Everyone Is You... Or Me

Frank Oppenheimer, Exploratorium

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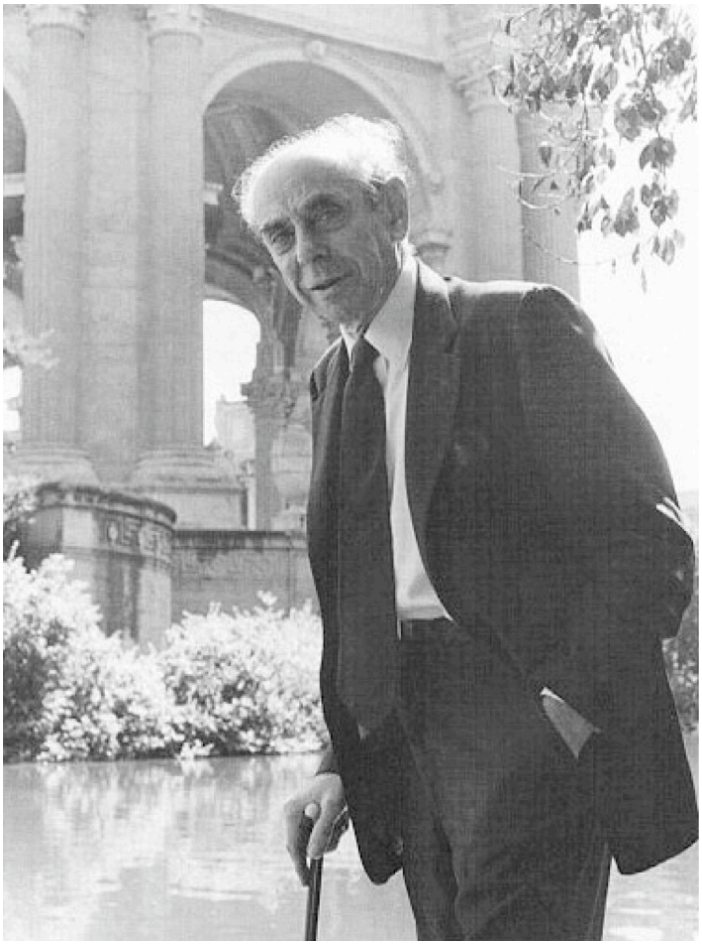
In my youth I used to wander in the mountains. I would gain a "feel" of the terrain and gradually build up a reliable intuition of how to get from here to there and back again. Always, on these expeditions, I would discover special places - a tiny area, the only one, where fairy slippers grew; a pool in a rushing stream that was deep enough to swim in. Invariably I would find myself excitedly climbing some promising knoll or uppermost peak. Suddenly a whole new vista would open up, showing a great expanse of prairie, a hidden lake in some inaccessible canyon, an entire new ridge of peaks.

As a result of these solitary expeditions, I would tell friends what I had found and would want to show it all to them. Somehow it was especially important that they see the view, often at a special time of day - perhaps precisely when the sun was setting. But we would start late or they would be unable to walk as fast as I. I would point to the place where I had found the fairy slippers, but we would walk on by. We would reach the top, and the view would be well worth the effort and the hurry. But gradually I began to realize that there was something wrong with these revisiting expeditions. Although the view far outweighed anything along the way in wondrous and memorable experience, the events along the way had been an integral part of the trip for me, and would also have to be so for the people I wanted to bring pleasure to. If the trip was spoiled through hurry or painful effort, then no one was moved to go searching for views on his own.

When I was teaching physical science to high school students, I felt the same kind of thing happening. The course was certainly an improvement on my mountain expeditions. It cleared the trail, mapped out switchbacks



Frank Oppenheimer, director of the Exploratorium

when the grade was too steep, and built bridges or steps when the terrain was impassable. But for those who built the course and came to know it well, it was crucial to reach the panorama of the final chapters, which put together everything that had gone before and opened up grand new vistas. From the vantage point of Bohr's model of the atom, one could look down and see where one had come from and how different and tiny everything looked down there. One could look out at new terrain that begged for future exploration. But in order to reach the vantage point soon enough, the trip had been spoiled. There was no opportunity to explore unexpected and pleasant nooks along the way.

The Exploratorium - or any good museum - is a response to the problems that beset both my guided tours in the mountains, and teachers who feel they must "cover the ground."

