the anatomical boundaries of individual bodies) even as she modeled the minds and bodies of her characters anatomically in accordance with post-1839 cell theory, with cells functioning as the atoms of the body (Shepherd, p. 4).

I have already suggested that the distinctively modern spirit of the last couple of centuries is characterized by a perspective at once anatomical and neuraesthetic. Alongside various reductive stances (mechanistic-materialist and vitalist-spiritualist), others have emerged that enable one to conceive of anatomical features, on the one hand, and neuraesthetic experience, on the other, as forming, in Stein's phrasing, "not a contradiction but a combination" (LIA, p. 93). Necessarily tied conceptually to the neuroscience of the day, although sometimes, as in the poetry of Wordsworth and Shelley, foreshadowing the neuroscience of a later era, these stances organize neuraesthetic experience in at least partly anatomical terms, without, however, reducing neuraesthesis to anatomy. Hence the significance of the heart and sense of touch in Sterne; of sight- and sound-based synesthesia in Wordsworth and Shelley; of pulsations in Pater, and connective tissue in Eliot; and, as I shall argue, of the neuron doctrine in Stein. In addition, stances tied to outdated neuroscience continue to thrive long after the scientific basis has been revised away, as in Moers's division between the "fatedness" of anatomy, its fixed nature, and the neuraesthetic "sound inside" which translates so readily into the "many voices of different rhythms, pitches, and timbres." This distinction may have had some scientific basis in Eliot's day, but it can only be read metaphorically today.

How, then, did Stein move from a sense of individual self-division like that expressed in *The Mill on the Floss* and *Middlemarch* (a self-division framed by Eliot in terms of a *social* organicism, that is, a social *organism* in which neuraesthesis and anatomy combine without contradiction) to the autopoietic perspective that informs the experimental writing of Stein's middle period? Or, to rephrase the question somewhat: How did compositions like *Tender Buttons* and "Old and Old" emerge from the same hand that penned "Melanctha" just seven years earlier, a work that at once allegorizes and literalizes the antinomy experienced by Maggie Tulliver between anatomy and neuraesthesis? Maggie, who "direct[s] her walk to the Red Deeps . . . on the first day she [is] free to wander at her will—a pleasure she loved so well, that sometimes, in her ardours of renunciation, she thought she ought to deny herself the frequent indulgence in it"; Melanctha, who, initially "wander[ing] on the edge of wisdom," "come[s] to see very clear . . . what it is that gives the world its wisdom" and begins to "wander very widely," wanting "something that would move her very deeply, something

that would fill her fully with the wisdom that was planted now within her, and that she wanted badly, should really wholly fill her" (*Mill on the Floss*, p. 275; TL, pp. 70, 73, 76). In Stein's more radically experimental writing, neuraesthetic experience (the "expanded interval" of Pater's "individual in his isolation") continues to be viewed as a function of anatomy; yet instead of anatomy proving to be fate, so much food for the cemetery, it is reconceived as a function, in its own turn, of physiological processes, and hence of life. At the close of the nineteenth century and the beginning of the twentieth, Johns Hopkins neuroanatomy offered the young writer-to-be a vigorous new scientific account of this Wordsworthian sense of anatomy as a function of physiology (as, in effect, a function of biological functioning), an account nonetheless at odds with the biases built into the very instruments being used to investigate it.

