DR. DONALD H. ENLOW on Craniofacial Growth

DR. GOTTLIEB Why is there still great controversy about the role of the condyle in mandibular growth?

DR. ENLOW We've inherited a terminology, based on concepts that were held in the 1930s, that is biologically off-target today. The term "condylar growth" is still often used to imply a kind of transcendental quality—that somewhere in the condyle is this capacity for controlling and regulating mandibular growth, and that the condylar cartilage contains a genetic code that determines the amount, direction, and timing of growth. It is implied that the condyle is responsible for determining the size, shape, and relationships of the mandible. Our understanding of the biologic basis for mandibular growth, however, has changed considerably. The condylar cartilage is no longer regarded as the repository for a genetic blueprint of the mandible as a whole. Rather than representing a "master center" for the control of growth, the condylar cartilage provides a function that's really more important than that.

DR. GOTTLIEB What could be more important than being a master control center?

DR. ENLOW The condylar cartilage provides a capacity for responsive adjustment, for compensatory growth, that makes it possible for the mandible to fit with the basicranium and the maxillary complex. Singling it out as *the* component involved in growth control is bypassing the *really* significant morphologic component that is basic to mandibular growth, and that is the *whole* ramus. The ramus is the site of attachment for the masticatory muscles, which contribute directly to growth pacemaking. The ramus bridges the pharyngeal space to place the lower arch in occlusion with the upper. There is enormous variability in the anatomic pattern of the nasomaxillary region, the mandible, and the basicranium. There are long, narrow faces with relatively close positioning of the right and left glenoid fossae; other individuals have a more rounded head with widely separated glenoid fossae. A great many other regional structural variations exist, and ramus growth, not just condylar growth, must accommodate them. The ramus must grow in whatever direction and to whatever extent is required to provide for a precise horizontal alignment. A significant point to mention is that, while the rami are important *compensatory* structures involved in mandibular adaptations during growth, if the latitude for this adjustive feature is exceeded, a structural misfit can occur. I believe this is a factor that underlies some forms of TMJ distress.

DR. GOTTLIEB And it's the same vertically?

DR. ENLOW Yes. The vertical dimension of the ramus must adjust to the vertical growth of the nasomaxillary complex, which also has a great deal of variability based on headform, sex, and age differences. As the midface grows inferiorly, the ramus elongates correspondingly to continuously position the lower arch. The basicranium and the maxilla undergo changes day by day, month by month, and the condyle and the entire ramus must accommodate and adjust to those growth changes. The tolerance for error is very small. We're dealing with the ramus in three dimensions—the horizontal breadth, the vertical

Dr. Enlow is Chairman, Orthodontic Department, Assistant Dean for Graduate Studies and Research, and Thomas J. Hill Distinguished Professor, Case Western Reserve University, 2123 Abington Road, Cleveland, Ohio 44106.

height, and the right-to-left spread. If the mandibular ramus is just three or four millimeters too wide or too narrow, a corresponding retrusive or protrusive malocclusion can exist. If the ramus is vertically a few millimeters too short or too long, there is a basis for a vertical malocclusion. The point is that it's the *entire* ramus that's involved, not just "condylar growth". In a real sense, the condyle is *following* the developmental circumstances occurring in the remainder of the ramus, not pacemaking them.

DR. GOTTLIEB It seems obvious that the basicranium is also an important architect of jaw development.

DR. ENLOW Many features of the face are established by the basicranium, because it determines the placement and boundaries for the nasomaxillary complex. The anterior cranial fossae determine the P-A length of the nasal chambers and the width of the nasomaxillary part of the face. The middle cranial fossae determine bicondylar and pharyngeal width. Head form, thus, is very important. If the morphology of the mandible were preordained, with control by the condylar cartilage as a "master center" of growth, and if that condylar cartilage were genetically programmed to create a mandible without regard to the rest of the face and the basicranium, there's no way that the mandible of a given individual would fit. Everybody would have severe skeletal malocclusions. The condylar cartilage, however, has the potential for *response* to all the variable circumstances. It provides *adaptive* growth for that regional part of the mandible, leading to the best compromise fit of the lower jaw to the upper jaw and the basicranium. The mandible is not an independent, self-contained, isolated growth unit without a feedback relationship with the rest of the skull.

