a receded jaw, which would cause the player to have a tendency to push the lips upward with the mouthpiece and out of alignment, would create the need to depress the corners somewhat for high and/or loud playing.

In ascending into the high and altissimo registers, a very slight widening of the corners takes place. This is probably due to the increased contraction of the risorius and platysma muscles and possibly the buccinator muscles.

c. Should the corners of the mouth hug the teeth? Why?

Haynie: Yes. If not, you may wind up with puffed cheeks.

Sexton: Yes. Again a feeling of strength from the grip of the corners against the teeth.

Stevens: Yes, to avoid slack in the lips, top and bottom.

White: Yes. All of the flesh of the face must "drape" firmly over the jaw and facial bone and teeth structure for the facial muscles to contract properly.

d. Should the corners of the mouth be relaxed or firm? Why?

Haynie: Firmly relaxed. The longer one keeps the tension out, the longer one has reserve left, somewhere to go.

Sexton: Firm in the middle and high--endurance.

Stevens: Relaxed during inhalation. The tension during playing should reflect the volume and area of range, which are based on the intent of the player. The speed of the air column, amplitude and frequency of the sound vibration, will determine the tension.

White: The corners of the mouth should be relatively firm at all times. The muscles of the face which insert into the lips, through the corners, must be contracted to hold the lips in place against the flow of air, while the center portion of the lips themselves remain as relaxed as possible. All of these radiating muscles converge at the modiolus, just outside the corner of the mouth. The amount of tension in these muscles should be governed by the amount of air pressure against the lips and by the amount of lip exposed to the air stream. The amount of lip so exposed is, of course, determined by the teeth opening. Obviously then, more lip exposed to air, and/or more air pressure = more muscular contraction and visa versa.

e. Have you any other ideas concerning the corners of the mouth?

Haynie: No.

Sexton: (No comment.)

Stevens: No.

White: If the corners are held properly, the player will experience the sensation of a slight "tucking-in" of the corners. This will allow the embouchure formation to be held in place against the air flow while the center portion of the lips remains relaxed, producing an efficient, vibrant, resonant sound.

2. Tension of facial muscles.

a. Should the buccinator (cheek) muscles be firm or relaxed in playing the low, middle, high, altissimo registers? Why?

Haynie: Firm in low, gradually getting firmer but staying as relaxed as possible for any given note.

Sexton: Firm throughout; otherwise, poor control of pitch level.

Stevens: The compression in the mouth chamber will determine the tension.

White: The buccinator muscles should be relatively dirm at all times. The higher and/or louder the playing, i.e. the more the air pressure and/or the more lip exposed to air, the firmer the buccinator muscles will become.

b. Should the muscles that elevate the upper lip (not including the corners) be tensed or relaxed in the various registers? Why?

Haynie: Same as preceding answer, all working as a team.

Sexton: As relaxed as possible, yes, but to be honest, it is not really relaxed in upper range. The upper lip must be rolled, so it is not completely relaxed.

Stevens: No attempt should be made to use these at all. They should be used to reinforce the original playing formation, and sympathy tension will be introduced when the two lips are exposed and resist the air column, equipping the two lips to resist mouthpiece playing weight (arm pressure).

White: The upper lip levators should remain relaxed in all registers. These muscles, when tensed, will separate the lips. If a player attempts to create what I call the necessary surface tension in the vibrating portion of the upper lip levators (levator labii superioris, levator superioris aleque nasi, and zygomaticus minor) he will find it necessary to offset the tendency of these muscles to raise the upper lip itself (orbicularis oris) and/or by an increase in mouthpiece pressure (which I assume everyone considers undesirable) to attempt to hold the lips together. This can become a really serious problem in ascending into the higher registers. In an ascending passage more surface tension is needed. A player can learn through trial and error that by tensing the upper lip levators, the needed surface tension is created; but at the same time, these muscles are beginning to elevate the upper lip, pulling the lips apart and creating a larger lip aperture, while a smaller aperture is needed to play the higher tone. The most expedient way to create the smaller lip aperture now becomes to resist the upward pull on the lip with the lip muscle itself and to begin to press harder with the mouthpiece to "mash" the lips back together. As the player continues to ascend, one factor continues necessitating the other until the lip cannot be "mashed" any further, or until he reaches his limit of endurance of pain, whichever comes first. Unfortunately, this limit often is reached before the desired high tone is reached. Also unfortunate is the fact that once this cycle of pulling the lips apart and pressing them back together has begun, the player becomes trapped in this method of ascending, i.e. he cannot continue to ascend without more of the same. Contraction of the upper lip levators is one of the contributing factors in starting this cycle, and should be rigorously avoided.

