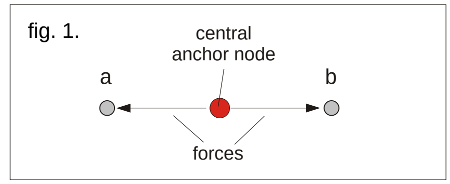
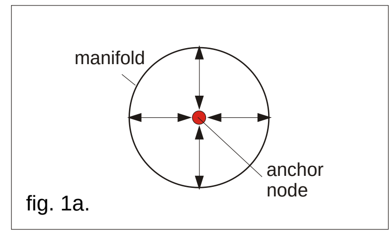
Preliminary precepts

A new and productive avenue in understanding phoneme production becomes available when its processes are examined in terms of kinesiological geometry. The following two established physical tenets are the starting point for such analysis.

Precept 1. Controlled motion imparted on an object requires that at least two mutually antagonistic forces act on it. The object moved has a center of mass where the controlling opposite forces meet (or anchor to one another), and it is the central anchor node of the total force framework, fig.1.



Precept 2. When the equilibrium of a system during movement becomes distorted and unbalanced, equalization is necessary return to equilibrium. Equalization is a component in any completed action.



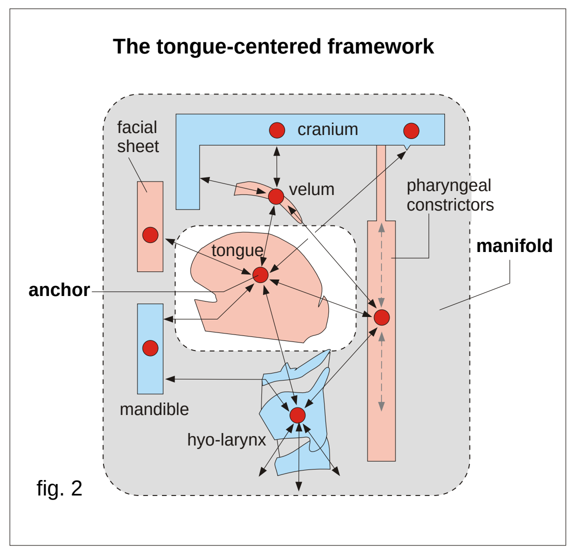
A particular equilibrium is exemplified by the solar system, which is a mechanical configuration where a central node is surrounded by a manifold of antagonist forces impacting it. The total planetary forces reaching the sun constitute the manifold, while the sun is the center of mass, or central anchoring node of the solar system, fig. 1a.

The five elements of oro-lingual geometrical mechanics

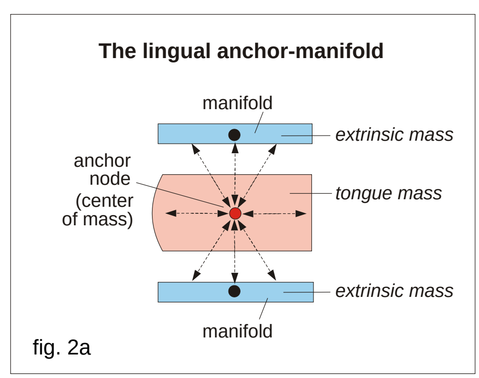
Together with the above precepts, there are five elements, each separately described below, which are the fundamentals of oro-lingual geometry from which a rigorous analysis can be built.

Element 1. The tongue as the center of an anchor-manifold system

Represented as a web of forces the tongue is an analog of a solar system, as it is located centrally in the oral frame, and extrinsic forces approach it from the surrounding regions. The tongue contains the central mass within this intersecting network of forces, fig. 2.

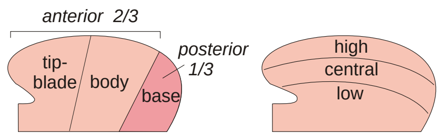


The tongue and the manifold of the forces surrounding it are mutually coactive and respond to actions by one another both as synergists and antagonist. The entire structure is a monadic unity in which any movement by one element generates a unique counterpart in the other. This means that if we know the behavior of one part of such monadic entity, then we can also predict the behavior of other parts, fig. 2a.



Element 2. The tongue divisions

fig. 3 **Tongue divisions**



The tongue is **divisible** both **horizontally**: tip-blade, body and base/root, (or front, center and back), as well as **vertically**: the high (dorsal), central and low (ventral) levels. Anatomically and developmentally, the tip-blade and body occupy the oral 2/3 tongue and the base comprises the pharyngeal 1/3. The middle section, i.e., the body, is the zone where these share control.