DR. GOTTLIEB What is the condylar growth mechanism?

DR. ENLOW As everybody knows, there are two general kinds of bone growth—endochondral and intramembranous. Wherever a bone is subject to extrinsic tension, intramembranous growth is operative, because the covering connective tissue membrane (periosteum) is vascular and structurally adapted to a tension kind of relationship. Wherever a surface pressure relationship occurs, an intramembranous mode of growth wouldn't work if the compressive force exceeds capillary pressure, because it would close out the vascular plexus. Therefore, in locations that involve a surface pressure, the endochondral mode of growth occurs. Cartilage is avascular and has the capacity to grow and to function without a vascular membrane. The condylar cartilage provides growth for that part of the mandible where a periosteal membrane could not, and this is why cartilage is present, not because it is some kind of pangenic "center" that somehow controls the whole growth process. Condylar growth is no more or less important than the growth of the coronoid process, the gonial region, the basal bone, the various tuberosities, or the alveolar bone. It's a morphologic and morphogenic adaptation to a regional circumstance—no more, no less.

DR. GOTTLIEB Granted that emphasis on "condylar growth" is really a misconception, what *is* the magic of mandibular growth?

DR. ENLOW It relates to *all* the contiguous tissues—masticatory muscles, hyoid musculature, pharyngeal musculature, tongue, oral mucosa, teeth, tonsils, adenoids, the airway, the nasal mucosa, the whole nasomaxillary complex, the basicranium, all of the major and minor salivary glands, and so on. Since the mandible is attached to the connective tissue stroma of the composite of all these parts, it is *displaced* anteroinferiorly together with their expansive changes and functional actions. At the same time, this same process activates the osteogenic membranes and cartilages throughout the ramus and corpus to provide for remodeling and adjustments in all regional

dimensions. The growth and the functioning of the muscles, etc., provide the signals and triggers to the osteogenic tissues—membranes in areas of tension, cartilage in areas of pressure; and this differentially activates their chondrogenic, osteoblastic, and osteoclastic components. The remodeling responses adjust the shape and the proportionate size of the mandible (and the other bones) to accommodate the growth and the altered functions of the soft tissues. In brief, the enlargement of the muscles, brain, salivary glands, mucosae, etc., produce the *displacement* of the mandible. As this occurs, the growth and functioning of all of them stimulate and pace the *remodeling* and enlargement of the mandible.

DR. GOTTLIEB Are we being held back by the way we measure the growth of the mandible? For example, from condylion to gnathion?
DR. ENLOW Virtually any measurement can be valid when it is used in proper biologic perspective and does not violate a biologic principle. In your example, if that plane is compared before and after treatment and found to decrease, the conclusion is that "condylar growth" was inhibited and that there was a decrease in overall length of the mandible. Actually, the effect could be a remodeling alteration in the alignment of the ramus relative to the corpus as the ramus responds to the altered functional environment. The ramus can increase in vertical length, but the overall dimension from the condyle to the chin can be less, due to the alignment change.

DR. GOTTLIEB How do orthodontic forces affect the growth of the ramus in the anteroposterior direction?
DR. ENLOW First of all, the ramus doesn't remodel itself. It's done by the composite of tissues that relate to it functionally. The actions and growth of those tissues give signals to the periosteum, the endosteum, and the condylar cartilages, which, in turn, carry out ramus growth, remodeling, and adjustments of the *whole* ramus. *All* parts of the ramus are involved. This is a very complex three-dimensional process. Now, if there is a mesial placement of the entire mandible using some appliance, the trajectories of muscle alignment have been altered and the whole physiologic environment has been changed. In addition, there is altered biomechanical alignment of all the connective tissues—that is, the collagenous fibers of the periosteum, the TMJ, the meniscus, the various ligaments, and all of the pharyngeal and oral soft tissues. There's a realignment of the mandibular artery and mandibular nerve. Everything's been changed by virtue of altered mandibular placement. The mandible, as well as the soft tissues and other skeletal parts, begins to grow differently to accommodate the new interrelationships. In a period of time you've got a new ramus, and many other collateral changes as well. It's apparent that there's much more to the story than merely "stimulating condylar growth".