c. Should the muscles that depress the lower lip (not including the corners) be tensed or relaxed in performing the various registers? Why?

Haynie: Same as above.

Sexton: Same answer as above--as relaxed as possible.

Stevens: They should not be thinned and weakened. They act as a cushion to receive the mouthpiece weight on the bottom.

White: The lower lip depressor should be as relaxed as possible for basically the same reasons as described in question 2b above. This muscle will also be discussed more fully along with the mentalis (chin) muscles below.

d. Should the mentalis (chin) muscle be relaxed or contracted in playing the various registers? Why?

Haynie: The chin should be flat and pointed. Try to reduce the weight of the mouthpiece on the upper lip. The flat, pointed chin forces the correct action of the muscles of the upper lip.

Sexton: Contracted--pointed--very poor embouchure control otherwise.

Stevens: Always in a state of contraction, only different degrees, with the degree being dependent on intent and area, exclusive of the concept of playing pedal tones, which require a complete collapse of the outer-red.

White: The mentalis (chin) muscles should remain as relaxed as possible at all times. When this muscle contracts, it begins to push the lip alignment up (lip alignment refers to the point where the lips must meet each other being aligned with the teeth opening).

Further comments concerning both 2c and 2d above (the depressor labii inferioris and the mentalis): One can feel tension in this area while playing but I believe it is incorrect to emphasize this tension, or to deliberately attempt to contract these muscles, i.e., to attempt to pull down or "point" the chin or "bunch up" the chin. The proper tension will materialize in sympathy with other deliberate muscle activity, e.g., activity in the modiolus and the depressor of the corner of the mouth (triangularis or depressor anguli oris), and the lower orbicularis oris.

e. Should there be a feeling of tension or relaxation in the face generally with reference to the various registers?

Haynie: There should be firmness in the low register, increasing as the player ascends, but with reserve as far as possible. This will vary from day to day.

Sexton: A feeling of relaxation, yes.

Stevens: There must be both. Relaxation is a matter of degree from tension. The player must avoid neutralizing or collapsing the playing formation. "Neutral" is the fixed point somewhere between force behind the air and muscular resistance.

White: There should be a feeling of "minimum tension" in the face while playing, although only enough to hold the playing formation against the air stream. The amount of air pressure then becomes the gauge for the amount of tension needed. This "minimum required tension" would be relatively small in the middle register, somewhat more at the corners of the mouth in the low register, and considerably more in the high and altissimo registers. As a general rule, the player should concentrate this tension in the lower portion of the face, i.e., in the modiolus, risorius, platysma, triangularis (depressor anguli oris), and the lower one-half of the buccinator.

f. Should there be a feeling that the focus of tension is within the lips rather than spread to include muscles outside the lips?

Haynie: No. The lips serve as the vibrating area. The musculature of the whole face is involved.

Sexton: I feel the tension in the lips more so than in the face, but when I study the mirror, I see that the face is working also. (Frank Simon was a firm believer that the face muscles must be working also.)

Stevens: The starting point is tension below the corners (depressor anguli oris m.). The rest of the embouchure muscles will and should work in sympathy, establishing various tensions if properly exposed to air. The radiating muscles from the corners across the cheeks (buccinator, and risorius including the masseteric and platysma strands) are dependent upon the orbicularis oris (top and bottom) being properly exposed to air between the teeth apertures, permitting the radiating muscles to exercise control over the two lips.

White: No.

3. Alignment of lip aperture with the opening between the upper and lower teeth.

a. Is it important that the lip aperture be opposite the opening between the upper and lower teeth? Why?

Haynie: Yes, so that the lips will be in position to receive contact with the air stream.

