CHAPTER 2

Articulatory Locality

1. INTRODUCTION

This chapter lays the foundation of the dissertation by exploring the articulatory structure of simple utterances. In particular, the chapter explores the articulatory events taking place in two sequences of sounds. The first sequence is VCV, a transition between two vowels seemingly separated by the consonant in the linear representation of the sequence. The second sequence is CVC, a transition between two consonants separated by a vowel. We will find that there is a fundamental asymmetry in these two sequences. The gestures of the two vowels in a VCV can be contiguous, but the gestures of the two consonants in a CVC cannot be contiguous (both with minor exceptions). Based on these facts, I will propose the central thesis of this work: Articulatory Locality, which claims that assimilations in phonology respect articulatory contiguity, and I will provide support for its correctness from different areas of phonology.

Section 2 begins with a review of the basic phonetic facts of V-to-V coarticulation. Articulatory and acoustic evidence show that in VCV sequences there is a smooth transition from the articulation of the first vowel to that of the second. The gesture of the consonant is superimposed at some point during this vocalic transition. The physiological basis of V-to-V coarticulation rests crucially on the notion of articulatory overlap (also known as co-production) between consonantal and vocalic gestures. In section 3, I give further evidence for this overlap, showing that the vowel is the articulatory foundation of the syllable, in the sense that vowel articulations extend throughout the syllable, overlapping with surrounding consonants. This makes vowel gestures contiguous in successive syllables, a phenomenon which I will call V-to-V contiguity. Consonant gestures, on the other hand, do not share the property of contiguity but are rather
interrupted by intervening vocalic gestures. This provides us with a fundamental asymmetry between vocalic and consonantal gestures: V-to-V contiguity in a VCV sequence, but no C-to-C contiguity in a CVC sequence. This asymmetry is related to a basic physiological distinction between vowels and consonants, namely, the absence versus the presence of a constriction in the mid-sagittal plane.

Having laid out the relevant phonetic facts, section 4 presents the main proposal, the claim that the notion of locality in phonology is based on articulatory contiguity between gestures, or "Articulatory Locality" for short. That claim entails that, in an assimilation of a target sound to a trigger sound which is sometimes at some distance from the target, the assimilating feature propagates through all articulatorily contiguous sounds. I review different sources of evidence, experimental and other, all of which converge to support this prediction of Articulatory Locality.

Section 5 is a discussion of past proposals on locality, and section 6 reviews standard assumptions about autosegmental spreading, arguing that it should apply as dictated by Articulatory Locality. Finally, section 7 summarizes the main points of the chapter.

2. ARTICULATION OF A VCV SEQUENCE
In this section, I discuss the basic results of Öhman's (1966) seminal study of coarticulation. I first review the acoustic effects of 'V-to-V coarticulation', and then their articulatory basis is considered. A number of subsequent studies substantiating Öhman's original result are also briefly discussed.

Öhman (1966) found that in Swedish Vowel-Stop-Vowel sequences (henceforth simply 'VCV'), the first vowel's second formant, $F_2$, at the beginning of the stop closure are a function not only of the stop consonant itself but also of the following vowel. Similarly, $F_2$ at the end of the stop closure is a function of both the consonant and the preceding vowel. For example, in the sequence /agV/ the $F_2$ at stop closure rises by 175 cps when the final vowel is /y/, but falls by 65 cps when the final vowel is /u/.

Formant frequency rise and fall are defined with respect to the values of $F_2$ in the stationary part of the vowel (this is the relatively invariant part of the vowel before stop closure in VC-, or after stop release in -CV). Similarly, in /Vb a/, the $F_2$ at the end of stop closure rises by 205 cps when
the initial vowel is /y/, but falls by 100 cps when the initial vowel is /a/.

The contextual effects of the vowels on each other across the consonant are apparently bidirectional, and can be observed during the whole period of consonantal closure. Figure (1), in the next page, illustrates these effects by showing spectrograms (or formant frequency trajectories as a function of time) for various VbV sequences. The sequences in any row have the same final vowel and the sequences in any column have the same initial vowel. The variation in the formant frequency due to the influence of the transconsonantal vowel can thus be seen by comparing the spectrograms in the same column or row.
Figure 1: Formant transitions in VbV sequences.
[Reproduced from Öhman (1966) with permission]
Öhman tabulated the ranges of formant frequency variation shown in the tracings of the previous figure. His findings are reproduced in (1) below. The ranges of variation for each of the three formants, $F_1$, $F_2$, and $F_3$, are shown for the case of a VbV sequence. For each formant, there are two columns. The Vb- column lists the ranges of variation of $F_i$ of vowel V in preconsonantal position, when the other vowel is one of the five vowels shown in the first column of the table. Similarly, the -bV column lists the corresponding ranges of variation of $F_i$ for the postconsonantal vowel. To simplify the discussion and to show the robustness of the basic finding, I have left empty those entries of the table in which the range of variation was not statistically significant as well as those where the frequency range could not be measured from the spectrograms. As can be seen, for every vowel (i.e. any vowel from /y, ø, ø, o, u/) and in every position ($V_1$, $V_2$) there is at least one formant variation that is statistically significant.

1. Ranges of variation in formant transitions in $V_1$bV$_2$ (in cps)

<table>
<thead>
<tr>
<th></th>
<th>$F_1$</th>
<th>F1</th>
<th>$F_2$</th>
<th>F2</th>
<th>$F_3$</th>
<th>F3</th>
</tr>
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<tbody>
<tr>
<td>Vb-</td>
<td>-bV</td>
<td>Vb-</td>
<td>-bV</td>
<td>Vb-</td>
<td>-bV</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>225</td>
<td>255</td>
<td>150</td>
<td></td>
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<td></td>
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<tr>
<td>180</td>
<td>220</td>
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<td></td>
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<td></td>
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<tr>
<td>130</td>
<td>60</td>
<td>305</td>
<td>220</td>
<td>150</td>
<td>135</td>
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<tr>
<td>55</td>
<td>315</td>
<td>275</td>
<td>240</td>
<td>245</td>
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<tr>
<td>60</td>
<td>510</td>
<td>300</td>
<td>225</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Öhman proceeded to investigate the articulatory events taking place in the VCV sequences that produce the observed acoustic effects. He noted that because traces of the final vowel are found during the initial vowel-to-consonant transition, the articulatory movements of the final vowel must start “not much later than, or perhaps even simultaneously with, the onset of the stop consonant gesture” (p. 581). X-ray motion pictures of Öhman’s own speech clearly confirmed this expectation. These
Figure 2: Tracings of X-ray motion pictures of VCV utterances.
[Reproduced from Öhman (1966) with permission]

In the first column above, the shape of the vocal tract is shown during the articulation of /d/ in three symmetric vocalic environments /ydy/, /oda/, and /uda/. Two important points should be highlighted here. First, the only invariant characteristic of the stop is the apico-alveolar contact of the tip-blade of the tongue in the alveolar region. Second, during stop closure the rest of the tongue assumes the configuration of the surrounding vowel, as can be seen by comparing the shapes in the first column with those in the second column, which shows the ‘neutral’ vowel configurations, that is, the vocal tract shapes when the vowels are produced in isolation. The same points apply for the third column, showing the shape of the vocal tract during closure of the stop /g/ in the
environments /yg/ /aga/ and /ugu/. Most telling are the tracings in the top rightmost figure. There, the solid line shows the tracing of the /g/ configuration in /yga/ a few milliseconds after the beginning of the closure. This tracing should be compared with the tracing of the /g/ configuration in the /gyg/ sequence which shares the /yg- part with the /yga/ sequence. In the case of /gyg/, the part of the tongue behind the dorso-palatal contact is further forward than the corresponding part of the tongue in the /yga/ tracing. This shows that anticipatory articulatory movements for the lower vowel /a/ have already taken effect a few milliseconds after the beginning of the closure of /g/. When the closure of the consonant is initiated, the vocal tract can be seen to have the global characteristics of the preceding vowel articulation, while at the same time increasingly anticipating in a ‘smooth transition’ the articulation of the second vowel.

So far I have reviewed the existence of a ‘smooth transition’ between vowels in a VCV sequence, observed both acoustically and articulatorily. The physiological basis of this ‘smooth transition’ is to be found in the significantly different articulatory characteristics of consonant and vowel production. Specifically, sounds are composed of two categories of gestures: consonantal and vocalic, each with distinct articulatory characteristics. As Sproat & Fujimura (1993) write, “consonantal gestures are those that produce an extreme obstruction in the mid-sagittal plane”, while “vocalic gestures are those that do not produce an extreme obstruction”. Vowels are produced by movements of the tongue body and jaw, with relatively slow changes in the global shape of the vocal tract because of the comparatively large mass involved. Because a consonantal constriction is localized at some area in the vocal tract, the free part of the tongue is allowed to assume different shapes, and thus move smoothly from the shape of the first vowel to that of the second. The two vocalic gestures in a VCV sequence are, for this reason, articulatorily contiguous, much as they would be if the sequence were VV, and the “stop-consonant gestures are actually superimposed on a context-dependent vowel substrate that is present during all of the consonantal gesture” (Öhman 1966: p. 165). This contiguity of vowel gestures I will call ‘V-to-V contiguity’.

Let us contemplate the physiological basis of V-to-V contiguity in
more detail by considering the gestures that are involved in a simple utterance like [ipa], shown in (2) below. The phenomenon of V-to-V contiguity rests on the ability of vocalic gestures to persist during the production of a consonant.