DR. GOTTLIEB What is happening when the jaw is positioned forward and open with a functional appliance?
DR. ENLOW A widespread series of interrelated responses throughout the face and cranium is involved. The ramus itself is quite sensitive to the morphologic, biomechanical, and functional environment relating to it. By an alteration of this environment, there are corresponding remodeling adjustments within the various connective tissues, muscles, and other tissues and organs. This gives information signals that activate corresponding remodeling activities of the membranes and cartilages of the ramus. The ramus then grows into the new, altered position, and it remodels to accommodate altered vectors of muscle and other soft tissue actions. A new ramus is produced that is, say, longer, wider, and with a different alignment relationship; and its magnitude and directions of future growth have been changed. However, unless other parts of the craniofacial complex have also

remodeled in such a way that a composite equilibrium exists, some rebound somewhere is possible.

DR. GOTTLIEB What is the fossa doing meantime in response to a functional appliance? Does it remodel forward?
DR. ENLOW It will be remodeling in whatever direction and amount will be consistent with the functional signals given to its osteogenic and chondrogenic tissues. Whatever the response of the condyle is, the fossae will remodel in a way that should be consistent with it. The potential is relatively constrained, however, because of the fossa's anatomic location.

DR. GOTTLIEB So, you could have a favorable effect from a functional appliance without stimulating growth in condyle, ramus, or corpus?
DR. ENLOW Any significant intervention will likely result in some kind of responsive effect in the magnitude or direction of remodeling, or both, in some part of the mandible. I don't need to tell you that nobody can yet identify all the responses and reactions taking place, and the ranges of variation that are involved. However, let me reemphasize a point. Many still use the term "condylar growth" when contemplating this, which immediately takes us right off the track by obstructing our understanding of the real scope of the biology that is involved. The craniofacial complex is just that—a composite of many regional components, each of which relates to all of the others. If there is an alteration in any one region, it's not likely to be merely a regional response, but there will be many other adjusting reactions elsewhere.

DR. GOTTLIEB Can such things be picked up with conventional cephalometrics?
DR. ENLOW It's very difficult to be able to identify all of these responses utilizing conventional cephalometrics, because most orthodontic planes and angles are not based on actual morphologic actions and reactions—that is, they don't represent actual, key sites of remodeling or growth activity, and they were never so intended. A plane such as sella-nasion or angles such as ANB are not at all sensitive to the underlying *biologic* responses that affect them. Of course, that doesn't mean such planes cannot be utilized to advantage, but the information forthcoming must be evaluated for what it does not reveal as well as for what it does.

DR. GOTTLIEB What, for example, don't they show?
DR. ENLOW Many conventional planes cannot reveal many of the remodeling changes that occur, say, throughout the ramus as a whole. Yet, this is the kind of information *really* needed if we are to understand how, for example, a functional regulator works. Also, one of the hazards in cephalometric interpretations is appraising some dimension without taking into account the effect of a rotation of that part, because a rotational realignment increases or reduces the anatomic effect of the actual dimension.

DR. GOTTLIEB Do changes in flexure occur with normal growth, or do we see them primarily as a result of orthodontic interference?
DR. ENLOW Both, and many examples exist. *Compensations* are a fundamental component of the growth process. Growth itself is an ongoing series of give-and-take adjustments throughout all the regional areas of the whole head, including all soft and hard tissue parts. Many specific morphogenic areas are actively concerned in a number of specific ways. The ramus is an active site of adjustment, as I've tried to explain. Another such area is the palate, which undergoes rotational remodeling compensations to adjust for displacement rotations of the entire maxilla during growth. Another is the vertical and horizontal positioning of the maxillary and mandibular dentition itself. A curve of Spee is the developmental

product of alveolar remodeling in the positioning of teeth. The teeth themselves can't remodel; this is a function of the alveolar bone and its osteogenic membranes.