Sexton: Yes. I cannot see how it could be otherwise for good response and control.

Stevens: From my point of view the law must be a two-aperture concept: teeth and lips. The lip aperture must comprise an equal amount of upper and lower lip between the teeth wherever the mouthpiece placement is made. Example: If one upper tooth is longer than the other receiving the mouthpiece, the longer will be the barometer for lining up the lips equally spaced between the teeth aperture. This necessitates a lowering of the corners so that the lips in their playing formation form a straight line between the two fixed points, corners of lips.

White: Yes. When either lip is not exposed to the flow of air, the air flow will be completely impeded and stop; or the lip receiving all the air pressure will blow out. In either case, the vibration and consequently the tone will stop.

b. Should the center of the two openings (lip and teeth) be perfectly aligned? Why?

Haynie: Afraid of the word perfectly. Reasonably well aligned.

Sexton: Again, yes. Same as reason above.

Stevens: Yes, so that the bottom teeth edges can exercise control over the lip aperture by articulating up and down relative to increasing and decreasing air compression, lengthening and shortening the stroke of vibration. All jaw motion up and down must be relative, based on the starting point of the predetermined jaw position. I do not advocate receding the jaw to its underbite position, contributing to extreme lip separation, resulting in excessive mouthpiece weight to overcome lip separation.

White: Yes. While the size of the teeth aperture will vary somewhat in changing registers and dynamics, it should average about 1/4 inch.

Therefore only 1/8 inch of each lip would be exposed to the air stream. Assuming that the teeth are aligned vertically, and since it is obvious that the vibration will stop the instant either lip is no longer exposed to the air stream, it would be imprudent not to attempt to maintain perfect alignment of the lips to the teeth aperture.

c. If alignment is to be maintained, how is this accomplished? What muscles are important in preserving alignment?

Haynie: I do not know.

Sexton: Equal pull between upper and lower lip and corners. Actually, a person with an extremely short upper lip cannot have good response.

Stevens: The fixed corners maintain the alignment. Do not use the upper one-half of the facial muscles. For example, no sneering, no sipping of air raising the corners, no lip thinning and weakening by pulling the corners back and up.

White: The caninus (levator anguli oris), and the triangularis (depressor anguli oris) appear to play the primary roll in maintaining the position of the corners of the mouth (the modioli). If the corners remain in place, i.e. aligned, the lips will remain aligned. This assumes that the mouthpiece is not at an angle other than ninety degrees to the plane of the labial surface of the teeth. If this were the case, the mouthpiece might push the lips out of alignment. The buccinator muscle, the combination of risorius and platysma muscles, and possibly the zygomaticus major also appear to play some part in maintaining the position of the corners of the mouth, especially under high levels of compression, e.g. playing very high or loud. The risorius and platysma muscles appear to increase markedly in activity when ascending into the high and altissimo registers.

d. Is alignment more important in one register than in another? Why?

Haynie: Yes, in the high register.

Sexton: Upper range extremely important. Not so much in lower range.

Stevens: Important in all registers. The higher you play the more perfect the alignment has to be since there is less room for error.

White: I would not characterize alignment as "more important in one register than another"; rather I would say that it is more critical (and more difficult to maintain) when playing high and/or soft, since the teeth aperture is smaller.

4. Alignment of the lower teeth with upper teeth vertically.

   a. Assuming a very slight overbite in normal occlusion, should the brass player align the teeth vertically in the various registers? Why?

Haynie: The jaw is most forward for the low register, gradually receding as the player ascends, being careful not to recede too much too soon. It would be great if the teeth alignment could be vertical all the way for stability of total embouchure.

Sexton: The normal person cannot align teeth vertically in the top range. To do so causes much strain of the lower jaw.

Stevens: Yes, in all registers, so that both lips can receive an equitable distribution of weight of the mouthpiece. Pain due to high spots or other irregularities in teeth formation may be partially overcome by bringing the teeth into vertical alignment.