2. [ipa]

<table>
<thead>
<tr>
<th>TB</th>
<th>i</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIPS</td>
<td>p</td>
<td></td>
</tr>
</tbody>
</table>

This persistence is articulatory, not acoustic. Acoustically, the vowel is masked by the superimposed consonant. During the consonantal constriction the vowel is not heard because the acoustic signal produced by the vocal tract is dominated by the narrowest constriction (silent during a stop, noisy during a fricative, and so on). Thus, the vowel formants, or the acoustic effects of the vowel, are necessarily absent during the consonant. However, the gesture of the vowel, being a positioning of the tongue body, still overlaps with the gesture of the consonant. This makes vowel gestures contiguous. Hence, the phenomenon of V-to-V contiguity in a VCV sequence.

Crucial to allowing the vocalic gestures in our example to persist during the consonant is the articulatory independence between the tongue body and the lips, the former being the major articulator for the vowels and the latter being the major articulator for the consonant. The tongue body is also articulatory independent from the tip-blade (evidence for this independence is documented in detail in chapter 4). This would allow V-to-V contiguity in utterances like [VtV] or [VsV], as indeed has been observed experimentally in some studies discussed briefly below.

If the intervening consonant in a VCV sequence also involves a certain positioning of the tongue body, we then predict that the contiguity of the vowels is interrupted. This is because in that case, during the production of the consonant, the tongue body would not be free, but rather it would be actively engaged as part of the consonantal gesture, blocking the smooth transition of the tongue body from V-to-V, observed in the cases where the intervocalic consonant is a labial or an alveolar. Precisely this pattern is found in Russian, a language where the stops [b d g] have
contrastive ‘palatalized’ and ‘non-palatalized’ variants, both involving a specific configuration of the tongue body. Öhman found that V-to-V coarticulation does not obtain in Russian VCV sequences where the C is any of these consonants (see also Purcell 1979 and Keating 1988b for relevant discussion).

To illustrate the situation in Russian, the alveolar stop [d], for example, consists of a consonantal gesture which involves a constriction with the tongue tip-blade at some point in the alveolar region, and a vocalic gesture which involves the tongue body. The relevant gestures are shown in (3) for the sequence [ida], where it can be seen that the tongue body gesture of [d] interrupts the contiguity of the two vocalic gestures.

To sum up, the basic finding is that in a VCV sequence vocalic gestures are produced in some sense independently from the consonantal gesture. The basis of this independence is found in the different articulatory dimensions under control in vocalic and consonantal articulations. To the extent that labial consonants, alveolar consonants, and vowels are produced with independent sets of articulators (lips, tongue tip-blade, and tongue body respectively) this independence in the articulatory execution of the gestures is expected. According to this interpretation, we also expect that some consonants which implicate the tongue body should block V-to-V contiguity in a VCV, as indeed is the case in Russian.

Around Öhman's result has developed a rich area of research which confirms and further explores the phenomenon of V-to-V contiguity by the use of various experimental techniques. Carney & Moll (1971), for example, provide cinefluorographic tracings of tongue movements in CVCV sequences. These tracings show that during production of the intervocalic fricative the tongue moves smoothly from the first to the second V. Subtenly et al. (1972) essentially reproduce the same result. Their cineradiographic data indicate that in the production of the utterance
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[isɔ], as in ‘Suzy saw’, the tongue body executes a continuous gesture from [i] to [ɔ]. This gesture involves “progressive lowering of the dorsum [tongue body: AG] and progressive retraction of the root towards the pharyngeal wall.”

The constriction formed with the tip of the tongue for the fricative [s] is superimposed while the tongue body movements are in progress” (p. 48).

Kent & Moll (1972) trace tongue movements in the sequences [ima] and [ia], as in the utterances “he monitored” and “he honored,” and find indistinguishable trajectories and velocities of the tongue moving from [i] to [a], irrespective of the existence of the intervening bilabial [m]. Finally, regarding the timing of V and C gestures, Harris et al. (1982, 1986) examine issues of the temporal organization of CVCVC sequences. Their results emphasize the importance of the articulatory vowel-to-vowel cycle, the cycle defined as the interval between the onsets of muscle activity of the two vowels. The basic finding here is that in CVCVC sequences the intervocalic consonantal articulation is timed with reference to an independent vowel-to-vowel cycle.

3. ARTICULATION OF A CVC SEQUENCE

Öhman's basic finding is that, in a VCV sequence, during the production of the consonant, there is a smooth transition from the articulatory configuration of the first V to that of the second V. The consonant overlaps with the production of the vowels. I now consider the implications of this overlap between consonants and vowels for the articulatory organization within a CVC syllable.

Extrapolating the property of overlap between consonants and vowels from a VCV to a CVC sequence leads to the view that the two consonantal articulations are superimposed on the vowel's leading and trailing edges (Fowler 1983). The correctness of this view is in fact well-supported in the literature. In their study of coarticulation in CVC utterances, MacNeilage & DeClerk (1969) make the following two central observations. First, there is a significant effect of the vowel on the initial consonant. The vocal tract shape at a point before closure of the consonant is already influenced by the identity of the following vowel (p. 1227). The same phenomenon is evident in their electromyographic (EMG) recordings, where significant differences in EMG activity are observed.
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during the production of the initial C depending on the following vowel. MacNeilage & DeClerk conclude that during the production of the initial consonant, the vocal tract shape is largely determined by the vowel, with the consonant having only a minor local effect on the overall shape of the vocal tract (p. 1224). Similarly, the identity of the final consonant has only a minor ‘localized’ effect on vocal tract shape during the production of the vowel. In contrast, the vocal tract configuration for the final consonant is very much affected throughout its period of closure by the preceding vowel. Both sets of effects show the articulatory dominance of the vowel during the production of the CVC syllable. The vowel is thus the articulatory basis of the syllable in the sense that the vowel's articulation extends throughout the syllable, overlapping with the consonantal articulations.

Fowler (1983) discusses the connection between the articulatory dominance of a vowel in a CVC sequence and the well-documented fact in several languages that the measured duration of a vowel decreases as the number of syllable-initial and syllable-final consonants increases (Lindblom, Lyberg & Holmgren 1981). If consonants are superimposed on the vowel articulation, then adding more syllable-initial or -final consonantism will have the effect of shortening the measured acoustic duration of the vowel.\textsuperscript{6} Articulatorily, then, the vowel is produced throughout the extent of the syllable but its acoustic effects are masked by the articulations of the overlapping consonants. This effect is schematically shown in (4) below. In this idealized representation, the length of a box indicates the duration of the corresponding gesture. In (4a) the vowel articulation overlaps with the two consonantal articulations at its leading and trailing edges. The measured acoustic duration of the vowel corresponds to the gap between the two C gestures. The addition of another syllable-final consonant in (4b) increases the duration of the syllable-final consonantism and hence decreases the measured duration of the vowel.
4. Overlap in a CVC(C)

- **a.**
  - C
  - V
  - C

- **b.**
  - C
  - V
  - C
  - C

The duration effect of consonants on vowels, then, receives a simple interpretation under this view of articulatory organization within the syllable. The assumption behind this interpretation is that the articulatory duration of the vowel remains constant, while the surrounding consonants overlap with it.\(^7\)

Another type of evidence for this articulatory organization is provided by a phenomenon which has been variously dubbed as ‘vocal relajada’ or ‘Dorsey’s Law’ (Menendez-Pidal 1926, Steriade 1990, cf. Ohala 1992). In late Latin, complex syllabic onsets consisting of obstruent-liquid clusters break up sporadically by the insertion of a vowel that has the same quality as the nucleus of the syllable with the original complex onset, i.e. CLV \(\sim\) CVLV (where L is a liquid consonant). Some examples are given in (5) below.

```
5. A.lek.san.dri  ~  Aleksandiri
   The.o.pras.tus  ~  Theoparastus
   Mi.tra          ~  Mitara
   Clau.dia.nus    ~  Calaudianus
   pa.tri          ~  patiri
   chla.my.dem     ~  chalamydem
```

This process follows from the proposed articulatory organization that sees the vowel as present throughout the whole syllable. Specifically, because the vowel gesture overlaps with the consonantal gestures of the cluster CL, a slight delay in the intiation of the L gesture will uncover the
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acoustic identity of the vowel. This explanation captures both the fact that the process applies only to onset clusters as opposed to heterosyllabic ones, and the fact that the intruding vowel is the same as the vowel in the original syllable.8

In contrast to V-to-V contiguity in VCV sequences, then, we see that consonants or, more accurately, consonantal gestures do not have the corresponding property of contiguity in CVC sequences. This is shown in the example below for the utterance [pat].

6. CVC: [pat]

The absence of C-to-C contiguity in a CVC also follows from the fundamental asymmetry between vocalic and consonantal gestures pointed out in the previous section, respectively, the absence versus the presence of a constriction. If the consonantal gestures of the two consonants were to be contiguous in a CVC, then there would be a continuous consonantal constriction overlapping with the production of the vowel, as shown in (7) below. This would completely obscure the acoustic effects of the vowel, however, producing the output [sp] instead of the intended [sap].

7. No C-to-C contiguity in a CVC

For completeness, consider the general case where a consonant also involves a vocalic gesture of the tongue body, as was the case with the 'palatalized' and 'non-palatalized' variants of the Russian stops [b d g]. In the general case the two consonants in a CVC sequence are composed not
only of a consonantal gesture, the definitional characteristic of being a consonant, but also of a vocalic gesture. As discussed above, the consonantal gesture of the first consonant cannot be contiguous with the consonantal gesture of the second consonant. Nor can the vocalic gesture of the first consonant be contiguous with any gesture, vocalic or consonantal, of the second consonant. This is because the vocalic gesture of the first consonant will be contiguous with the vocalic gesture of the intervening vowel, which acts as a barrier between the two consonants. Hence, no gesture of the first consonant can be contiguous with any gesture of the second consonant. There is, then, no sense in which there exists direct C-to-C contiguity between any of the gestures of the two consonants in a CVC sequence. Anticipating the discussion of consonant harmony in the following section, two consonants could assimilate to one another in a CVC sequence only if the assimilating gesture of the trigger consonant is able to propagate through the articulatorily contiguous vowel to affect the target consonant on the other side of the vowel. We will see that there are indeed two such consonantal gestural parameters that can propagate in this way.