DR. GOTTLIEB From what you have said, the ramus does not have a given pattern and does not continue to grow in accordance with that pattern.

DR. ENLOW The ramus undergoes fundamental changes in alignment and proportions during childhood growth. As the nasal and oral parts of the midface, the middle cranial fossa, the temporal lobe of the cerebrum, the anterior cranial fossa, the frontal lobe of the cerebrum, and the pharynx all continue to develop, the "problem" encountered by the ramus is to match them in amount and timing, vertically and horizontally. The frontal lobe grows early and very rapidly, but slows sooner than the temporal lobe, which continues to enlarge for a number of years. This means that horizontal growth of the anterior cranial fossa has a differential growth timing and velocity compared to the middle cranial fossa. The vertical growth of the nasomaxillary compartment relates to overall body size. As the entire body grows, lung size increases and the airway correspondingly expands. However, the differential timing in the vertical growth of the nasal region is quite different from the horizontal growth of the anterior cranial fossa, which in turn is quite different from the growth of the pharyngeal space and the temporal lobe of the cerebrum. Well, the ramus is computer-like. The osteogenic membranes and cartilages of the ramus receive this diverse information from all of these other cranial and facial parts, and remodeling is provided that leads to the best compromise fitting for the mandibular arch relative to the maxillary arch—by adjusting the vertical height of the ramus relative to the height of the nasal and oral regions, the horizontal breadth of the ramus relative to the pharyngeal space, and the angular relationship of the ramus relative to the corpus. Thus, there is a constantly changing process of adaptive response in the growth of the ramus, and this is paced by the composite of the musculature anchored to the ramus, the architectonics of the airway, the dimensions and configuration of the basicranium, the height of the nasal region, the size of the eyeballs, the dimensions of the teeth, the size and actions of the tongue, lip seal, activity of the mentalis muscle and the hyoid musculature, the adenoids and tonsils—all giving information to the membranes and cartilages that produce the growth and adjustments of the ramus. In the meantime, the various osteogenic tissues of the maxilla are producing their own regional, adaptive growth changes. Everything is enlarging and developing in conjunction with everything else in such a way that there's an adjustive give and take among all the regional parts. The developmental "problems" encountered by the mandible, and especially the ramus, are indeed most complex; the result is always some degree of compromised fitting.

DR. GOTTLIEB As far as the timing of the growth of the various parts is concerned, you have said the maxilla grows backward, but is translated forward faster than the mandible is either growing or being positioned forward; so that you have a Class II skeletal relationship early on, but normally the mandible will catch up.

DR. ENLOW The reason is that the growth of the frontal lobes of the cerebrum is precocious, and the anterior cranial fossa is the template that establishes the basic dimensions of the maxilla. Because the basicranium is precocious, the forward displacement movement and certain horizontal dimensions of the nasomaxillary complex develop earlier and to a greater extent than the mandible. The relationship of the mandibular ramus is specifically with the middle cranial fossa and pharynx, all of which continue to grow for

several years after anterior cranial fossa growth and resultant forward maxillary displacement have slowed and ceased. Also, the mandible is a separate bone associated with the hyoid musculature, the muscles of mastication, and other growth circumstances quite different from the maxilla. The composite result is a natural tendency for an early mandibular retrusive relationship even in a normal occlusion.

DR. GOTTLIEB Can cuspation interfere with the catching-up process?
DR. ENLOW Cusp interference can fire sensory nerve endings in the periodontal membrane, and this will be relayed to the motor nerves for the muscles of mastication. In response, the cartilages and osteogenic membranes of the ramus can alter ramus growth and remodeling to adapt the morphology and fitting of the ramus to help accommodate the occlusal interference. This is another example of the adaptive capacity of the ramus. But here again, the morphologic result is likely to be compromised because of the architectonic complexity involved.