White: Yes (overbite = distoclusion or horizontal overbite). The two surfaces which serve as a background for the lips, the upper and lower front teeth, should present a reasonably even background upon which to place the mouthpiece. With the jaw receded, there is a strong tendency to apply more than one-half of the mouthpiece pressure to the upper lip. The pressure from the mouthpiece should be distributed approximately equally between the top and bottom lips, with very slightly more than one-half of the total mouthpiece pressure on the bottom lip. Problems relating to overbite and to vertical alignment of upper and lower teeth will be discussed further in answers 5a, b, and c.

b. Have you had a student with severe overbite (1/4 inch approximately) develop good, excellent, or outstanding tone quality?

Haynie: It is possible to produce outstanding tone quality with a severe overbite. In fact, I have such a student now. This student also has fine range and power.

Sexton: Yes, excellent.

Stevens: I have had students with severe overbite. However, according to my understanding of the physical laws involved, I consider this condition a physical deficiency and a severe handicap. I would not take the trouble to find out if his tone quality could develop to good, excellent, or outstanding since this condition would not produce a relative five octave scale. The first step is to overcome the physical deficiency and to find a playable starting point.

White: Yes. Of course, the student would not play in this natural overbite position.

c. Have you had a student with severe overbite develop good high range in playing? Good altissimo? Good low range?

Haynie: I cannot recall a good altissimo with severe overbite.

Sexton: Good high range and good low range.

Stevens: No. He cannot continue being my student since I will not tolerate that playing formation. The physical deficiency must be overcome.

White: Yes, all three. Same as above.

d. Have you had a student with severe overbite develop power in playing? In what range?

Haynie: Yes, up to G. Not altissimo.

Sexton: No.

Stevens: Same as c.

White: Yes. All ranges. Same as above.

e. Can you establish a relationship in playing with an overbite as regarding tone quality, range, flexibility, tonguing (single, double, triple)?

Haynie: Normally, the person with extreme overbite has more problems.

Sexton: Probably the following: only medium tone quality, poor to medium range, medium flexibility, medium tonguing.

Stevens: Yes. The tone quality, range, and flexibility will depend on the degree the player recedes from his original starting point. Regarding tonguing under these conditions, the player must, out of necessity, tongue to the top teeth or gum line or possibly higher to effectively block the air column. The law is that under any circumstances the player must tongue to the most forward point, in this instance, the top of the upper jaw. In double and triple tonguing, the striking point of the K attack will adjust itself. The distance between T and K may vary if the jaw motion is extreme.

White: I would not allow a student to play in his natural jaw position in the case of an extreme overbite (more than 1/4 inch). However, pushing the jaw forward an extreme amount does appear to have a detrimental effect on tonguing. In such a case, a student would have to undergo orthodontal work or a compromise would have to be reached. The exact compromise would also be strongly influenced by other factors, e.g. the slant of the front teeth, to be discussed later.

f. Consider any of the above as applied to underbite.

Haynie: If extreme, problems will exist. I find that such persons play with the mouthpiece lower on the upper lip, and tend toward more shrill, strident tone. The higher the player places the mouthpiece, the more mellow the tone.

Sexton: Moderate underbite is no handicap in any respect. Many power players have it.

Stevens: A slight underbite is not a deficiency. I have never seen a person with a severe underbite. A person with a slight underbite is a "ready-made customer." However, the angle of the horn must conform to the jaw position.

White: I have never had a student with a severe underbite. A mild underbite is not a problem in trumpet playing.

5. Slant of the upper teeth.

a. Have you had a student whose upper teeth slant outward? If so, describe any advantages or disadvantages noted.

Haynie: I have had such students. The outward slant encourages playing low on the upper lip and a backward pivot on high notes. There is no advantage.

Sexton: Yes. Nothing but problems as to control and response.

Stevens: There is a disadvantage. To overcome this we introduce the bottom teeth edges to match the most forward point of the top teeth edges if possible.