4. CONVERGING SOURCES OF EVIDENCE FOR ARTICULATORY LOCALITY

The fundamental notion of locality in phonology expresses the conditions under which a sound can assimilate to another sound. The main claim of this dissertation is that articulatory contiguity between gestures is the correct condition for this notion of locality. This is the essence of Articulatory Locality as stated in (8) below.

8. Articulatory Locality

Two gestures of segments S1 and S2 are in a phonologically local relation if and only if their articulations are contiguous.

Assimilations in consonant-consonant (CC) sequences and consonant-vowel (CV) sequences provide two trivial cases wherein the condition of locality imposed by Articulatory Locality is satisfied. For example, in cases of nasal place assimilation, a cross-linguistically widespread phenomenon, the gestures of the two consonants in the nasal-consonant cluster are clearly contiguous. There are, however, other assimilatory
phenomena which would seem at first to contradict Articulatory Locality, because the gestures of the trigger and of the target of the assimilation appear to be at a distance from each other. In what follows, Articulatory Locality will be carefully tested by examining its predictions for different areas of phonology: vowel harmony (4.1), consonant harmony (4.2), and spreading in nonconcatenative languages (4.3). As I argue, different sources of evidence, experimental and other, from all three areas of phonological theory, converge to support the correctness of Articulatory Locality.

4.1 Vowel Harmony
In many languages we find assimilations which at a descriptive level affect sequences of vowels in different syllables while leaving intervening consonants unaffected. Such assimilations are called vowel harmony. In Turkish, for example, suffix vowels assimilate to the backness feature of the last stem vowel. The suffix vowels are the targets of the assimilation, while the last stem vowel is the trigger of the assimilation. Illustrating some examples of this harmony, in (9a) below, I show the vowel inventory of Turkish, and in (9b), some alternations in the case of two suffixes -ler/lar and -inan.

9. a. Turkish vowel inventory

<table>
<thead>
<tr>
<th>![back]</th>
<th>[+back]</th>
</tr>
</thead>
<tbody>
<tr>
<td>![high]</td>
<td>![high]</td>
</tr>
<tr>
<td>![rnd]</td>
<td>![rnd]</td>
</tr>
<tr>
<td>![high]</td>
<td>![high]</td>
</tr>
</tbody>
</table>

b. Nominative Plural | Genitive Plural | Gloss
---------------------|-----------------|-------
ip-ler | ip-ler-in | 'rope'
yiz-ler | yiz-ler-in | 'face'
k✈-lar | k✈-lar-än | 'girl'
pul-lar | pul-lar-än | 'stamp'

It appears, then, that vowel harmony is an instance of *action à distance* (Bloch 1914), skipping over the intervening consonants. As we have seen, however, there is V-to-V contiguity: vocalic gestures can
persist during the production of consonants, so that in a VCV sequence there is “a continuous vocalic substrate” on which the gesture of the consonant is superimposed; acoustically the vowels are masked by the superimposed consonant, but articulatorily their gestures persist. Hence, in vowel harmony, the assimilating gestures of the trigger and target vowels are in fact articulatorily contiguous, as required by Articulatory Locality.

We have also seen that in a VpV sequence, for example, V-to-V contiguity rests on the articulatory independence of the tongue body, the main articulator for the vowels, from the lips, the main articulator for the consonant. In the case where the consonant involves a gesture of the tongue body the contiguity of the vocalic gestures is interrupted (recall the discussion of Russian stops in section 2). In terms of vowel harmony, then, we predict that assimilation should be blocked in the case where the intervening consonant involves the tongue body. This is indeed what we find in Turkish. The velar consonants and /l/ have ‘palatalized’ and ‘non-palatalized’ variants. These latter consonants block back harmony, as can be seen by examples like idrak’i ‘perception (acc.sg.)’, petrol’i ‘petrol (acc.sg.)’, where the backness of the vowel suffixes [i], [i] does not agree with the backness of the corresponding last stem vowel [a], [o] (c’ denotes the palatalized variant of a consonant).

I now turn to experimental evidence supporting the correctness of Articulatory Locality. If vowel harmony were a true instance of action à distance, we would expect to find no trace of the assimilating feature on the material intervening between target and trigger. In contrast, if the assimilation respects the condition of articulatory contiguity, as Articulatory Locality predicts, then we expect to see traces of the assimilating feature on the intervening material. Specifically, in Turkish, we predict that the tongue body posture effecting a particular value of backness should persist during the intervening consonants. While there is a relative dearth of experimental evidence on this issue, the evidence that exists provides striking support for Articulatory Locality.

In particular, the relevant experiment has been performed for the vocalic feature of rounding, not for backness. Turkish, as many other languages of the Turkic family, exhibits rounding harmony along with the backness harmony discussed above. In (10) the rounding of the suffixal vowel is determined by the rounding feature of the stem vowel, hence the
alternations in the genitive singular suffix seen in the forms (10a-b) and (10c-d) respectively. In the standard analyses of this rounding harmony, the assimilating feature [round] is thought to spread from vowel to vowel, 'skipping over' the intervening consonants.

10. Turkish rounding harmony
   a. ip ‘rope’        ip-in ‘rope-gen.sg.’
   b. sap ‘stalk’      sap-un ‘stalk-gen.sg.’
   c. pul ‘stamp’      pul-un ‘stamp-gen.sg.’
   d. son ‘end’        son-un ‘end-gen.sg.’

It is useful in this connection to compare Turkish with languages lacking vowel harmony, such as English. In (11) below, I show an idealized course of electromyographic (EMG) activity of the Orbicularis Oris muscle in the production of the utterance [utu] by an English speaker (Boyce 1988, 1990). The Orbicularis Oris is the muscle involved in the rounding gesture for the vowel [u]. Contraction of this muscle causes protrusion of the lips with concomitant approximation of the upper and lower lips. The schematic EMG trace in (11) is idealized only in the sense that the changes in EMG activity are gradual instead of having the shape of the step function depicted here. More accurately, then, the EMG activity gradually increases during the production of the first vowel, and then gradually decreases during the transition between the vowel and the consonant, reaching a local minimum at some point during the production of the consonant, after which it again begins gradually to increase.

11. EMG trace for English [utu]

   U T U

The characteristic trough, coincident with the production of the consonant, indicates that there is cessation of muscle activity during the consonant. The two identical vowels on either side of the consonant are
therefore scheduled as two independent events. The same trough pattern is found in the production of utterances like [kipip] or [kitip]. The relevant muscle here is the genioglossus, which is primarily involved in the protrusion and bunching of the anterior tongue associated with the vowel [i] (Gay 1977, 1978).

Turning to other languages, the same trough pattern in the activity of Orbicularis Oris is attested in Spanish, French (Perkell 1986), and Swedish (Engstrand 1981, Lubker & Gay 1982). Crucially these languages differ from Turkish, which shows a plateau in the EMG activity of the Oribicularis Oris (Boyce 1988, 1990). The difference between the English, Spanish, French, and Swedish patterns, on the one hand, and the Turkish EMG patterns, on the other, which is statistically significant, is depicted in (12).

12. EMG trace comparison in different languages

a. 'Trough' in English, Spanish, French, and Swedish

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U   T   U
```

b. 'Plateau' in Turkish

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U   T   U
```

Because the Orbicularis Oris is the principal muscle involved in the articulatory gesture of lip protrusion, similar plateaus or troughs can be observed when the measured variable is the amount of lip protrusion, which is generally thought to be a reliable index of lip rounding.
This difference between the group of languages in (12a) and Turkish in (12b) is precisely what Articulatory Locality predicts. Turkish is a language with rounding harmony in which the rounding value of the leftmost vowel determines the rounding of all following vowels. Articulatory Locality correctly predicts that the rounding gesture of the trigger vowel should spread through all articulatorily contiguous segments. In the simple case illustrated above by the EMG traces, the intervening consonantism happens to be just [t], but the same results are obtained in utterances with longer intervocalic consonantal sequences such as [ktl] in words like [uktlu] (Boyce 1988: p. 90). English, French, Spanish, and Swedish, on the other hand, do not have rounding harmony. In these languages, then, there is no spreading of features and hence there is cessation of muscle activity during the intervening consonant.

Thus in the one case of long distance assimilation with available articulatory movement data, the experimental results support our view that vowel harmony does not skip consonants intervening between harmonizing vowels. However, our view faces a clear challenge from some well-known cases where not only consonants but also certain vowels seem to be transparent to the assimilation (e.g. Hungarian, Finnish, various African languages). In Hungarian (Vago 1980), for instance, all vowels in a word in principle agree in terms of the feature ["back"] (tongue body backing) and suffix vowels alternate according to the last root vowel, harang+nál ‘bell+adessive’, hegedü+nél ‘violin+adessive’ (the acute accent denotes length, the umlaut denotes front round vowels). Yet one finds words like papír+nak ‘paper+adative’ and kávé+nak ‘coffee+adative’, where the non-low front vowels [i, e] and their long counterparts [í, é] may intervene in the sequence of [+back] harmonizing vowels. Previous analyses exclude transparent vowels from the domain of the assimilation using various devices such as underspecification of the transparent vowel's features or projection of those features on another tier (Clements 1977, Kiparsky 1981, Goldsmith 1985, Steriade 1987b, Ringen 1988; for a critical review see Kenstowicz 1994: pp. 357-9, Farkas & Beddor 1987 and Steriade 1995a: pp. 135 ff.).

Hungarian, then, seems to illustrate a case of direct assimilation between the first and last vowels in a [VCVCV] sequence, skipping over not only the consonants but also the intervening vowel. I believe, however, that Hungarian harmony and other cases like it can be analyzed
insightfully under our approach.