THE NEW BIOLOGY

In 1924, Mina Loy compared Stein to Marie Curie in the verse epigraph that headed her ten-page missive to *the transatlantic review* on the subject of Stein and modern letters:

> Curie
> of the laboratory
> of vocabulary
> she crushed
> the tonnage
> of consciousness
> congealed to phrases
> to extract
> a radium of the word (p. 305)

Hence Stein as chemist. More often, Stein's writing has been likened to the New Physics, a connection she herself made "on the inside cover of a notebook for 'Sentences' (1929)," where, according to Ulla Dydo, she "played with two words—two names—or perhaps it is one: 'Caesar Onestone / Mr. Einesteine.'" "No time, no space, no center, standard, or authority," Dydo remarks. "Stein wrote in a world changed by Einstein and even more by Heisenberg and Schrödinger. She knew she was one of them, constructing for words what they had constructed for quantum mechanics." Dorothy Dudley Harvey, writing to Stein in 1928, compared her to the new physicists described by Bertrand Russell. "Nowadays," Russell suggested in the *Saturday Review of Literature*, "physicists, the most hard-headed of mankind . . .

have embodied in their technique this insubstantiality which some of the metaphysicians have so long urged in vain." "In connection with grammar," Harvey proposed, "I thought at once of you, and wondered, knowing little about them, if you have not been one of the metaphysicians as an artist, with whom the physicists have just caught up" (SR, pp. 2–3). Hence Stein as physicist.

Yet correspondences like these are only persuasive to the extent that the sciences in question posit a world that operates in terms of organicist principles—on the basis, that is, of what Whitehead called "organic mechanisms." Jacques Loeb (who taught the physiology seminar at Woods Hole the summer Stein attended the embryology seminar) may have sought to reduce biology to the mechanical operations of classical physics, but several decades later Whitehead would provide the New Physics with a theoretical basis in organicist, and hence biological, processes. A broad distinction may nonetheless be drawn between the biological and the physical (that is, physics-derived) sciences on the basis of the relative adequacy of mechanical or computational explanations to account for purely physical phenomena by contrast with biological phenomena. Donna Haraway and Evelyn Fox Keller have argued that biology in the twentieth century has itself alternated between frameworks that subordinate it to physics and others that represent it as an area of study (and, by extension, a domain of reality) distinct from although not entirely divorced from physics. Haraway thus demonstrates in *Crystals, Fabrics, and Fields* that in the 1930s, while Stein was lecturing on "lively words" and being subjected to textbook diagnoses by psychologist and physician alike, developmental biologists like Ross Harrison, Joseph Needham, and Paul Weiss were conducting embryological and morphogenetic studies on the basis of a model of "nonvitalist organicism" irreducible to the inorganic mechanisms of physical science. (This model was derived in large part from the "philosophy of organism" articulated by Whitehead the previous decade.) More recently, in *Refiguring Life*, Keller has described the rise in the aftermath of World War II of a reductionist frame of analysis within biology, and in particular in molecular biology, as well as subsequent challenges to this genetics-centered perspective that have accompanied a renewed interest in developmental biology. Even so, important recent studies of the influence of scientific doctrine on modern literature by Gillian Beer (*Open Fields: Science in Cultural Encounter*), Daniel Albright (*Quantum Poetics: Yeats, Pound, Eliot, and the Science of Modernism*), and Ira Livingston (*Arrow of Chaos: Romanticism and Postmodernity*) concur, despite great differences among them, in mapping modern literature along coordinates derived chiefly from the New Physics,

whether in terms of late nineteenth-century wave theory, or the quantum theory contemporaneous with Stein, or the physics-inflected chaos theory of our own day. In this context Stein's extensive exposure to the New Biology offers an invaluable opportunity to consider the influence on literature of modern *biological* theory, with its distinctive experimental praxis, as well as the related question of the extent to which literature may be regarded as an appropriate, and perhaps inevitable, domain for physiologically based scientific experimentation.

Stein moved from Radcliffe to Johns Hopkins in order to acquire the hands-on physiological training that James deemed necessary for further study in psychology.[19] At Johns Hopkins she was soon working in the Anatomical Laboratory with the great anatomist and embryologist Franklin Mall. "She delighted in Doctor Mall, professor of anatomy, who directed her work," she recalled thirty-five years later, and "always quotes his answer to any student excusing him or herself for anything. He would look reflective and say, yes that is just like our cook. There is always a reason. She never brings the food to the table hot. In summer of course she can't because it is too hot, in winter of course she can't because it is too cold, yes there is always a reason." Mall also "believed in everybody developing their own technique . . . [and] remarked, nobody teaches anybody anything, at first every student's scalpel is dull and then later every student's scalpel is sharp, and nobody has taught anybody anything" (ABT, p. 81).