White: This teeth formation can cause serious problems, depending on the severity of the outward slant and whether or not it is in conjunction with a severe distoclusion (horizontal overbite). If the upper front teeth slant outward, and if the player does not bring the jaw forward to a position at least even with the upper teeth edges, the mouthpiece will be resting partially upon the biting edge of the upper incisors, which is a poor resting place indeed. On the other hand, there is a physical limit to the extent the jaw can be extended, and an even greater limitation before tongue action appears to be adversely affected. If the jaw is only partially extended, the player will have a strong tendency to push the upper lip out of alignment, since the mouthpiece is at an angle more acute than ninety degrees. This player will tend to simply ride up the slope of the upper teeth. Unless orthodontic work can be accomplished, the only solution is an intelligent compromise.

b. Have you had a student whose upper teeth slant inward? If so, what advantages or disadvantages do you associate with this condition?

Haynie: I have had such students. The mouthpiece is then supported in position by the lips, and tends to slide downward.

Sexton: Same as above. Nothing but problems.

Stevens: I still align the teeth edges to a parallel bite. The purpose is to keep the bottom lip facing as close as possible to the top lip reed (vibrating area).

White: Yes. No disadvantages. I have never had a student with what I would call a severe inward slant of the upper front teeth.

The point should be made here that the outward appearance of the angle of the trumpet <u>vis-a-vis</u> the position of the jaw is deceiving because of the variation in teeth slant from person to person. The trumpet will be held perfectly horizontally only if the slope of the front teeth is exactly vertical. If, for example, the front incisors slant inward, the trumpet will point downward even though the jaw has been brought forward to align the teeth vertically. The angle of the mouthpiece to the teeth is still ninety degrees and is correct.

c. What do you consider to be the ideal formation of the upper teeth as related to trumpet playing?

Haynie: A wedge shape formed by the upper incisor teeth. Flat front teeth (upper) encourage playing to one side for an anchor place to prevent the mouthpiece slipping.

Sexton: Vertical, not too long, not spaced, flat in front, which is rather rare.

Stevens: Teeth that match each other in structure and have no unusual high spots; even in length; vertical.

White: The most ideal formation of the upper front teeth is for the two central incisors to be reasonably straight or to form a slight wedge, and vertically slant straight downward or slightly inward. Any formation that accomplished the same benefits as the "wedge" is advantageous, i.e., any formation that creates the primary pressure point on the upper lip at the top center of the mouthpiece, while the sides of the mouthpiece (in the area of the biting surface of the upper teeth) rest on the lip somewhat more lightly. Bringing the jaw forward the correct amount also accomplishes this benefit. The opposite of this condition, i.e., with the mouthpiece "pinning down" the upper lip on the sides (in the area of the biting surface of the upper teeth) tends to isolate the "reed" (the vibrating portion of the upper lip) from muscular contraction at the corners of the mouth and in the cheeks, etc., as described in sections C, 1, 2, and 3 above.

6. Movement of the jaw vertically and horizontally.

   a. How much opening should there be between the upper and lower teeth for performance on trumpet in the various registers? Why?

Haynie: Among the subjects X-Rayed by Dr. Finlay, the most opening showed in my own case. Herbert L. Clark recommended an opening the size of a nickel on end. Mine did not show that much. There is less opening for the high register than for the low.

Sexton: Tiny opening in upper range, larger in lower range, for control, endurance, quality.

Stevens: Approximately 1/4 inch for all brass instruments irrespective of the mouthpiece. However, whatever the starting point in teeth aperture, total jaw motion must be limited to one-half the distance of the original aperture. Example: 1/4 inch aperture, 1/8 inch motion. The law: Jaw motion should not exceed twenty-five per cent of the original teeth aperture upward from the starting point, nor twenty-five per cent descending. Example: 1/4 inch aperture, 1/16th inch up, original starting point, 1/16th inch lowering, total movement 1/8 inch, equivalent to one-half the original teeth aperture. This enables a player to play any pitch at any dynamic level throughout a four-to-five octave range. The combination is increased-decreased air and increased-decreased teeth opening.

White: The opening between the upper and lower teeth should average approximately 1/4 inch. This size will increase for playing low and/or loud, and decrease for playing high and/or soft. With an opening considerably more than 1/4 inch, it becomes increasingly difficult to muscularly hold the embouchure formation and to keep the lips closed. (Research by

Martin, Henderson, Weast, and Leno has revealed that the lips must touch to vibrate.) When the teeth aperture is considerably less than 1/4 inch, it becomes increasingly difficult, if not impossible to maintain lip alignment to the teeth aperture. The size of the teeth aperture divided by two is the amount of each lip that must be kept exposed to the air stream.

b. What is the horizontal position of the lower jaw in relation to the upper in playing trumpet in various ranges?