In Articulatory Phonology, the basic units of phonological action, the gestures, have spatio-temporal characteristics and therefore can overlap in time (see chapter 1: §2.1). Transparency can be seen as an emergent property of gestural overlap and its articulatory and acoustic consequences. The details will depend on the particular harmony system, but the basic idea is straightforward. As a harmonic gesture extends it overlaps with other local gestures. This overlap causes articulatory perturbations on the local gestures due to conflicting demands on shared articulators. Some of these perturbations have significant acoustic consequences, but others do not. The sounds for which the articulatory perturbations of their component gestures, due to overlap with the harmonic gesture, have no significant acoustic consequences are transparent.

To illustrate the basic idea with Hungarian, consider a word like radír+nak 'eraser+dative', with the transparent vowel [i] intervening between the two [+back] harmonizing [a] vowels. In our view, harmony involves the continuous activation of the gestural tract variable that specifies the tongue body constriction location (TBCL) for the vowel ‘a’ throughout the entire word. Abstracting away from the particular consonants, a schematic representation of that continuous activation is shown in (13) below. The tract variables of the vowel gestures in CaGCCaC are as follows. The tongue body constriction location, TBCL, has the value {uvular} for the two ‘a’ vowels (in Hungarian, orthographic ‘a’ corresponds to phonetic [a]), and the value {palatal} for the vowel ‘i’. The tongue body constriction degree, TBCD, for the vowel ‘a’ is {wide}, and for the vowel ‘i’ it is {narrow}. The control regime for the constriction location tract variable TBCL={uvular} is specified, via rule or constraint, to be active during the entire word (shown shaded).

13. Continuous activation of TBCL={uvular} in [CaGCCaC]

<table>
<thead>
<tr>
<th>a’ { , wide}</th>
<th>i’ {palatal, narrow}</th>
<th>a’ { , wide}</th>
</tr>
</thead>
<tbody>
<tr>
<td>uvular</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In contrast to the standard autosegmental view, harmony in our view is always continuous. As shown above, then, during the production of /i/ the tongue body must simultaneously respond to two different target values of TBCL, {palatal} for the temporary high front vowel /i/ and {uvular} for the ongoing harmony. The result of this overlap is that the actual constriction location of the vowel /i/ is effectively retracted. What are the acoustic consequences of this retraction? Stevens, using simple tubes, and Wood, using natural human vocal tract profiles, have shown that the acoustic outputs for non-low front vowels such as [i, e]—exactly the transparent vowels of Hungarian—are insensitive to a limited amount of variation in the articulatory parameter of constriction location (Stevens 1989: p. 12, Wood 1979: p. 41). We hypothesize that the retraction of the constriction location for the vowel /i/ falls within that limited region of variation so that it does not result in any significant acoustic consequences. In other words, consistent with our central hypothesis, the transparent vowels participate articulatorily in the activation domain of TBCL={uvular}. The apparent skipping of these vowels is in our view an epiphenomenon due to the fact that the acoustic consequences of the gestural overlap are insignificant.

If this account is correct, it provides a principled understanding of the cooccurrence of two properties of the phenomenon, the nature of the assimilating parameter (TBCL) and the set of transparent vowels in Hungarian ([i, e, í, é]). Clearly the standard view of transparency as skipping cannot explain this cooccurrence. It is only when gestural overlap and its acoustic consequences are considered that this link becomes visible. To add further support to an analysis along these lines, consider the fact that the high front rounded vowel [ü] is not transparent in Hungarian. This at first appears to be problematic for us since [ü] has a tongue body configuration almost identical to that of [i] (there tend to be slight tongue height differences). Of course [ü] is also rounded and this turns out to be the crucial fact. Wood (1986) shows that the effect of rounding is to make the region of acoustic indifference to constriction location perturbations “considerably advanced,” and that “the midpalatal position is avoided for [y] [AG:ü] in speech” (pp. 394-5). Hence, the retraction of the tongue body constriction location from the overlap of TBCL={uvular} of [j] (a’) and TBCL={palatal} of [ü] would have
significant acoustic consequences on [ü]. This would explain why [û] and its long version [øː] are not transparent in Hungarian.

Before concluding, let me elaborate on a technical aspect of the gestural representation in (13). Note therein that for the two ‘a’ vowels, the activation windows of the tract variables TBCL (shaded) and TBCD (unshaded) have different durations (hence, the empty slots for the values of TBCL in the ‘a’ windows). This entails an important extension to the dynamic model of gestures in Articulatory Phonology. The activation of all tract variables of a gesture is currently implemented under a uniform control regime. This means that for a tongue body gesture, for example, the variables TBCL, TBCD are under active control for the same period of time. However, our characterization of harmony as persistence of active control of a tract variable within some domain requires that we add to the model the capability of differential active control of paired tract variables. In vowel harmony, for example, active control of a tract variable like LP (lip protrusion for rounding harmony) or TBCL (tongue body constriction location for back harmony) extends throughout the domain of a word, independently from the temporary control of LA (lip aperture) or TBCD (tongue body constriction degree) of local gestures.

The proposed addition to the model of Articulatory Phonology incorporates one of the basic insights of autosegmentalism. Features gain autonomy so that they may span domains of different sizes with some features being local to their segments whereas others extending over several segments (Goldsmith 1976, Clements 1976). In fact, the decoupling between a gesture’s CL and CD I see necessary to account for harmony has also been proposed by Clements (1992) based on facts of nasal place of articulation assimilation and vowel height assimilation.

To conclude, I have reviewed evidence supporting the view that vowel harmony does not skip segments intervening between harmonizing vowels. Pursuing this view, I have argued, may lead us beyond our current understanding of recalcitrant cases of this phenomenon.
4.2 Consonant Harmony
Parallel to vowel harmony, there are also processes affecting sequences of consonants while leaving intervening vowels unaffected, called consonant harmony. An example of consonant harmony from the American Indian language Chumash (Hokan) is given in (14) below (Beeler 1970). The consonants which trigger the harmony are underlined.

14. Chumash consonant harmony
   a. s-api-tso-it 'I have good luck'
   b. s-api-tso-uš 'he has good luck'
   c. k-sunon-uš 'I obey him'
   d. k-sunon-š 'I am obedient'

In Chumash, assimilation proceeds right to left: the laminal (s, tš) versus apical (s, ts) articulation of coronal sounds is determined by the rightmost laminal or apical coronal sound. Hence the alternations between (14a) and (14b), and between (14c) and (14d). Nothing seems to happen to the intervening vowels and the other consonants that may lie between the trigger and the target(s) of this assimilation. In the standard analyses of this phenomenon, the assimilating feature of apicality/laminality is thought to spread from the trigger consonant to the target consonant(s), again ignoring the intervening segments (Poser 1982, Steriade 1987b, Shaw 1991).

The presence of such phenomena is perhaps rather surprising at first, given the view of assimilation we are developing. In particular, we have seen that consonant gestures in a CVC are not contiguous. This is shown in (15) below for the simple utterance [mat].

15. CVC: [mat]

<table>
<thead>
<tr>
<th>TB</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIPS</td>
<td>m</td>
</tr>
<tr>
<td>TT</td>
<td>t</td>
</tr>
</tbody>
</table>

Absence of C-to-C contiguity between the gestures of the two
consonants in a CVC sequence should preclude a direct influence of one
consonant on the other, according to Articulatory Locality. Hence
examples of consonant harmony seem to provide a prima facie
counterexample: consonant harmony seems to involve direct assimilations
between two consonants in a CVC sequence, ‘skipping over’ the
intervening vowel.

However, on closer scrutiny, the properties of consonant harmony, as
they will emerge from the cross-linguistic investigation of chapter 5,
provide striking confirmation for the correctness of Articulatory Locality.
The most important property of consonant harmony is that it is limited to
sounds articulated with the tongue tip-blade. More accurately, consonant
harmony involves assimilations in terms of one of the following two
features of the tip-blade. The first feature, TTCO for ‘Tongue-Tip
Constriction Orientation’, specifies the shape of the tip-blade articulator in
the mid-sagittal plane. TTCO controls the orientation angle of the tongue
tip-blade with respect to the tongue dorsum. It is the feature controlling
the apicality-laminality distinction seen in Chumash consonant harmony.
The second feature, TTCA for ‘Tongue-Tip Constriction Area’, specifies
the cross-sectional area of the channel created by the approximation of the
tip-blade articulator to the palate. This feature controls the shape of the
tip-blade articulator on the cross-sectional plane.

Both TTCO and TTCA, the only two features attested to assimilate in
consonant harmonies, are parameters which specify the shape of the tip-
blade articulator. This shape is a consonantal characteristic with the
special property that it can propagate through a vowel for two reasons.
First, the tip-blade is independent from the tongue body with which
vowels are articulated. Hence, its mid-sagittal or cross-sectional shape can
be maintained throughout the production of a vowel. Second, the precise
shape of the tip-blade has no effect on the acoustic quality of the
intervening vowel, much as the lip rounding in Turkish [utu] did not affect
the quality of the intervening [t]. In chapter 5, I will provide experimental
evidence for the articulatory independence between the tongue body and
the tip-blade, as well as for the fact that TTCO and TTCA can propagate
through vowels with no significant acoustic effects on the quality of these
vowels.

The second property of TTCO and TTCA explains the apparent effect
of ‘skipping the vowels’ in consonant harmony. The first property allows
the gestural characteristics of the trigger consonant, as defined by TTCO and TTCA, to propagate through the vowel so that it is contiguous with the target consonant. This is precisely what Articulatory Locality predicts. The properties of consonant harmony, then, provide strong additional confirmation for the correctness of Articulatory Locality.