DR. GOTTLIEB What would cause a person not to catch up, to develop a Class II?
DR. ENLOW Many things, of course. The problem is for all of us to appreciate that there *are* so many different factors involved, and to understand the specific anatomic and developmental effects that different orthodontic procedures have on morphology and morphogenesis, and the seemingly subtle but quite significant anatomic variations that exist.

DR. GOTTLIEB With all the complexities that the growth process involves, is it extraordinary that anyone is Class I?
DR. ENLOW First of all, an anatomically separate "Class I" group doesn't exist as such. Any given Class I individual is a mix of more-or-less offsetting retrusive- and protrusive-causing regional anatomic factors throughout the face and cranium. There is a spectrum of malocclusions from extreme Class III, in which almost all the underlying regional anatomic features contribute to mandibular protrusion, to extreme Class II, in which nearly everything sets up mandibular retrusion. In between the extremes are variable combinations that include the "Class Is" and less severe Class IIs and IIIs. In most individuals, intrinsic adaptations—the changeable height and breadth of the ramus, the vertical drifting of the anterior versus the posterior teeth, the remodeling of the alveolar region, the alignment of the ramus relative to the corpus, the remodeling of the palate and its alignment and vertical position—all such factors are involved as compensatory adjustments. If the magnitude of responses is adequate, some kind of a "Class I" will be forthcoming, although there may be anterior crowding, which itself is a compensation, since the teeth (unlike bone) don't have the capacity for remodeling. If the latitude for compensation is exceeded, or if the compensatory adjustments are inadequate or precluded, a built-in malocclusion predisposition, which we all have, will then more fully express itelf.

DR. GOTTLIEB Some Class Is become Class IIIs.
DR. ENLOW Variations in configuration of the basicranium, the breadth of the face, the size and the function of the nasal chambers and other airway parts, the relationship of the nasopharynx to the middle cranial fossa, and a great many other such relationships set up the positioning of the lower jaw relative to the upper jaw in different ways in different individuals. Thus, there are Class I individuals who have a number of these regional anatomic relationships that are more on the Class II side, and others more on the Class III side. If a given orthodontic procedure is carried out on two children—one with this intrinsic combination toward mandibular protrusion, the other toward retrusion—the results can be quite dif-

ferent. However, these underlying anatomic variations are not ordinarily taken into account. I think they should be, because different procedures have different effects on them. Yes, a Class I can become a Class III, without treatment or as a result of it.

DR. GOTTLIEB Why do we never see a Class II malocclusion correct itself?
DR. ENLOW Look earlier in childhood. Virtually all Class I individuals have self-adjusted malocclusions. All of us have built-in tendencies toward mandibular retrusion or protrusion, open bite, etc. This is part of our evolutionary heritage, and it varies widely among different ethnic groups. The normal growth process, as we previously discussed, has adjusting, compensatory actions and reactions, and this begins during fetal development. I've often wondered if the natural intrinsic compensatory processes could be better incorporated in treatment. So many of the changes brought about by surgery or by orthodontics really haven't attempted to utilize these intrinsic adjustments.

DR. GOTTLIEB Well, functional appliances are presumably doing that.
DR. ENLOW Presumably, and this is certainly a noteworthy feature. But any given appliance may or may not be addressing the individualized anatomic and developmental circumstances in a given patient.

DR. GOTTLIEB And this is what's confounding functional appliance clinicians: that they can't predict a response that an individual is going to give them under what seem to be the same conditions with the same appliance.
DR. ENLOW This is because, as we have discussed, the composite of structural and morphogenetic features is different in different individuals. The problem is that, presently, there is no really effective way to determine or recognize all of them. The treatment effects for these different anatomic combinations have, to date, not been worked out. I'm speaking of real anatomy, not routine cephalometrics.