The Medical School, which had opened its doors only four years earlier when several Baltimore women contributed half a million dollars on the condition that women be admitted on equal terms with men, was already, as one historian of experimental medicine has put it, "the model institution for new medical science and medical teaching in the United States" (Pickstone, p. 738).[20] In conjunction with "purely mechanical" brain modeling for Mall, Stein also studied the histology of the central nervous system with Mall's assistant, Lewellys Barker.[21] In his influential textbook on *The Nervous System and Its Constituent Neurones*, published in 1899, Barker cited a description by Stein of the appropriately named nucleus of Darkschewitsch, an obscure collection of nerve cells situated near the top of the midbrain (see Figures 2 and 3; also see Figure 8 below).[22]

Just above the oculomotor nucleus, the nucleus of Darkschewitsch serves as one of three accessory oculomotor nuclei, along with the interstitial nucleus of Cajal and the nucleus of the posterior commissure.[23] (The oculomotor nucleus derives its name from its key role in eye movement, as well as in covert changes in visual attention, and it appears that the nucleus of Darkschewitsch, like the other accessory nuclei, has a related function,

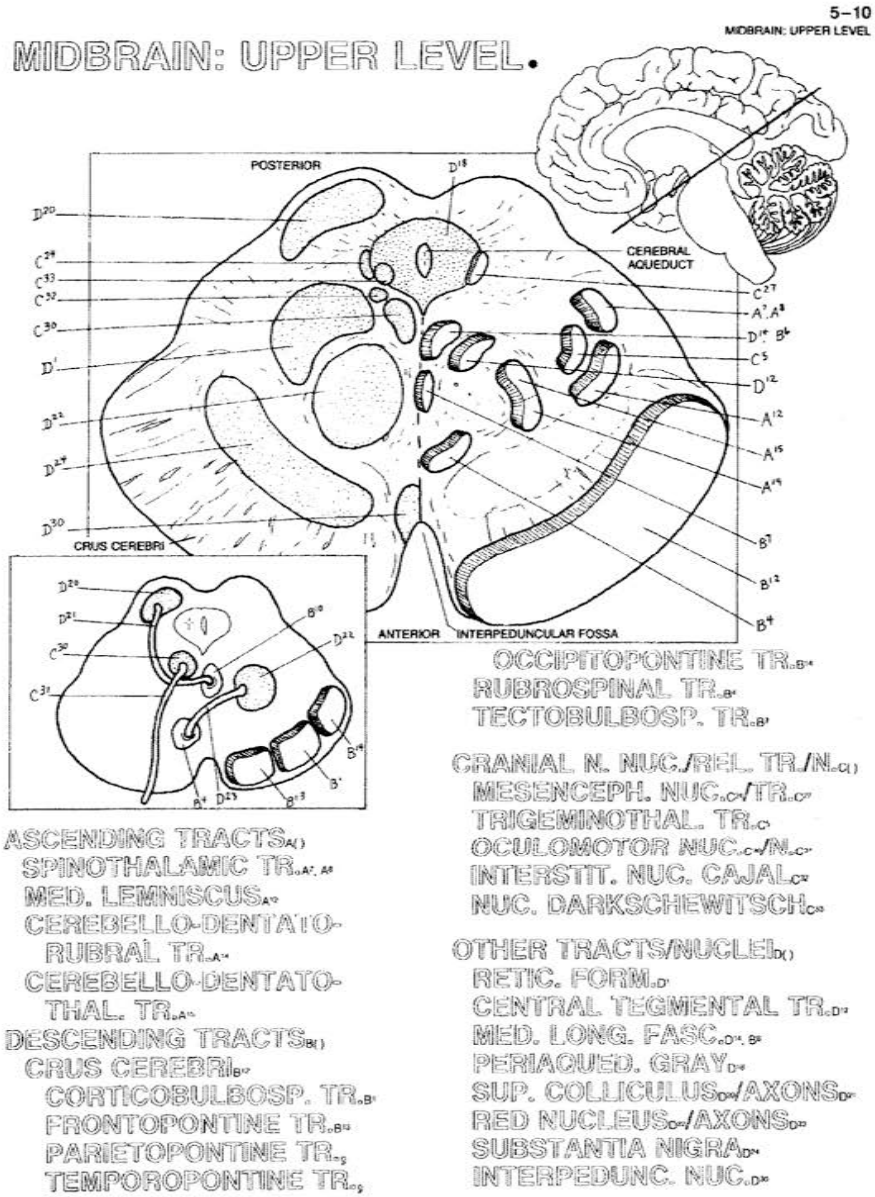

Figure 2. Midbrain, upper level, with nucleus of Darkschewitsch indicated ("c33"). (From Diamond, Scheibel, and Elson, *The Human Brain Coloring Book*, Plate 5-10. © 1985 Coloring Concepts, Inc. Reprinted by permission of HarperCollins Publishers, Inc.)