4.3 Spreading in Nonconcatenative Languages

In the morphology of Semitic languages, roots may consist solely of consonants which are intercalated with vowels marking categories such as aspect and tense. The sequencing of consonants and vowels is defined by a prosodic template, called binyan in the Hebrew tradition or conjugation in the Arabist tradition, which marks other grammatical categories such as voice and transitivity/causativity. In formal terms, the three different constituents of a Semitic word, the root consonantism, the vocalism, and the prosodic template, are assumed to be on three different planes in the representation (McCarthy 1979, 1981). For example, in the noun /hodu:d/ ‘passing’ (/hadda/ ‘to pass’), the melody of the root /hd/ is intercalated with the melody of the nominal vocalism /ou/ into the prosodic template CVCV:C. The representation of that noun is shown in (16) below.

16. Constituents (planes) in the representation of /hodu:d/ ‘passing’

```
   h    d
   C    V    C
   o    u
```

As can be seen above, the noun /hodu:d/ is not formed by simple concatenation of its constituents, in contrast with the case of the English morphemes /un-/ and /do/, which are concatenated to form the output /undo/. Hence, the terms ‘concatenative’ versus ‘non-concatenative’ for English and Semitic respectively. To derive the form /hodu:d/, the melodies of the vocalic affix and the root are mapped onto the template from left-to-right by following linking principles of autosegmental phonology. Of interest here is that the final consonant of the root /d/ ends
up being linked to two positions in the template by the application of autosegmental spreading, known in its particular instantiation here as ‘long-distance consonantal spreading’.

Here, then, we encounter another *prima facie* counterexample to Articulatory Locality. Under standard assumptions, autosegmental spreading is the mechanism involved in assimilation. If, as Articulatory Locality dictates, phonological assimilations respect articulatory contiguity, then spreading of the whole consonant /d/ in the final CV:C sequence of /ho\(d\)u:d/ should propagate through the intervening vowel, completely obscuring the vowel by creating the wrong output /dd(d)d/ instead of the desired /du:d/.

Consider in this connection the following three points relevant to long-distance consonantal spreading. First, what allows the spreading of the consonant to take place is the assumption that vowels and consonants in nonconcatenative languages like Arabic are segregated on different planes, also known as the V/C planar segregation hypothesis (McCarthy 1979, 1989). According to this hypothesis, the two consonants in a CVC sequence are adjacent on their own plane. This predicts that there should be assimilations between the two consonants similar in character to assimilations found in CC clusters, because in both a segregated CVC sequence and a CC cluster nothing intervenes between the two consonants. For example, V/C planar segregation predicts cases of long-distance assimilation as in (17).

17. /nap/ ~ [map]

\[
\begin{array}{c}
\text{C} \\
\downarrow \\
\text{V} \\
\downarrow \\
\text{V-Root}
\end{array}
\]

\[
\stackrel{\text{coronal}}{\delta} \quad \stackrel{\text{labial}}{\text{C}} \quad \text{C}
\]

In the above hypothetical assimilation, the [labial] place of articulation of the second C spreads to the first C, with concomitant delinking of the original place of articulation of the nasal. This type of nasal place assimilation is widely attested in CC clusters cross-linguistically, but it is simply not attested over intervening vowels. Hence,
Articulatory Locality

A theory which admits V/C planar segregation does not explain why this type of 'spreading' always spreads the whole consonant and never its place node.

Second, note that the effect of long-distance consonantal spreading in the Arabic form /hodud/ essentially is to create another instance of the consonant /d/. This is the same effect found in reduplication, an independent operation in morpho-phonological theory. An example of reduplication is illustrated in (18) below, from the Philippine language Ilokano (McCarthy and Prince 1986). The progressive aspect of verbs in Ilokano involves the prefixation of the segmentally specified affix ag-, and prefixation of a reduplicative morpheme. As is typical of reduplication, the reduplicative morpheme is left unspecified for segmental content, but it is specified for a prosodic template, which in this case is a heavy syllable, namely, a CVC sequence. This empty prosodic template of the reduplicant is filled by literally copying segments of the base (McCarthy & Prince 1995a).

18. Ilokano reduplication

<table>
<thead>
<tr>
<th>Stem</th>
<th>Progressive</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>basa</td>
<td>ag-bas-basa</td>
<td>'be reading'</td>
</tr>
<tr>
<td>trabaho</td>
<td>ag-trab-trabaho</td>
<td>'be working'</td>
</tr>
<tr>
<td>takder</td>
<td>ag-tak-takder</td>
<td>'be studying'</td>
</tr>
</tbody>
</table>

Hence, both long-distance consonantal spreading and reduplication create copies of segments, but whereas in the former the underlying mechanism is autosegmental spreading, in the latter the mechanism is literal copying of a segment.

Third, cross-linguistic patterns of copying show that both long-distance consonantal spreading and reduplication serve the same need of filling empty positions in a prosodic template supplied by the morphology. In Arabic, the long-distance spreading of /d/ in the form /hodud/ is necessitated by the fact that the binyan CVCV:C consists of three consonantal slots, whereas the root /hd/ has only three consonants. Hence, the final C slot of the binyan is filled by creating an extra instance of a consonant of the root. In Ilokano, the reduplicative morpheme is required to have the prosodic shape of a heavy syllable, essentially a CVC. This
prosodic template is then filled by copying segments of the base. Thus the two operations, long-distance consonantal spreading and literal copying, seem to apply under identical conditions. This similarity between long-distance consonantal spreading and reduplication is not captured by a theory postulating these two unrelated mechanisms of segmental copying.

There are, therefore, three observations that call into question the assumption that the Arabic pattern /ḥoːdud/ involves autosegmental spreading. First, spreading the consonant to create the output /ḥoːdud/ has the same effect as in reduplication, namely, creating a copy of a segment. Second, long-distance consonantal spreading and reduplication serve the same need to fill empty prosodic positions with segmental material, and third, whenever long-distance consonantal spreading is claimed to apply, it spreads the whole consonant and never less than that. All three observations converge to the same conclusion, that what was seen as ‘spreading’ in /ḥoːdud/ in fact involves the same formal mechanism as reduplication, namely, literal copying of a segment. This explains the identity of conditions under which reduplication and the former spreading operation occur. It also explains why ‘spreading’ always targeted the whole consonant: copying of segments targets the whole segment and not just its place of articulation or any particular feature(s).

We have arrived at the conclusion that there is no long-distance consonantal spreading. This is precisely what Articulatory Locality predicts, as pointed out in the beginning of this subsection. Chapter 3 will be devoted to two goals: (a) the elimination of long-distance consonantal spreading, and (b) the development of the surprising and welcome consequences for morpho-phonology ensuing from this elimination.

5. PREVIOUS PROPOSALS ON LOCALITY
In this section, I discuss a number of previous proposals on locality and their relation to Articulatory Locality. Subsection 5.1 reviews definitions of locality as tier-adjacency in various feature geometries. Subsection 5.2 discusses the notion of locality advanced in the theory of Grounded Phonology and Dependency Phonology, and subsection 5.3 reviews definitions of locality as segmental Root-adjacency.

Many of the proposals on locality that will be discussed here have been developed within various feature geometric frameworks, which propose different hierarchical organizations of features in the feature tree.
It should be made clear from the outset that what is criticized in this section is not the architectures of the various feature geometries per se, but rather the recurring attempt to define locality as tier adjacency. The goal of feature geometry is to identify and characterize properly the sets of features that pattern as a unit in phonological processes (McCarthy 1988). This is in principle a different goal from the one of defining the correct notion of locality, although, as will be seen below, in some cases the two goals have been conflated with unsuccessful results.

5.1 Tier-Adjacency in Various Feature Geometries

I begin by considering notions of locality in one species of feature geometries proposed in the line of work initiated with Clements (1989), and further developed in Clements (1991a), Odden (1994), and Clements & Hume (1995) (see also Keating 1985).

The general approach taken in these geometries is to have two separate nodes for vowels and consonants. The vocalic place node, V-Place, expresses the functional unity of all the vocalic features, and also sometimes serves to add secondary vocalic articulations to consonants. The place node for consonants, C-Place, is the node from which the various consonantal articulations, such as Labial, Dorsal, and Coronal emanate. The relevant representation is shown in (19) below. There are further details about the dependents of V-Place and C-Place, which are however irrelevant to the present concerns. I refer the reader to Clements & Hume (1995) for a thorough presentation of the details of that framework.

\[
\begin{array}{cccc}
C & V & C & V \\
| & | & | & | \\
| & V-Pl & | & V-Pl \\
| & | & | & |
\end{array}
\]

In this geometry, because C- and V-Place nodes lie on different tiers, vowel-to-vowel assimilations over a consonant and consonant-to-
consonant assimilations over a vowel are equally predicted. The statistical
gulf between these two phenomena is left unexplained. For example, the
geometry above predicts unattested consonant harmonies. The Cor
dependent of CPI could spread docking on the preceding CPI of the
following consonant, with concomitant delinking of the Lab place
specification of that consonant. Consonant harmonies of this type are not
attested and there does not seem to be any principled reason in this
framework for their absence.

The fact that segregated V-Pl/C-Pl nodes theories are too permissive
is also noted in Clements & Hume (1995), who remark that assimilations
which spread the whole place node of a consonant to a preceding nasal, a
kind of a long-distance nasal place assimilation are not attested. An
example of such an assimilation is shown in (20) below. The absence of
such assimilations contrasts with the cross-linguistic frequency of nasal
place assimilation seen in consonant clusters. This contrast remains
unexplained under segregated C-Pl/V-Pl node geometries. Segregation
misses the distinction between a CC cluster and and a CVC sequence
because in both the CC and the CVC configuration the two C-Pl nodes are
tier adjacent.

20. N V C
   C-Place C C
   \delta
   \text{place} \hspace{1cm} \text{place}

Motivated by this problem, Clements & Hume (1995) propose a
modified C-Pl/V-Pl geometry where the V-Pl is now a dependent of C-Pl,
as shown in (20) below. In this geometry, it becomes impossible to spread
the CPI of the second consonant to the first consonant because the
intervening vowel is endowed with a C-Pl node of its own.