The vertical divisions consist of the intrinsic musculature, namely the superior longitudinal, the mid-central vertical-transverse mass, and the inferior longitudinals, fig. 3**.**

Each division is equipped with an appropriate central

Tongue divisions and nodes

fig. 4

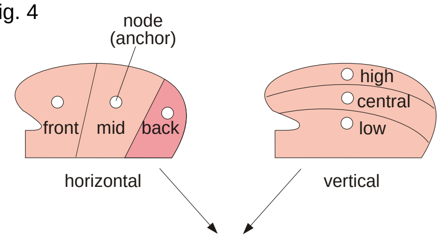
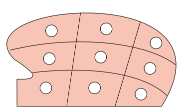


fig. 5



3x3 matrix of nodes and cells

fig. 6

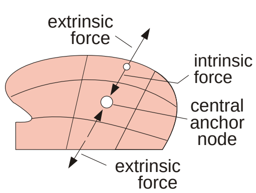
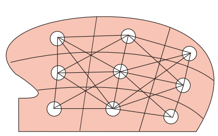


fig. 7



network of
interconnected nodes

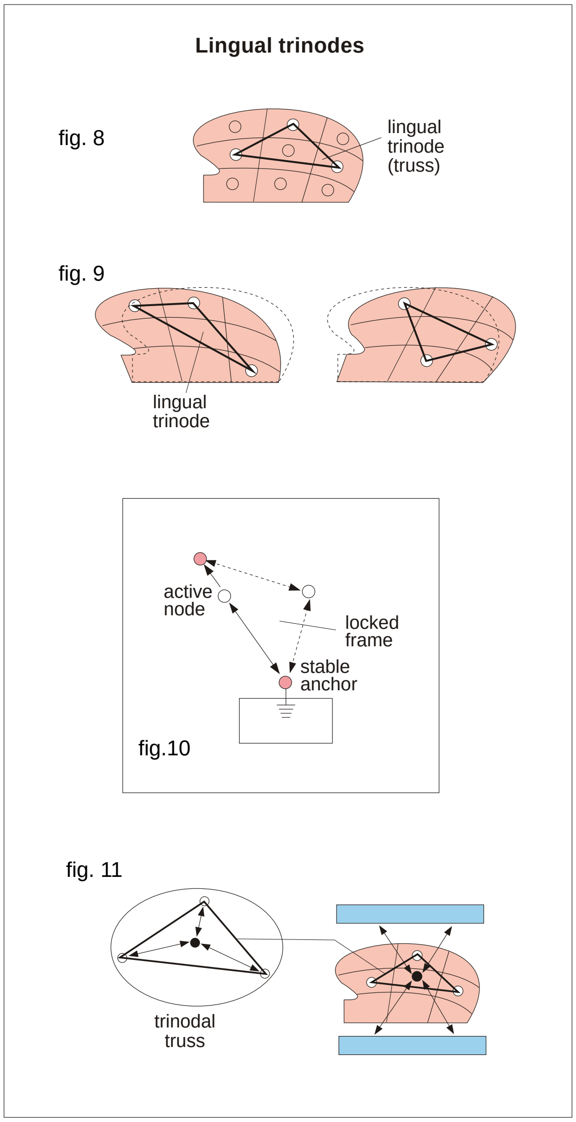
When the horizontal and vertical divisions are merged a 3x3 matrix of cells is formed, each with its own central node. Each cell can be designated by its position in the tongue, such as mid-central, high-back, etc., figs. 4 and 5. These cells and their central nodes are moved by specific muscular forces and each cell performs a role in lingual articulations. The vowel quadrilateral concept derives from this arrangement. There is both the ability to lock a node, and to translate between nodes.

This structuring is evident in the 3 x 3 matrix of the vowel quadrilateral in which stable locking of a vowel, as well as transiting between vowels is possible. Consonants can also be arranged in such a 3 x 3 matrix. For instance, /t/ is in the high front cell, while /n/ is in the mid central one, etc.

In relation to incoming forces the central anchor node of each division is controlled by a specific map of intrinsic and extrinsic forces. Extrinsic antagonists meet centrally at the lingual center of mass, in whatever position and shape the tongue may take, fig. 6.

The various nodes constitute a dynamic network connected by lines of force, fig. 7. The action sequences of anchor nodes follow a certain hierarchy, which is typical in mechanical devices, and therefore of the speech engine. Order of actions in the system starts with the simplest element and builds up toward more complex ones.