Haynie: Lower jaw projects forward for low register, gradually returning to the more natural position of the overbite when ascending.

Sexton: (No comment.)

Stevens: There is no horizontal motion while playing except for a slight motion that might be necessary in lowering or raising pitch.

White: The jaw should be positioned so as to keep the upper and lower front teeth aligned vertically at all times, with a minimum of jaw movement permitted in changing registers. It does appear to assist in playing the high and altissimo registers to move the jaw either forward or back very slightly, so as to direct the air stream either up or down. I believe it is much more advantageous to move the jaw forward slightly. This encourages the player to put slightly more mouthpiece pressure on the bottom rather than the top lip, which is desirable, and it appears to encourage muscular activity in the triangularis, risorius and platysma muscles, and makes it easier to bring the lips forcefully together to produce the extremely high tones. On the other hand, receding the jaw slightly encourages the player to put more mouthpiece pressure on the top lip which is undesirable, and appears to discourage muscle activity in the triangularis, risorius, and platysma, making it more difficult to bring the lips together. Also, receding the jaw for the extreme high register just when the air pressure and mouthpiece pressure are greatest, makes it more difficult to resist the tendency to push the upper lip out of alignment. This does not appear to be the case with the lower lip when the jaw is extended, possibly because the lower lip is provided with a rather strong muscle to elevate it (the mentalis) while the upper lip is not provided with a similar muscle to assist in bearing downward.

Whatever the reason, the lower lip is obviously stronger and more mobile than the upper.

The amount of horizontal jaw motion in either case is extremely slight and should not be construed to represent a "pivot" system for changing registers. I would not consider any horizontal jaw motion as basic to embouchure technique.

7. Movement of the red of the upper lip inward or outward.

   a. Should the red portion of the upper lip be turned outward with the air stream in any register?

Haynie: The lips should be allowed to turn outward in the low register, turned inward for the high.

Sexton: Extreme low, yes.

Stevens: No.

White: No.

   b. Should the red portion of the upper lip be turned inward toward the air stream in any register?

Haynie: No. Try to maintain visibly some red of the lower lip all the way to the top.

Sexton: From middle to top, inward.

Stevens: Yes, for all registers. Sensitivity is achieved by muscularly matching the air column, be it fast or slow.

White: Yes, very slightly in all registers. There should be the sensation of the upper lip turning inward slightly more when ascending in register.

8. Movement of the red of the lower lip inward or outward.

a. As a preface to the following, do you agree that the lower lip is not important as vibrator, but rather works to regulate the size of the lip aperture? If not, what is the function of the lower lip?

Haynie: Yes.

Sexton: Yes.

Stevens: Yes.

White: Yes.

b. Should the red of the lower lip turn outward in any of the various registers?

Haynie: Yes, in the low.

Sexton: It will turn outward in lower range.

Stevens: Only relative to the reduction of tension. In any event, the surface of the lower red will be firmer than the upper red.

White: No.

c. Should the red of the lower lip turn inward in any of the various registers?

Haynie: Yes, to a slight degree in the upper registers.

Sexton: Yes. I try to turn it inward, in middle and top.

Stevens: It can turn inward if playing low softly and if playing high loudly. Because the lip is a circular muscle, a player cannot isolate tension in one lip (two independent tensions). If the bottom lip turns inward, the top also will turn inward equally, relative to the effort and the force behind the air column. The lip inversion will be relative to the register and force of the air column necessary to sustain the embouchure musculature. (Remember, an intent has been declared in the mind to resist the air column. Therefore, tension will be governed by the air column and its force.)

White: Yes, very slightly in all registers.

9. Amount of lip in the mouthpiece for various registers.

a. Is the amount of lip in the mouthpiece the same, less, or more proceeding from the low register upward? Why?

Haynie: More lip is in the mouthpiece for the upper registers, the lip turned inward. This is how the lip contraction manifests itself.