21. C V C
    |   |   |
    C-Pl C-Pl C-Pl
    |   |   |
    V-Pl
This representation, however, essentially stipulates the lack of processes such as long-distance place assimilation over a vowel by hardwiring the C-PI node under the Root node of every vowel and positing the additional dependency relation between C-PI and V-PI. Although Clements & Hume (1995) provide independent arguments for the existence of a dependence relation between C-PI and V-PI in the feature geometry of consonants with secondary vocalic articulations, no such arguments are given for the existence of a C-Place node in the feature geometry for vowels. Requiring the presence of a C-Place node in every vowel is thus left unjustified, and it seems rather unintuitive to have a featureless C-Place node implanted in the feature tree for every vowel. To sum up, the C-PI for vowels serves no function other than to encode diacritically the observed asymmetry between vowel and consonant harmony.

Another family of locality proposals is based on the species of feature geometries developed in the work of Clements (1985), and Sagey (1986), and continued in Archangeli & Pulleyblank (1986), McCarthy (1988) and others. Henceforth, I will call these geometries ‘Sagey-type’ geometries, because they all retain a core property of the geometry of Sagey (1986), namely, that vowels and consonants are described by the same set of articulator nodes. In the geometry of (22) below, the node Lab(ial) is used for both round vowels and labial consonants, Cor(onal) is used for coronal consonants, and Dor(sal) is used for both velar consonants and vowels. Note that there is no C-Place/V-Place distinction, as was the case with the geometries discussed earlier.12

22. Sagey-type geometry

```
Root
     | Place (other features)
     |     Lab Cor Dor
```

Suppose that we are trying to capture the locality of vowel-vowel assimilations across consonants in this geometry. Velar consonants are typically transparent to such assimilations. Consider, for example, back
harmony in Turkish, where the [+back] feature of a stem vowel spreads to the vowel of a suffix, e.g. /ayak + ten/ → [ayaktan] ‘foot (ablative)’ (Shaw 1991, cf. Archangeli & Pulleyblank 1987). Because in Sagey-type geometries both vowels and velar consonants use the dorsal articulator, the two vowels, /...aṅten/, are not adjacent at the Dor tier. Backtracking toward the Root of the feature tree above, we find that the levels of the Place node and the Root node also do not yield tier-adjacency between target and trigger, because all intervening consonants are specified for these two nodes. Moving one level up, above the Root node of a vowel lies the nucleus of its syllable. Consonants do not project nuclear positions. The two nucleus nodes of the vowels are thus adjacent at that level, and hence locality is defined at the prosodic level as adjacency between nuclear nodes.

Other rules require adjacency at a different level, however. For example, Turkish also has a rule assimilating the velar consonants /k g/ to the [+back] specification of a tautosyllabic vowel, e.g. sirk ‘circus’, k’urk ‘fur’ vs. fark ‘difference’, zamk ‘glue’. An example is shown in (23) below.

23. /s i r k/ → [sirk']

Because the rule targets consonants and is triggered by vowels, adjacency between target and trigger could not be defined at the syllable nuclei. Moreover, because “irrelevant” consonants may intervene between trigger and target (e.g. sirk), adjacency cannot be defined either at the level of the Root nodes or the Place nodes. Adjacency is defined, instead, at the level of the Dor tier. The ‘irrelevant’ consonants do not have a Dor
node, as demonstrated in (23) above.

Based on evidence of this sort, Archangeli & Pulleyblank (1987) propose that a 'scansion parameter', set for every rule, specifies the tier in the feature geometry that identifies trigger and target as adjacent. The problem with this parametric definition of locality is that it is too strong. If the locality parameter is set individually for every rule, it is possible to generate phenomena that are not attested. An illustrative example is provided by Shaw's (1991) discussion of a rule of consonant harmony in Tahltan, a Northern Athabaskan language. In that language, certain coronal consonants assimilate to other coronal consonants over vowels and other non-coronal consonants. Assimilation spreads the Cor node of a consonant to a preceding coronal consonant, as shown in (24) below. The level on which adjacency between trigger and target exists seems to be the Cor tier. The intervening vowels and the labial consonant do not have a Cor node (although they do have their own place specifications, e.g. /p/ has Lab).

24. Spreading of Coronal

\[ s \ V \ p \ V \ \hat{s} \]

<table>
<thead>
<tr>
<th>Place tier</th>
<th>Cor tier</th>
</tr>
</thead>
<tbody>
<tr>
<td>C C C C C</td>
<td>C C</td>
</tr>
<tr>
<td>( \delta )</td>
<td></td>
</tr>
</tbody>
</table>

\[ [+\text{str}] \quad [! \text{ant}] \]

However, it is generally assumed that spreading a node X (here, Cor) which is a dependent of another node Y (here, Place), results in associating the node X to all nodes that possess the node Y. This assumption, if applied in the Tahltan case, would give incorrect results, as noted by Shaw, associating the spreading Cor node to all place nodes of vowels and non-coronal consonants which are specified for a Place node. For example, the labial consonant above would end up being linked to a Cor node under this account, perhaps with concomitant delinking of its Lab node. To avoid this, Shaw assumes that the Cor node links to only those Place nodes which already have a Cor node. To locate its target segments, then, the rule must scan not the Place tier but the Cor tier.
Hence another value for the scansion parameter of Archangeli & Pulleyblank (1987) must be recognized for the case of Tahltan consonant harmony. What are the costs of proposing such rule-specific parametrizations of locality? Among others, this proposal predicts just the case that Shaw has attempted to avoid in Tahltan, that is, spreading of the Cor node, docking to the Place node of all segments specified for a Place node, which includes labials, velars, vowels, and so on. Such assimilations are unattested.

To conclude, two approaches in defining locality have been discussed. The first is based on geometries wherein consonants and vowels have segregated C-Place and V-Place nodes. The notion of locality based on such segregated feature geometries is tier-adjacency on the individual V-Place and C-Place tiers. The second approach to locality, based on a different species of feature geometries, again defines locality as tier-adjacency but employs a parameter which specifies, for every rule, the tier in the feature tree which would make the trigger and the target of an assimilation adjacent. Both approaches to locality are too strong in that they predict unattested phenomena.

5.2 Grounded Phonology and Dependency Phonology

Another proposal on locality is that of Grounded Phonology, developed in Archangeli & Pulleyblank (1994). They relate locality to a formal notion of precedence, call the ‘Precedence Principle’. According to this principle, spreading of a feature [f] must not create contradictory precedence relations. I consider the prediction of this notion of locality in two environments: spreading between the two consonants in a CVC sequence, and spreading between the two vowels in a VCV sequence.

First consider the case of CVC. In (25) below, the feature [f] linked to the two consonants across a vowel results in a violation of the Precedence Principle for the following reason: [f] precedes V by being linked to the first C node, and also follows V by being linked to the second C node.13

25. Precedence violation

```
      [f]
     /\  
C   V   C
```

Hence, "spreading from consonant to consonant is ruled out in a CVC
Articulatory Locality agrees with this end result, ruling out direct assimilations between the two consonants skipping over the vowel. However, it differs crucially from the proposals of Archangeli & Pulleyblank in that it grounds locality in the independent articulatory basis of speech and not on an abstract principle of precedence. Moreover, Archangeli & Pulleyblank provide no account of consonantal spreading in nonconcatenative languages and consonant harmony, in which the Precedence Principle would seem to be violated. These phenomena will be shown to be consistent with Articulatory Locality in chapters 3 and 5, respectively.

Consider next the prediction of the precedence principle for the case of a VCV sequence. In (26) below, the formalism of Archangeli & Pulleyblank yields no violation of precedence. This is because the anchors of the feature \([f]\) are now the moras of the vowels, although \([f]\) is linked to the Root nodes of these vowels, and at the moraic level no anchor intervenes between the two vocalic moras to result in a contradiction in terms of precedence. Again, there is no need to review the technical details for why the anchors for the feature \([f]\) are the moras instead of the Root nodes of the vowels. It is the end result that is of interest in the present discussion.

\[
\begin{array}{ccc}
V & C & V \\
| & | \\
\mu_i & \mu_j \\
\end{array}
\]

Hence, "vowel-to-vowel spreading in a VCV sequence is in fact well-formed: the consonant is ignored" (p. 358). This is, then, the traditional view of vowel harmony, which attempts to capture the intuition that vowel harmony is a local process by some method unrelated to the articulatory basis of speech. It is in the latter, I argue, that this intuition finds its natural expression: V-to-V contiguity is the articulatory basis for the locality of vowel harmony.

Archangeli & Pulleyblank's proposal about the locality of vowel harmony is similar to the view of vowel harmony in dependency and
government-based theories of phonology (Anderson & Ewen 1987, Kaye, Lowenstamm & Vergnaud 1985). Vowel harmony, in these theories, is expressed as a relation of agreement which involves syllable nodes. A nucleus of a syllable is defined as the ‘syllable head’. Agreement among syllable nodes implies agreement among their heads and thus agreement among the vowels which occupy the nuclei of the syllables. Hulst & Weijer (1995) illustrate an instance of vowel harmony in this approach with the representation in (27) below. The spreading feature links to the syllable node, and because vowels are 'syllable heads', it percolates to the vowels of the syllables.

27. $\begin{array}{c}
\text{[+f]} \\
\hline
\text{S} \\
\text{C V C} \\
\hline
\end{array}$

The locality of vowel harmony is captured by the notion that vowels are syllable heads and the fact that syllable nodes are adjacent. Because of the importance of the notion of syllable head, Hulst & Weijer (1995) call this approach the 'syllable-head' approach to the locality of vowel harmony. Grounding locality in the articulatory facts reviewed earlier gives content to the intuition that vowels are 'syllable heads': the vowel is the articulatory foundation of the syllable in the sense that its gesture extends throughout the whole syllable, overlapping with the surrounding consonantal articulations.