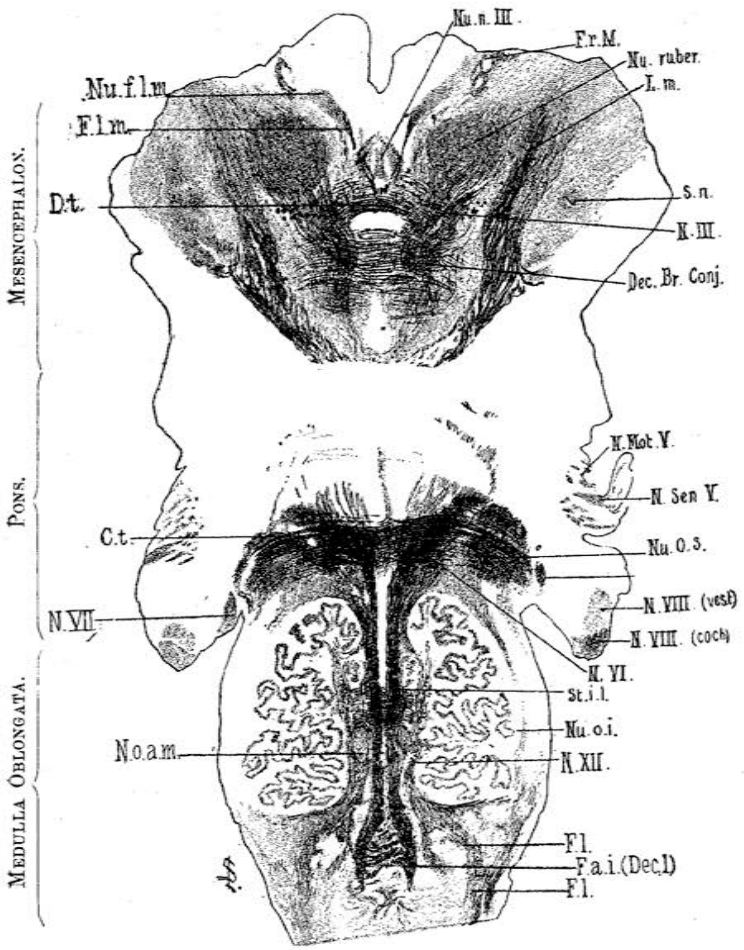

FIG. 462.—Horizontal section through the medulla, pons, and midbrain of newborn babe. Level of stratum interolivare lemnisci, corpus trapezoideum and nucleus ruber. Weigert-Pal staining. (Series iii, section No. 136.) *C.t.*, corpus trapezoideum; *Dec.Br.Conj.*, decussatio brachii conjunctivi; *D.t.*, decussatio tegmenti ventralis (ventral tegmental decussation of Forel); *F.a.i.(Dec.l.)*, fibræ arcuatæ internæ (decussatio lemniscorum); *F.l.*, fibres continuous with the funiculus lateralis of the spinal cord; *F.l.m.*, fasciculus longitudinalis medialis; *F.r.M.*, fasciculus retroflexus Meynerti; *L.m.*, lemniscus medialis; *N.III.*, radix N. oculomotorii; *N.Mot.V.*, motor root of N. trigeminus; *N.Sen.V.*, sensory root of N. trigeminus; *N.VIII.(coch.)*. radix N. cochleæ; *N.VIII.(vest.)*, radix N. vestibuli; *N.VI.*, radix N. abducentis; *N.VII.*, radix N. facialis, pars secunda; *N.XII.*, radix N. hypoglossi; *Nu.f.l.m.*, nucleus fasciculi longitudinalis medialis, or nucleus commissuræ posterioris (*oberer Oculomotoriuskern* of Darkschewitsch); *Nu.n.III.*, nucleus N. oculomotorii; *Nu.o.a.m.*, nucleus olivaris accessorius medialis; *Nu.o.i.*, nucleus olivaris inferior; *Nu.o.s.*, nucleus olivaris superior; *Nu.ruber*, nucleus ruber; *St.i.l.*, stratum interolivare lemnisci; *S.n.*, substantia nigra. (Preparation by Dr. John Hewetson.)

Figure 3. Horizontal section through the medulla, pons and midbrain, with nucleus of Darkschewitsch indicated ("Nu.f.l.m."). (From Barker, *The Nervous System and Its Constituent Neurones*, p. 723.)

although there is still considerable uncertainty as to its precise function.) "Peculiarly puzzling," Barker observed, are "the relations of the fasciculus longitudinalis medialis at its anterior extremity. . . . One has only to read the descriptions in the various text-books and in the original articles dealing with this topic to appreciate the confusion which exists with regard to it." "Especially conflicting," he added, "are the views which have been held concerning the relations to the nucleus of Darkschewitsch," which is adjacent to the fibers of origin and termination of the medial longitudinal fasciculus. "I shall restrict myself, therefore, in the main, to a mere statement of the results of my own studies, and of those of Miss Sabin and Miss Stein, who have especially studied this region" (p. 721).[24]