Sexton: My opinion is that it is extremely difficult to change the amount as you play, but that it is changed during a breath inhalation or a short rest.

Stevens: If we articulate the jaw motion as previously described, the higher one plays, the less lip proportionately (two lips) will be exposed to air. The big factor is not how much lip is in the mouthpiece, but rather, how much lip is exposed to air relative to the changing tensions and teeth aperture. As far as the outer grip is concerned, the same amount of lip stays in the mouthpiece.

White: The amount of lip in the mouthpiece should not change in playing in any register. It is possible to allow either or both lips to slide out of the mouthpiece while playing, e.g., when descending in register; but it is not possible to slide more lip into the mouthpiece while playing (or to "return" lip to the mouthpiece which was allowed to slide out). Allowing either lip to slide out of the mouthpiece while playing should be rigorously avoided.

b. If the amount changes, how is this change accomplished while slurring upward?

Haynie: By contraction of the lips, tightening the corners.

Sexton: It probably is not.

Stevens: The amount exposed to air proportionately changes as we increase the force of the air column and relatively articulate the jaw upward. At no time in any area does the player permit the bottom teeth edges to be parallel to the bottom lip. To be consistent there is a law of constancy: the bottom lip must al all times overlap the bottom teeth edges relative to the fixed corners (not enough to go into the mouth since both lips occupy equal space between the teeth edges).

White: No change.

c. Is the amount of lip in the mouthpiece in the pedal register more or less than the other registers?

Haynie: There is less lip in the mouthpiece. The lips are more relaxed and the red turns outward.

Sexton: Less, because, in my opinion, the opening is wider.

Stevens: Pedal tones destroy the actual image of your playing formation. Practicing pedal tones, the player sacrifices his outer grip of the mouthpiece. In the case of larger mouthpieces such as trombone, pedal tones are a requirement of overall playing and, therefore, permissible. The inner red would be unrolled to introduce the softer mucosa which vibrates wider and slower.

White: The same. There would be no useful purpose in practicing the pedal register on the trumpet using anything other than the normal setting.

10. What is the importance of lip surface tension to range and timbre? How is surface tension regulated?

Haynie: The tension is regulated by isometric contraction in the embouchure. The lips must support the mouthpiece and change the air to vibration.

Sexton: I am not sure what lip-surface tension is.

Stevens: The lip must vibrate rim to rim. Timbre will be determined by the amount of top lip exposed to air and sealed by bottom lip facing. Varying tensions in the surface area of the top lip will change the timbre if the player increases the arm pressure (mouthpiece pressure) on the top lip as he proportionately reduces the compression in direct ratio to the increase in arm pressure while sustaining any given note or tone. In referring to change of timbre as a result of increased mouthpiece weight on the top lip, it has been my experience that the player automatically and subconsciously reduces the compression as the arm pressure increases. The issue specifically relates to the fact that in certain registers the subconscious mind, acting as the governing agent for the overall playing, realizes that air displacement will not be possible in a closing lip aperture, since the former compression will not be able to displace itself, and will automatically compute and reduce the force in relationship to the resistance or back up of the air column at the lip aperture. To do otherwise would collapse the embouchure musculature since no one is capable of resisting his maximum ability to produce compression of the powerful breating muscles governed by the contracting rib cage, upper and lower abdominal wall, into a sealed or blocked lip aperture. To properly allow for air displacement at a fixed compression, the playing weight of the mouthpiece should favor the bottom lip by a little more than one-half the overall playing weight. This permits the player to have a fixed tension, steady, free-flowing air column, and a matching muscular resistance permitting an equal ratio of air displacement to the vibrations. Surface tension may then be regulated and changed by varying the force of the air column and proportionately varying muscular resistance.

White: The importance of lip surface tension to range is obviously that more surface tension is needed to play higher, and less to play lower. I would not want to speculate about the intricacies of lip surface tension and timbre. Surface tension is regulated by the relationship and interaction of air pressure, air flow, relative facial muscle activity, jaw position, teeth aperture, tongue position, mouthpiece placement, and mouthpiece pressure--hopefully, only reasonable amounts of the latter.

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