The 'syllable-head' approach also seems to explain the asymmetry between vowel and consonant harmony. Because consonants are not heads of syllables their relation over a vowel cannot be local. However, as Hulst & Weijer (1995) point out, this approach faces difficulties in the cases of vowel harmony where consonants interfere to block the spreading of the harmonizing feature (e.g. Turkish back harmony is blocked by the palatalized versions of /k, l/). The reason is that consonants are 'dependents' of the vowel and their features are not accessible to the syllable node. Some special convention is thus needed to capture effects of this sort. Clearly the same problem exists in the case of consonant
harmony, where the relation of agreement would presumably involve only the consonants.

5.3 Locality as Root Adjacency
I turn now to a discussion of some recent proposals which argue that locality should be identified with Root adjacency. After a brief review of these proposals, I show that the notion of locality as Root adjacency is essentially consistent with Articulatory Locality.

McCarthy (1994) discusses spreading of the vocalic feature pharyngeal, [phar], in the the Najdi dialect of Bedouin Arabic. My discussion of both the facts and the analysis is simplified here, highlighting only issues relevant to locality. The generalization to be expressed in this dialect of Bedouin Arabic is that in a VCV configuration, when the C is a coronal consonant, the two vowels are identical. A few examples are shown in (28).

28. Bedouin Arabic
   jalas ‘he sat’  bgarak ‘your cattle’
   jaraf ‘he washed away’  şanag ‘he hanged’

McCarthy captures the identity effect between vowels across coronal consonants in the following way. First, we assume that the feature [phar] spreads in a strictly local fashion, under Root adjacency, as shown in (29) below. Note that [phar] is linked to the intervening consonant as well, creating a segment with more than one place specification, [cor, phar], or what is known as a ‘complex’ segment.

29. Spreading under Root adjacency

   [phar]
     j a l a s

Second, we assume that the coronal place is the least marked place of articulation, as expressed by the constraint ranking in (30a) below (Prince & Smolensky 1993, Smolensky 1993). According to this ranking,
superimposing another place specification, X, to a coronal segment results
in a less marked segment than superimposing the same place specification
X to a non-coronal segment (labial or dorsal), shown in (30b) below.

b. *PL[LAB, X], *PL[DOR, X] >> *PL[COR, X]

If the constraint enforcing spreading of [phar], SPREAD, is ranked
below *PL[LAB, X], *PL[DOR, X] and higher than *PL[COR, X], it follows
that non-coronal consonants would block the spreading of [phar]. Were
such spreading to take place, it would incur a fatal violation of *PL[LAB,
X] or *PL[DOR, X], as exemplified in (31) below for the case of an
intervening dorsal.

31. Ranking: *PL[LAB, X], *PL[DOR, X] >> SPREAD >> *PL[COR, X]

```
[phar]
   |
  j a k a s
```

incurs fatal violation *PL[DOR, X]

This analysis crucially relies on the assumption that the spreading of
[phar] applies under Root adjacency. This is also the assumption
Padgett (1995), who proposes a similar account of consonant transparency
in VCV sequences, where the C is now a laryngeal. In Kashaya Pomo, for
example, the vowels in the configurations VV and VhV must be
identical, a phenomenon that Steriade (1987a) has dubbed 'translaryngeal
harmony'. Specifically, Padgett assumes that (a) spreading of the vowel
features applies under Root adjacency, and thus the vowel features are
linked not only to the two vowels but also to the Root of the laryngeal
consonant, and (b) laryngeal consonants are not part of the markedness
hierarchy of (30a) above because they lack place of articulation. From the
latter assumption it follows that linking the vowel features to a laryngeal
does not create a complex segment, whereas linking of the vowel features
to any other consonant will result in a complex segment and thus a
violation of some constraint in (30b). Hence, the transparency of laryngeals versus the opacity of all other consonants follows from the ranking: *Pl[LAB, X], *Pl[DOR, X] >> *Pl[COR, X] >> \text{SPREAD}.^{14}

The two analyses just reviewed argue for a notion of locality based on segmental Root adjacency: given a phonological representation as a string of segments, spreading cannot skip segments (i.e. their Roots). Articulatory Locality is similar to the Root adjacency notion of locality, with one important difference. In a VCV sequence not only are V-C and C-V articulatorily contiguous, but the two vowels can also be contiguous (V-to-V contiguity). In total, then, there can be three locality relations in a VCV. In the segmental notion of locality, however, the two Vs are not Root-adjacent; the only locality relations are between V-C and C-V. This difference derives from the fact that the linear representation of a string of segments assumed in autosegmental phonology abstracts away from the ability of vowels and consonants to overlap. After the discussion of consonant harmony below, I will return to this point to further compare Articulatory Locality and Root adjacency.

When it comes to the issue of spreading the two notions of locality are indistinguishable. According to Articulatory Locality, spreading between the two vowels in a VCV must propagate through the C because this C is contiguous with both Vs. This is the same as requiring spreading under Root adjacency. Similarly, in a CVC configuration spreading between the two consonants must propagate through the vowel, according to both Root adjacency and Articulatory Locality. In the autosegmental framework, then, the requirement of Articulatory Locality is equivalent to spreading under Root adjacency.

Next, I turn to proposals on locality relevant to the phenomenon of consonant harmony. Ní Chiosáin & Padgett (1993), noting the absence of place of articulation assimilations across a vowel in a CVC sequence, as in the hypothetical /nap/ ~ [map], propose an explanation based on two assumptions. They assume that (a) spreading applies under Root adjacency, and (b) that place and stricture of consonants spread together as a unit (see also Padgett 1994). According to (a), if spreading was to apply in a CVC sequence, it would have to go through the vowel. According to (b), this would impose a consonantal constriction on the vowel, resulting in a fatal violation of syllable structure (the latter idea is attributed to Bruce Hayes).
This account, then, predicts that no consonantal place, Labial, Dorsal, or Coronal, could spread through a vowel. Nevertheless, there are cases of consonant harmony where it seems necessary to assume that the spreading node is Coronal because its two dependent features [ant] and [dist] spread, as in Sanskrit and Tahltan (see Schein & Steriade 1986 and Shaw 1991 respectively). To solve this problem Ní Chiosáin & Padgett suggest that these cases do not involve spreading of the Coronal place but, instead, spreading of another node, called Site, in the revised feature geometry shown in (32) below. Spreading of the Site node now does not implicate spreading of the stricture feature [cont].

32. Coronal harmony in terms of both [ant] and [dist]

```
Place
  Coronal
    [cont] Site
      [ant] [dist]
```

The addition of the Site node under Coronal 'hardwires' the fact that only coronal consonants exhibit consonant harmonies and, as Ní Chiosáin & Padgett note, it essentially stipulates the existence of coronal harmonies. However, it should be noted that the intuition encoded in this representation is that spreading in coronal harmonies does not involve spreading of consonantal stricture. This is also an important aspect of the proposals developed in chapters 4 and 5.¹⁵

The question then still remains: why is consonant harmony limited to coronal consonants? This brings us to the crucial differences between Articulatory Locality and locality as Root adjacency. Locality as Root adjacency in autosegmental representations predicts perfect symmetry between the two phenomena of vowel harmony and consonant harmony in VCV and CVC sequences, respectively. Consider, on the one hand, that vowel harmony is cross-linguistically well-attested (in African, Romance, American Indian, Uralic/Altaic languages etc.), and for all vocalic features
Articulatory Locality

(height, frontness, roundness, and tongue-root position), while, on the other hand, consonant harmony is rather limited. This asymmetry in the distribution of the two phenomena is not captured by the notion of locality as Root adjacency. The two vowels in a VCV are not Root-adjacent, and thus not in a local relation with each other, exactly as with the two consonants in a CVC.

In contrast, according to Articulatory Locality, the two vowels in a VCV sequence do enter in a local relation to each other (except of course when C involves a tongue body gesture). In a CVC sequence, however, consonant gestures do not have this property of contiguity. Hence the asymmetry between the presence of V-to-V contiguity versus the absence of C-to-C contiguity, from which the asymmetry in the distribution between vowel harmony and consonant harmony follows.

Moreover, Articulatory Locality also predicts the limitation of consonant harmony to coronal sounds, or more accurately, the limitation of the assimilating features in consonant harmony to the gestural parameters introduced in section 4, TTCO and TTCA. TTCO and TTCA are the only assimilating features in consonant harmonies because they are the only consonantal gestural parameters that can propagate through the intervening vowel in a CVC so as to affect the consonant on the other side of the vowel.

To sum up, Articulatory Locality provides a natural explanation for the asymmetry in the distribution of vowel harmony and consonant harmony, following from the asymmetry between presence of V-to-V contiguity in a VCV versus absence of C-to-C contiguity in a CVC. The Root adjacency notion of locality, lacking a notion of gestural contiguity, does not capture the noted asymmetry, because the two Vs in a VCV and the two Cs in a CVC are equally non-local. Furthermore, Articulatory Locality makes the right predictions about the specific restrictions applying in consonant harmony.

Finally, none of the proposals on locality discussed in this and the previous subsections address the issue of locality across all three different areas of phonology reviewed in section 4: vowel harmony, consonant harmony, and 'spreading' in nonconcatenative languages. As shown in that section, Articulatory Locality receives independent confirmation from all these areas of phonological research.
6. AUTOSEGMENTAL SPREADING AND ARTICULATORY LOCALITY

Building mainly on a discussion of association lines by Sagey (1986), this section argues that autosegmental spreading must apply in the ways dictated by Articulatory Locality.