DR. GOTTLIEB Is there any reason for a clinical orthodontist to become discouraged with functional appliances at this point because we can't demonstrate the things that they like to demonstrate—so far, anyway—such as stimulating mandibular growth, condylar growth?
DR. ENLOW You're pulling my chain. That's the superficial approach—trying to determine whether a functional appliance does or does not either "stimulate condylar growth" or inhibit it. As long as that's the level of approach, key answers will not be forthcoming.

DR. GOTTLIEB So the idea is to get to an improved diagnostic approach that will permit you not to waste your time and the people's time and money on a potentially fruitless functional appliance regime, but to try to aim specific appliances and specific appliance effects at specific problems.
DR. ENLOW Beautiful—and not merely a fruitless procedure, as you say, but some inappropriate procedure that can actually have anatomical and developmental effects contrary to those intended.

DR. GOTTLIEB How do you feel about orthodontists using functional appliances?
DR. ENLOW I recognize great opportunity in the use of functional-type appliances, but, of course, we all see the definite need for *much* more fundamental understanding of the true biologic parameters that relate to them. We're attempting to address fundamental issues without having nearly enough of a biologic basis to truly evaluate them.

DR. GOTTLIEB What's needed to do that?
DR. ENLOW I see two needs. First, we will have to unshackle ourselves from nonproductive and obstructive language and biologic

concepts that are obsolete or off-base, and then, investigative methodologies are needed that can provide answers that heretofore were not possible. Conventional methods have largely been nonproductive, and there is need for redirection. Many of the research-type questions that are being asked have yet to ring bells. Much of the actual biologic rationale needed, I think, already exists. The level of required morphogenic and physiologic insight is probably adequate at present, but definitive studies and the methodologies to evaluate them have yet to be formulated.

DR. GOTTLIEB Do you think it will be possible to select a specific functional appliance to treat a specific orthodontic problem?
DR. ENLOW A recent graduate student at Case Western Reserve—Dr. Dennis DiPalma—compared different orthodontic procedures, including headgear and functional appliances, for use in different kinds of anatomical/malocclusion combinations. His finding was that different types of procedures have different growth effects on different individuals having different but specific anatomic patterns. So the answer is "absolutely". This is our fertile future.

DR. GOTTLIEB Can functional appliances do something, and perhaps do it early, that a fixed appliance cannot do or cannot do later?
DR. ENLOW I don't think there's any doubt that they can. But how do you recognize which particular child will or will not respond? And what specific appliance to use? To date, patient selection has taken into account a number of legitimate and fundamental criteria, but there are so many other morphologic variables that have not been considered. Dr. DiPalma identified a number of these, and they should be taken into account in patient selection and diagnosis. I hope that, in the very near future, definite morphologic categories of facial combinations will emerge as they relate to the appropriateness and effectiveness of different appliance systems. Dr. DiPalma demonstrated that a given type of appliance has desirable anatomic effects for some malocclusion patterns, but contrary effects for others. This, I think, is very significant and foreshadows the near-term research and clinical future.

DR. GOTTLIEB Is there a rationale for the very early use of functional appliances?
DR. ENLOW The use of a functional appliance early in development has great theoretical potential *if* key craniofacial circumstances in an individual patient could be determined, and *if* a given appliance could be utilized because it was known to have desirable rather than contradictory effects for those particular craniofacial circumstances. The problem, as I've emphasized, is that conventional cephalometric analysis and diagrams do not fully provide that kind of information at present.

DR. GOTTLIEB What do you think are the requirements of analysis that would really tell us something more about the growth of the head and face than we know now?
DR. ENLOW Simply that it will have to be much more biologically and morphologically targeted than most systems utilized today. Norms and standards based on anatomically superficial criteria also will have to be phased out.

DR. GOTTLIEB Is there good growth and bad growth?
DR. ENLOW Well, no. Growth for any individual is "normal", given the circumstances that exist for that individual. Growth is a process striving toward a state of functional equilibrium, and it is always responsive to the conditions that occur, unless pathology is involved. Most structural dysplasias, of course, are in "equilibrium".

DR. GOTTLIEB Is there anything to the often-used expressions of "horizontal grower" and

"vertical grower"?