Definitions of several terms of direction should prove helpful in following Stein's description: "The back of the brain and spinal cord is *posterior*. In the case of the brain stem and spinal cord (as well as the body in general), the term *dorsal* is used synonymously with *posterior*. . . . The front of the brain and spinal cord is *anterior* . . . [and] the term *ventral* is used synonymously." In addition, "when comparing two structures, the structure closer to the midline is said to be *medial* to the other, which is *lateral*," whereas "the terms *proximal* and *distal* refer to relative distances from a reference point, proximal being closer and distal being farther" (Diamond, Plate 1–5). Here, then, is the passage from *The Nervous System and Its Constituent Neurones*:

> Miss Gertrude Stein, who is now studying a series of sagittal sections through this region from the brain of a babe a few weeks old, describes the nucleus of Darkschewitsch as follows: "The nucleus is more or less conical in shape. It lies dorso-medial from the red nucleus, being about as thick in a dorso-ventrical direction as is the dorsal capsule of the red nucleus in which it lies. At this period of medullation [or *myelinization* as the process is more commonly known—the layering around axons of the fatty substance myelin, which serves to increase the rate at which impulses travel] the commissura posterior cerebri, considered simply topographically (that is, as a medullated fibre-mass without particular reference to the course of the fibres), appears as a dorso-ventral bundle, solid in the middle, subdivided dorsally into an anterior (proximal) portion and a posterior (distal) portion, while ventrally it expands in the form of a hollow pyramid, which rests directly upon the nucleus of Darkschewitsch." As to the bundle of fibres described above as being situated ventral to the nucleus, and passing forward and ventralward, Miss Stein in the brain she is studying can follow the fibres only as far as the fasciculus retroflexus. (pp. 725–26)[25]