Sagey (1986) addresses a fundamental question for autosegmental representations: what is the linguistic relation between a feature [F] and a skeletal slot X encoded in the representation \([F] \rightarrow X\)? One possibility, proposed in Goldsmith’s original proposal of the autosegmental framework, is simultaneity (Goldsmith 1976: p. 23). As Sagey notes, this interpretation leads to a contradiction. Consider, for example, the autosegmental representation of a geminate in (33) below (Hayes 1986, Schein & Steriade 1986). If association lines encode simultaneity, this representation implies that F is simultaneous with the first X, and also with the second X. This is a contradiction because the two X’s are ordered on the skeletal tier. An autosegment F cannot be simultaneous with two other non-simultaneous autosegments.

33. Geminate

\[ \begin{array}{c}
\text{F} \\
\text{X} \\
\text{X}
\end{array} \]

(F here is the Root of a segment)

Sagey proposes that the only coherent way to interpret association lines is through the notion of overlap: the association line in ‘\(F \rightarrow X\)’ encodes the fact that F and X overlap in time, not that they are coextensive. Hence, the representation in (33) above, repeated in (34a) below, receives the depicted interpretation in (34b).

34. a. \[ \begin{array}{c}
\text{F} \\
\text{X} \\
\text{X}
\end{array} \]

b. \[ \begin{array}{c}
\text{--- X ---} \\
\text{time}
\end{array} \]

In this representation, F is not coextensive with the first X, but rather
continuous in time after this X stops. No contradiction in precedence relations exists here.

Sagey pursues further this interpretation of association lines to eliminate the Well-Formedness Condition as a principle of the grammar. The Well-Formedness Condition (henceforth WFC), given in (35) below, operates as a constraint on autosegmental spreading, which can apply only if it does not violate this condition.

35. Well-Formedness Condition (Goldsmith 1976)
Association lines do not cross.

What does the WFC encode? A representation that violates the WFC is shown in (36), where the associations are ‘a ----- d’ and ‘β ----- ?’. This representation, Sagey writes “is ill-formed--not because of any physical or geometric properties of the representation, but simply because the relations it encodes are contradictory” (p. 294): in (36), ‘a ----- d’ implies that a overlaps with d, and ‘β ----- ?’ implies that β overlaps with ?; but ? must precede d because they are ordered in their tier.

36. Violation of WFC
\[
\begin{align*}
\text{a} & \quad \beta \\
\text{------- a -------} & \quad |------- \beta ------- \\
\text{-------- a} & \\
\text{-------- } & \\
\text{-------- } & \\
\text{-------- d} & \quad |------- ? ------- |
\end{align*}
\]

Sagey concludes that that "once the assumptions on which the Well-Formedness Condition depends are made explicit, it becomes clear that the proposed condition is equivalent to ‘overlap relations may not contradict precedence relations’" (p. 296). Hence, according to Sagey, the WFC can be eliminated from the grammar altogether, because it derives from extralinguistic principles. Sagey's reduction of WFC to "what our knowledge of the world tells us" relies crucially on the assumption that duration is part of the representation. In fact, Sagey proposes a simple representation where every autosegment or X-slot is viewed as a unit with some fixed duration. The gestural units I employ in this dissertation are
simply more realistic developments of Sagey’s representation (see chapter 1).

I now turn to my main main goal in this section. Further pursuing Sagey’s interpretations of autosegmental representations I wish to show that autosegmental spreading should apply as required by Articulatory Locality. Consider the representation in (37a), showing an instance of [round] vowel harmony as it is usually represented in the autosegmental framework (ignore 37b for the moment). The V and C in these representations are the X slots of the skeletal tier.

\[
\begin{array}{c}
V \\
\_ \\
\_ \\
V
\end{array}
\]

Sagey uses the representation in (37a) to further illustrate the incoherence of Goldsmith’s interpretation of association lines as expressing simultaneity; if they did, [round] would be simultaneous with two non-simultaneous X slots, a contradiction. In contrast, the interpretation in terms of overlap, given in (37b), yields no contradiction.

Notice, however, that there is an inconsistency between (37a) and (37b). On the one hand, as shown in (37b), the feature [round] overlaps with the three segments in the sequence VCV. On the other hand, in (37a) there is no association line between the two [round] and the consonant C. If association lines represent overlap, as in fact Sagey argues, then there should be an association line between [round] and the consonants C, and not only between [round] and the two vowels. Hence, autosegmental spreading must be understood to apply exactly as dictated by Articulatory Locality, with spreading in a VCV propagating through the articulatorily contiguous C.

For completeness, consider also the representation shown in (38a) depicting a case of whole consonantal spreading, or long-distance consonantal spreading, as formerly argued to exist in nonconcatenative languages (McCarthy 1979). Its interpretation in terms of overlap is shown in (38b). F represents the Root of the consonant, that is, the totality of consonantal features.
Here we encounter another problem not discussed by Sagey. What does it mean for a consonant to overlap with a vowel? It means that the consonant is superimposed on the vowel, a configuration which is certainly impossible for the grammar of any language. Hence, pursuing Sagey’s interpretations of autosegmental association forces us to exclude consonantal spreading skipping a vowel, exactly as Articulatory Locality requires. Chapter 3 presents among other things a reanalysis of this type of spreading.

The representation in (38a) is also the usual representation of spreading in consonant harmony, with the only difference being that here F corresponds not to the Root of the consonant, but to some consonantal feature which is subject to spreading (Shaw 1991). The interpretation of that representation in terms of overlap, as shown in (38b), is then that the feature F overlaps with the intervening vowel. Again, this is precisely what Articulatory Locality requires (see chapters 4 and 5 for detailed discussion).

7. SUMMARY AND CONCLUSION
Reviewing the basic articulatory events in VCV and CVC sequences, I have argued that there is a fundamental asymmetry between vowel and consonant gestures. In a VCV sequence, the two vowel gestures are articulatorily contiguous. In a CVC sequence, the two consonantal gestures are not contiguous. I have proposed that this asymmetry, which I call V-to-V contiguity versus no C-to-C contiguity, plays a fundamental role in the phonology of languages.

In particular, I have put forth the Articulatory Locality thesis, which claims that assimilations respect articulatory contiguity. I have examined three distinct sources of evidence bearing on the correctness of Articulatory Locality: electromyographic patterns, articulatory patterns, and cross-linguistic sound patterns. I have argued that each type of
evidence supports Articulatory Locality. The following chapters develop the details of these arguments and pursue the implications of Articulatory Locality for different areas of sound structure. The next chapter, in particular, deals with the proper characterization of the morpho-phonology of non-concatenative languages.
NOTES

1. There is a difference between /d/ and /g/, in that the actual locus of constriction for /d/ shows much less variation, as a function of the vocalic context, than /g/. See endnote 3.

2. The categorical distinction between vocalic and consonantal gestures is also an assumption of Articulatory Phonology, where two gestural categories, V and C, are recognized. As Browman & Goldstein write, “consonantal gestures typically have a greater degree of constriction and a shorter time constant (higher stiffness) than vocalic gestures” (Browman & Goldstein 1992a: p. 164). See also Fujimura (1992).

3. As Stevens (1990) points out, different consonants exhibit different degrees of precision in the formation of their constrictions. For example, the tongue position of a velar stop at the point of contact can vary between 1-2 cm without influencing perception. In the case of alveolar stops, however, the position of the point of the contact of the tongue tip with the alveolar region can vary only by a few millimeters while maintaining the appropriate acoustic property. This does not affect the point made in the text. The crucial property is existence of constriction in the case of consonants versus lack of constriction in the case of vowels.

4. I use quotes because various other terms have been used to describe the distinction between the two variants of these consonants in the literature (velarized, dorsal etc.). The point is that the distinction involves two different positionings of the tongue body.

5. Recasens (1984) also confirms Öhman's predictions for Catalan, showing that consonants with more tongue body involvement exhibit less V-to-V coarticulation across them.

6. For a discussion of possible phonological consequences, especially concerning the phenomenon of compensatory lengthening, see Fowler (1983), Browman & Goldstein (1988), Smith (1991), Munhall et al.
7. See Fowler (1983) on a hypothesis about how listeners perceive rhythm based on this assumption.

8. The same intrusion of the vocalic nucleus is observed in the developments of coda consonantism of Proto-Slavic CVL(C) syllables. South, Central, and certain Western Slavic dialects shift the liquid L leftwards, giving CLV(C). Eastern Slavic CVL(C) syllables, in contrast, develop to CVLV(C), where the two vowels are identical. The explanation given in the text for the breakup of onset clusters can be extended straightforwardly to these cases as well (Steriade 1990).

9. Spreading of rounding in Turkish vowel harmony also requires that the assimilating vowels all be [+high]. This condition can be safely ignored in the following discussion.

10. For the purposes of the present discussion let us put aside the apparent skipping (or transparency) of certain consonants, and concentrate on the skipping of vowels. Both will be discussed at length in chapter 5.

11. Note that there is a descriptive difference between long-distance consonantal spreading and reduplication: the former creates copies of isolated segments, while the latter seems to create copies of multiple segments. This difference, as will be discussed in chapter 3, follows from independent factors, which will ultimately provide further evidence for the correctness of the proposed reduction of long-distance spreading to reduplication.

12. Further dependencies in this geometry which are not shown in the representation are: the feature [round] is a dependent of Lab, [anterior], [distributed] are dependents of Cor, and [high], [back] are dependents of Dors.

13. Archangeli & Pulleyblank formally define a notion of 'cross-tier'
ordering that allows them to have a notion of order between a feature and an anchor for that feature, such as a Root of a segment in the case at hand. In the context of my discussion, it is not necessary to describe how this is done (see pp. 36 ff.). No accuracy is compromised.


15. Ní Chiosáin & Padgett (1997) is a development of the ideas in Ní Chiosáin & Padgett (1993) and builds partly on the proposals and the results of this dissertation in chapters 3, 4, and 5.