DR. ENLOW It's a convenient but morphologically non-specific way to visualize what the mandible is doing in response to the maxillary complex and basicranium, and what all of them are doing together.

DR. GOTTLIEB Is there any validity to the concept that you can make a mandible grow beyond its potential, or that a functional appliance, for example, is permitting a mandible to achieve its potential? Is potential growth involved in this whole concept of what we think we might be doing with a functional appliance or with any other orthodontic means that we use?

DR. ENLOW I can't respond to that in an informative way, because nobody presently has any idea what constitutes full growth potential, genetic or otherwise, or how to determine it. It's a theoretical concept for which we have virtually no hard understanding. The idea, however, is attractive.

DR. GOTTLIEB Is there any potential in using some chemical action to influence isolated areas of growth?

DR. ENLOW Sure. Consider this question: Is the force of an orthodontic appliance the actual force that directly moves a tooth? Or is the orthodontic force serving to fire cell receptors in the periodontal membrane, which, in turn, "chemically" activate contractile elements within the periodontium, and *this* moves the tooth?

DR. GOTTLIEB What are those contractile components?

DR. ENLOW They are special, regionally located populations of fibroblasts within the periodontal connective tissue that are believed to undergo coordinated contractile responses. The resultant mechanical force is exerted on the collagenous fibers within the periodontal membrane and this, in turn, moves the attached tooth. The same process is believed to produce eruption, mesial and vertical drift, and rotation and tipping. The idea is that the source of tooth movement is within the periodontal membrane itself, and this is in response to any variety of intrinsic or extrinsic triggers that activate the process. If this muscle-like contractile tissue, which is a smooth-muscle counterpart, indeed represents the principal tooth movement agent in normal growth and development, and also in orthodontic movements, the process would presumably be subject to pharmacologic control and thus utilized orthodontically.

DR. GOTTLIEB It's easier to see it with regard to tooth movement than with regard to influencing the growth of a bone, such as a mandible.

DR. ENLOW Well, these same contractile connective tissue cells may also be involved in the displacement movements of whole bones. In the forward-downward displacement of the mandible or the maxilla, we ordinarily regard the functional matrix, or something equivalent, as the force that carries the ball. However, there is a considerable amount of connective tissue remodeling taking place within the periosteum itself and at the interface between the muscle and the bone. This remodeling of the stroma accompanies the growth of the muscle tissue anchored to the bone and the remodeling of the underlying bone tissue. There is widespread coordination in the remodeling of the perimysium, endomysium, and epimysium of the muscle in concert with corresponding remodeling throughout the connective tissues of the periodontal membranes, sutures, periosteum, tendons, and ligaments. These connective tissues are sometimes subjugated in our thinking of facial growth. They are actually involved as fundamental-level participants. I think there would be much more to a "chemical" control of, say, the mandible as a whole than just looking for some magic juice that "stimulates condylar growth".

DR. GOTTLIEB What's moving that connective tissue?
DR. ENLOW Other than a possible slight "shrinking" action, the connective tissue fibers themselves don't have the capacity for self-movement. Some force exists that positions the linking and relinking fibers as the bones grow and as the growing muscles migrate over bone surfaces. My hypothetical explanation is that the rich distribution of contractile fibroblasts, which are known to exist where such movements occur, is responsible for this. These cells contain actin and myosin microfilaments and do indeed have contractile capacity. Other fibroblast types are responsible for enzyme productions involved in the degradation and synthesis of old and new collagenous fibers and related proteoglycans. The "myofibroblasts" are responsible for placing the fibers as they become linked and relinked into new bundle combinations. These movements of the connective tissue relate to the growth movements of the bone, muscles, salivary glands, tonsils, nerve bundles, and everything else. Everything is moving and relocating as part of the composite growth process, and the great complex of all the tissues and organs is involved. I think the connective tissues play a fundamental role. This is a tissue that has not been given its due by most of us. It is more than merely "connective".