Forty years later in his autobiography, Barker recalled Stein as having been among the first batch of medical students to whom he taught "modern neurological histology," or the neuroanatomical structure of animal and plant tissue, and acknowledged that he had "often wondered whether my attempts to teach her the intricacies of the medulla oblongata had anything to do with the development of the strange literary forms with which she was later to perplex the world" (*Time and the Physician*, p. 60).

At the outset of *The Principles of Psychology*, James had provided a summary of the "nerve-physiology" with which his reader needed to be acquainted in order to follow the work's general argument concerning the physiological basis of psychology. The principal difference between James's understanding of neurophysiology at the beginning of the decade and the instruction Stein received first at Radcliffe and then at Johns Hopkins, as the decade wore on, stems from the articulation in 1891 of what has come to be known as "the neuron doctrine," which amounts to the claim, as Shepherd has characterized it, that "the nerve cell is the anatomical, physiological, metabolic, and genetic unit of the nervous system" (p. 4).[26] The difference that this assertion makes can be summed up as follows: Before 1891 it was intellectually respectable for a neuroanatomist to argue for the reticular theory of neural organization, that is, for the existence of a continuous network of branches connecting nerve cells. After 1891, it was widely recognized that nerve cells, like all other types of cells, are discontinuous from one another. As Barker put it in *The Nervous System and Its Constituent Neurones*, a work in which, as he subsequently observed, "for the first time, the conduction paths of the central and peripheral nervous system were comprehensively and systematically described from the standpoint of the neurone doctrine": Nerve branches "often enter into close proximity to other nerve cells . . . but nowhere could any evidence . . . be found of actual union." "The interrelations of the nerve elements," he concluded, depend "entirely upon contact or contiguity, not upon organic connection" (*Time and the Physician*, p. 61; NS, p. 22).

Furthermore, in 1897, the year Stein entered medical school, the English neurophysiologist Charles Sherrington introduced the concept of the synapse as "an anatomical and functional explanation for the mechanism by which the individual neuronal units could communicate with each other" (Shepherd, p. 5). Hence Stein, in her first two years at Johns Hopkins, much of the time spent conducting laboratory research, found herself in the midst of a paradigm shift if ever there was one. The crucial thing to note here is that in taking neurons, as described by the neuron doctrine, as paradigmatic of organic life (and thereby presuming that nerve cells, like other cells, don't form "actual unions," or organic unities, but are only exceptional in that they "do something very different from other cells of the body," namely, they

"process information"), it becomes necessary to reconceive organicism as a function of contact or contiguity, rather than of organic connection (Shepherd, p. 292). It was this perspective that Stein brought to her experimental writing, although it didn't come fully into play until a decade after she left medical school, when she began writing her "studies in description." Here is "A Long Dress," from the "Objects" section of *Tender Buttons*:

> What is the current that makes machinery, that makes it crackle, what is the current that presents a long line and a necessary waist. What is this current.
>
> What is the wind, what is it.
>
> Where is the serene length, it is there and a dark place is not a dark place, only a white and red are black, only a yellow and green are blue, a pink is scarlet, a bow is every color. A line distinguishes it. A line just distinguishes it. (TB, p. 17)

Writing like this might be characterized, in properly radical empiricist fashion, as *studies of exchanges at word junctions and across word membranes*, designed *to show the ways in which words join together into functional multi-word units*.