Element 3. Trinodes



Efficient natural design employs certain minimal structures that are also used in human engineering. Such a device is the triangle, or truss, the most stable unit of construction, as in bridges or buildings. The triangular truss appears in many instances of natural design, as in the tripodal leg locomotion of insects. The behavior of the intrinsic musculature of the tongue is governed by triangular trusses, each consisting of three nodes interconnected by lines of force.

The vertices consists of three interacting nodes which form the **lingual trinode**, fig. 8. Any anchor in the nine lingual divisions or cells may be a vertex, that is, the prime mover or agent of a trinode, although in practice only a limited number are primary actors. The behavior of the lingual trinode, governed by the intrinsic lingual muscles primarily determines the shape of the tongue, fig 9. Tongue positioning is chiefly determined by extrinsic muscle action.

Factors underlying the utilization of a three node unit in lingual behavior, as for example, the i-a-u vowel system, include the following: (a) it is the **simplest** and most stable structure; (b) if all nodes were active, and therefore relatively tense, the tongue as a whole would lose its ability to fluidly change its shape. Therefore some nodes remain relatively inactive while others undergo motion; (c) at least one mode must remain stable to provide reference ground to motion by the other two, fig. 10. The center of the lingual trinode, is where the tongue,s intrinsic forces meet and also where the surrounding extrinsic forces meet fig. 11.

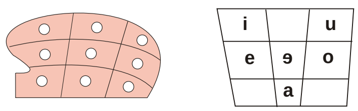
Element 4. Locking

The tongue mechanism can exercise fluid movement, as well as actions of locking into semi-stable positions, as during holding the frames of vowels, consonants, syllables or phrases. Without the ability to stabilize a phoneme for a certain time speech could not function: in a moving sequential system in order to provide a reference ground for the subsequent action some part must remain stable, e.g., the left-right functional alternation of legs in walking, or in the process of peristalsis. The ability to lock parts of a truss is an essential agency in speech production. The syllabic frame of speech is a stable frame setting over which the less stable phonemic articulation is superimposed.

Element 5. Active-stable interaction

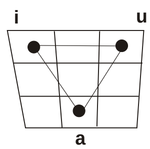
The trinodal matrix

fig. 12



3x3 matrix   vowel quadrilateral

fig. 13



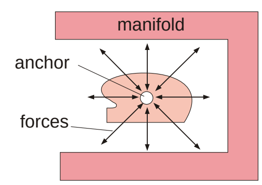
basic vowel trinode

In trinodal action one node acts as the stable anchor and remains relatively stationary, while the two other nodes serve as the primary and secondary agonists that gener ate shaping movement. Stability for the stable anchor is enabled by the locking function. The allotment of moving vs. stable roles among the three nodes is an essential variable in lingual behaviors.

As mentioned earlier, when the horizontal and vertical tongue divisions are integrated into a 3x3 matrix of cells the positions of their nodes correspond to the positions of generalized vowels of the vowel quadrilateral, **f**ig. 12. The vowel quadrilateral is, thus, one of such stable nodal frameworks, over which vowel forming actions are superimposed. Similar analogous stable ground frames exist in respiration and mastication.

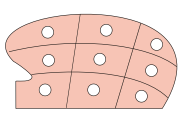
The notion that /i/, /a/, and /u/ are the basic vowels recognizes a particular trinode whose elements are the central nodes of these three vowels. Languages with only these vowels have reduced vocalic inventory to a minimal mechanical structure, a triangle or truss, fig. 13. The consonantal counterpart to the basic vowel triangle, consists of /t/, /k/ and /w/, in English.

fig.14



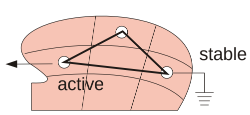
the lingual anchor-manifold system

fig.15



divisions and anchor nodes

fig.16



a trinode

Integration of elements

1. The tongue as the center of an anchor-manifold system, where agonist-antagonist coaction of the intrinsic (anchoral) and extrinsic (manifold) components constitutes the lingual anchor-manifold system, or phonemic articulation engine, fig. 14

2. Tongue divisions and anchor nodes, fig. 15

3. Trinodal organization, fig. 16

4. The locking capacity, fig. 10

5. Active-stable interaction, fig. 10 and fig. 16

The analysis presented in *Phoneme Production* takes the **preliminary precepts** listed at the start and examines how they govern the way in which the above five **elements** engage in their coactive interactions. In phoneme generation these elements are integrated into a single **monadic** mechanism, and as they combine the many variables possible in their particular actions they create a large number of kinesiological states and permutations. Such a potential accounts for the great variety and high degree of resolution present in phoneme generation. Since these actions can be **geometrically** organized and mapped, it becomes possible to explain the mechanism underlying a wide range of speech behaviors.