DR. GOTTLIEB Is there validity to the concept of a growth spurt? Should orthodontists be hitching their wagon to a growth spurt?
DR. ENLOW It seems to me that utilization of a pubertal growth spurt is coming in rather late. All of the underlying anatomic relationships we've been discussing have already largely been established. *If* such relationships are *truly* affected by a treatment procedure, most of the growth action has long since passed, and I have to wonder whether enough still remains to allow, first, any significant amount of underlying anatomic restructuring or, second, region-by-region adjustments among all of the multiple parts presumably involved. If not the latter, then rebound, which is a normal, natural protective process, will attempt to restore the equilibrium established through the years.

DR. GOTTLIEB Some pretty good edgewise orthodontists are saying with regard to early treatment, "I can do the same thing later in a circumscribed period of time without treating people over eight years, and do just as well". But don't Class II mechanics affect the whole craniofacial growth process in some way?
DR. ENLOW I would like to think that this could be true. Otherwise, why should the orthodontist worry about having to understand all about the biology of the growth process? "Working with growth", really exploiting this craniofacial growth process, is a conceptual icon, but looking at pre- and post-treatment headfilms, none of us really knows to what extent or exactly where throughout the head the growth process itself is actually affected. This is worrisome in the extreme.

DR. GOTTLIEB Are so many children Class II because the anterior cranial fossa is growing earlier than the middle cranial fossa and the corpus of the mandible?
DR. ENLOW I think so. We briefly alluded to this before. The earlier growth of the anterior cranial fossa (frontal lobe) relative to the middle cranial fossa (temporal lobe) preprograms an earlier state of maxillary protrusion during normal development. The maxilla becomes displaced anteriorly with its overlying anterior fossa. The ramus of the mandible matches the pharyngeal space, the PA size of which is established by the later-maturing middle cranial fossa, thus leading to differential timing and mandibular "catch-up".

DR. GOTTLIEB The effect might also be because of the alignment and growth direction of the cranial floor.
DR. ENLOW That is another key factor. Class

IIs tend to have a more obtuse (maxillary protrusive) alignment of the middle cranial fossae, which augments the effect. Class IIIs tend to have the converse.

DR. GOTTLIEB An orthodontist is frequently going to see what looks like a growth imbalance at an early age. If everyone whose mandible was behind were to become a candidate for a functional appliance, then maybe we're spinning our wheels if he's going to catch up later.

DR. ENLOW That is indeed a good point, because it highlights a conceptual need. *Much* more needs to be determined than merely whether or not the mandible is retrusive at an early age, as much of our previous conversation shows. All of the underlying, region-by-region morphologic and morphogenic relationships must be taken into account, because *these* are the factors that program a future malocclusion. Let me mention again that I don't believe conventional cephalometrics can provide the kind of information required. Determinations of underlying, truly morphologic relationships are needed.

DR. GOTTLIEB Is there potential harm in taking what seems to be a skeletal Class II early on, which may grow to a correct position if left alone, and placing a functional appliance?

DR. ENLOW This is clearly a red flag, and I worry about the indiscriminate use of potentially powerful appliances, for this and other basic reasons. First, if *regional* changes are introduced, and if collateral adjustments elsewhere in the craniofacial complex are not responsive or are incomplete, developmental imbalances have been created that may not be intrinsically adjusted to the growth process later in childhood. Nobody knows at this point what can happen then. Importantly, also, very little information exists at present as to the actual effects various types of removable appliances have on the different morphologic combinations we've been discussing. *This* is significant. Further, an effective system is badly needed for classifying these morphologic combinations so they can be recognized and specifically identified.

DR. GOTTLIEB This is all information we hope we can get someday?

DR. ENLOW Until this category of information is forthcoming, all the discussion and all the speculation rampant at present merely underscore the need for it. I'm saddened when I hear people arguing the issues in the absence of such factual information and conceptual biologic understanding to justify opinions.

DR. GOTTLIEB Don, I want to thank you on behalf of our readers for giving us these insights into the growth process, and especially into mandibular growth and condylar growth, which are so basic to an undertanding of what is happening to our patients both from normal growth and as a result of our intervention.