In describing "A Long Dress" in this way, as a collection of words that functions after the manner of a collection of neurons in the brain, I have actually appropriated Jane Maienschein's characterization of biological research of the last half-century on cellular organization, merely substituting the term *word* for *cell*. "The most serious weakness of the cell theory," Maienschein writes,

> is its inability in itself to explain cell-to-cell interaction or [the] organisation of many cells. . . . Especially since the Second World War[,] . . . studies of exchanges at cell junctions and across cell membranes have begun to show the ways in which cells join together into functional multi-cellular units. ("Cell Theory," p. 370)

However, I could just as well have cited Stein directly, in remarks concerning the composition of *Tender Buttons* which she made in an interview shortly before her death in 1946. "I took individual words," she noted,

> and thought about them until I got their weight and volume complete and put them next to another word, and at this same time I found out very soon that there is no such thing as putting them together without sense. I made innumerable efforts to make words write without sense and found it impossible. Any human being putting down words had to make sense out of them. (TI, p. 18)

Half a century earlier, in *The Principles of Psychology*, James had already observed that "*subjectively*, any collocation of words may make sense—even the wildest words in a dream—if one only does not doubt their belonging together." Yet Stein is not concerned here with the "feeling of rationality" that one may experience while writing (or reading) what is, objectively speaking, sheer nonsense. Because she isn't seeking rational or "abstract" knowledge in the first place, she doesn't *fail* to abstract her thought processes from her compositional practices, as occurs with rational-seeming nonsense like James's example of a 784-page "volume . . . lately published in Boston" entitled "*Substantialism; Or, Philosophy of Knowledge*, by 'Jean Story.'"

This work, James observes, is entirely "composed of stuff like this passage picked out at random":

> The flow of the efferent fluids of all these vessels from their outlets at the terminal loop of each culminate link on the surface of the nuclear organism is continuous as their respective atmospheric fruitage up to the altitudinal limit of their expansibility, whence, when atmosphered by like but coalescing essences from higher altitudes,—those sensibly expressed as the essential qualities of external forms,—they descend and become assimilated by the afferents of the nuclear organism.

"Take the obscurer passages in Hegel," James continues, "it is a fair question whether the rationality included in them be anything more than the fact that the words all belong to a common vocabulary, and are strung together on a scheme of predication and relation,—immediacy, self-relation, and what not,—which has habitually recurred." Even so, he adds, "there seems no reason to doubt that the subjective feeling of the rationality of these sentences was strong in the writer as he penned them, or even that some readers by straining may have reproduced it in themselves" (PR, pp. 254–55).[27] By contrast, Stein is thinking autopoietically, and neuraesthetically, in the course of "thinking about" the relations that emerge when the words are "join[ed] together in functional multi-word units." Hence in compositions like "A Long Dress," as she observed in 1928, she "correlated sight, sound and sense," attempting, as she was already proposing four years earlier, to achieve "completed composition . . . through the study of the relation of words in meaning sound and volume."[28] This sense of the *volume* of words, reiterated more than twenty years later, suggests that she conceived of words, like cells, as existing in three-dimensional space rather than two-dimensionally on the page or the microscope slide.

Stein's writing practice may thus be viewed as a form of laboratory science, descending, by way of the psychological and anatomical laboratories at Harvard and Johns Hopkins, from the medical laboratory described

several decades earlier by Claude Bernard in his *Introduction to the Study of Experimental Medicine*. In *her* laboratory she experimented with words in an attempt to articulate her sense of their life. For Bernard, the intellectual rigor of physiology treated "as an experimental subject" was based on the possibility of controlled experiments in which "the animal suffers all but the single interference in question, so allowing the experimenter to separate the specific effect from others which the whole procedure may involve." Through "the careful regulation of experimental procedure," the phenomenon in question might "be controlled at will," although such control required both a "determinism of physiological phenomena, in the sense that experimentalists could produce and reproduce them in specified ways," and the relative freedom of these phenomena from external constraints. Bernard accounted for this last feature with his notion of the *milieu intérieur*, or internal milieu, whereby "the constancy of bodily fluids in higher animals" served as a "precondition of their sophisticated functions and their relative independence of external factors such as temperature" (Pickstone, p. 735). Stein, in characterizing her experimental writing in *Tender Buttons* as involving a "conscious struggle with the problem of correlating sight, sound and sense, and eliminating rhythm," and further proposing that "some of the solutions . . . seem to me still alright," clearly regarded her writing as consonant with Bernard's model (TBr, p. 13).

"The role of the [experimental] scientist," Sally Shuttleworth has observed, "was not simply to record and observe, but actively to construct experiments, to bring about, as Bernard observed, 'the appearance of phenomena which doubtless always occur according to natural laws, but in conditions which nature has often not yet achieved' " (p. 22; cited from Bernard, p. 18). The question, of course, is the extent to which Stein's literary experiments are *controlled* in the sense that other experimentalists might "produce or reproduce them in specified ways." Would such reproduction require original experimental writing, or might analysis of Stein's writing in terms of the constraints she set herself, and "the specific effects" she produced, suffice? What about reading in the manner attributed to Toklas in the *Autobiography*? "I always say," one reads / Toklas says / Stein writes, "that you cannot tell what a picture really is or what an object really is until you dust it every day and you cannot tell what a book is until you type it or proof-read it. It then does something to you that only reading never can do." Again: "Correcting proofs is, as I said before, like dusting, you learn the values of the thing as no reading suffices to teach it to you" (pp. 113, 217). In typing or proofreading, the reader experiences a composition as it has already been experienced by the writer, acquiring a sense of it as an

"object," with "weight and volume." The dissociative writing of Stein's middle period differs from ordinary writing (and even from *The Making of Americans*, the immediate subject of these remarks on correcting proof and typing manuscripts) in that works like "A Long Dress" and "Old and Old" and "Mildred's Thoughts" render conventional reading practices self-evidently inadequate to the task at hand. To prevent one's experience of reading from "dwindl[ing] into [the] inaudible hum" which seems to have been Morris Fishbein's experience, certainly not Stein's, the reader is obliged to reproduce the recursive act of reading which, in line with the parameters under investigation, was part and parcel of the original process of writing. Such *experimental reading*, as it were, is not a matter of reductively decoding Stein's writing word for word or phrase for phrase but of neuraesthetically reproducing her "stud[ies] of the relation of words in meaning sound and volume" in ways specified by the compositions themselves. That only some of Stein's experiments may have succeeded ("*some* of the solutions seem to me still alright") does not make them any less scientific; after all, every successful experiment leaves behind it a trail of false turns. "Experimenting," as Stein observed in one of the lectures she gave in Chicago several months after Fishbein's "editorial suggestion," is "trying to do some thing in a way that may produce a result which is a desired result by the person doing it" (N, p. 31). By the same token, in failing to conform to the desired result, the outcome may oblige one to reformulate one's objectives. An apparent failure turns out to have the makings (supposing one to be broad-minded enough, and sufficiently radical an empiricist) of a desired solution, at least at the level of the experiment's parameters if not within the framework delineated by them.

DELIBERATE ERROR

A particularly ignominious failure capped Stein's association with Johns Hopkins, when the faculty decided not to award her a degree despite four years of courses and, as she put it, a "reputation for original scientific work" (ABT, p. 82). Even before Barker's departure for the University of Chicago at the end of the third year, her coursework had begun to slide. The first two years' grades ranged, on a scale of 1 (best) to 4 or lower (failure), from a 1 in anatomy to a 2.5 in physiological chemistry, with a pair of 1.5's in normal histology and in pathology and bacteriology, as well as 2's in physiology and in pharmacology and toxicology. In her third year, by contrast, they dropped almost a full point to a 2 in medicine, a 2.5 in surgery, and three 3's, in clinical microscopy, neurology and obstetrics. Then, her