At the Exploratorium we've invented a new style of exhibit to do it.

Interchangeable Links in Common Chains

Consider our audience as contemplating a tree. Science museums all describe themselves as having interactive, involving, hands-on exhibits. But they misunderstand the implication of the terms they use. A tree has no pushbuttons, no cranks, no manipulative parts; but there are a lot of ways of interacting with it. One can look at it, lie under it, climb and feel it. One can watch the leaf buds unfold, mature into deepening greens and then oranges and reds until they fall off. One can study the bark, the cambium layer, the root hairs; extract sap; learn about photosynthesis. One can hear the rustle and watch the swaying in the wind. One can draw or photograph the tree, carve initials on it, chop it down, or just stand and watch the sunlight diffract around the edges of the leaves. One can even learn its name.

Our exhibits do not have quite this versatility. For one thing, we do not want people to chop them down; for another, the time scale is more defined: at most, half an hour at any one exhibit piece, often much less. More importantly, however, we conceive most of our exhibit pieces as props to link a pedagogical chain; frequently the links are common to several different chains. Thus, the Relative Motion Swing, which has a swinging table beneath a pendulum of the same period, can be used in many contexts. One can use it in talking about vectors, about polarized light, about Lissajous figures, about phase, amplitude and frequency, about damping, about kinetic and potential energy, about frame of reference and relative motion. For each of these topics this exhibit is but one link shared by several other chains of exhibits, which may intersect at other links as well.

Why is the Relative Motion Swing - a swinging table beneath a pendulum of the same period - such a good exhibit? Because it can be used in so many different ways, writes its designer, Frank Oppenheimer - an exhibit for everybody, including this girl watching how the pendulum can draw a circle while in straight back-and-forth motion.

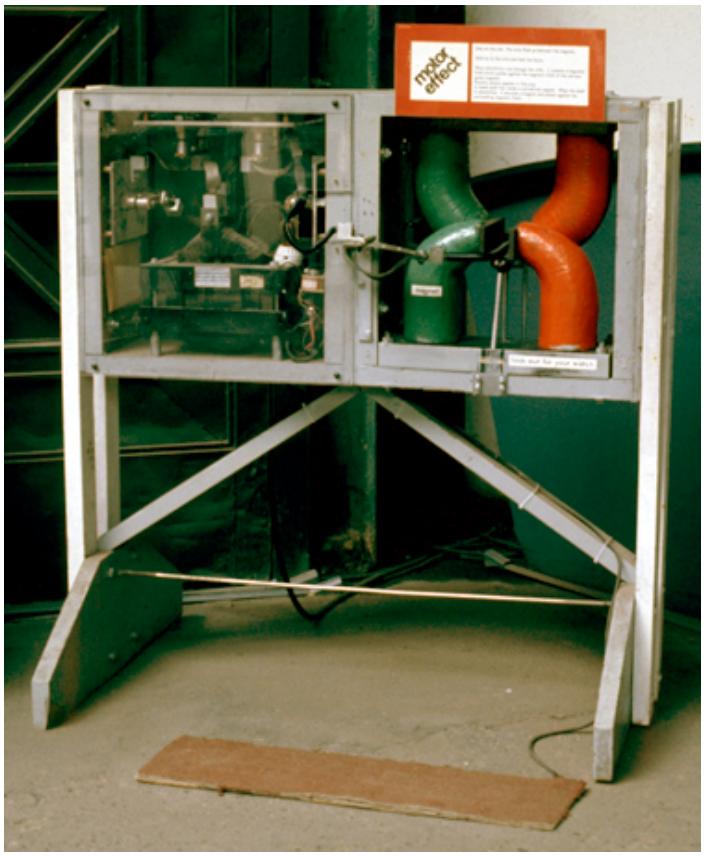
The fact that we use this exhibit for these multiple but specific purposes limits the versatility of people's interactions with it, but not as severely as one might imagine.. True, visitors cannot disassemble and rebuild the exhibit. True, we have not made provision for the visitor to vary the swing periods of the table or the pendulum. (The clearest pedagogy arises when the two motions swing synchronously. If either were readily adjustable, most visitors would not take the time to make the two motions synchronous and thus would not perceive the most delightful effects of relative motion.) On the other hand, we have not designed out all possibilities of variation. Although the pendulum swings most readily at right angles to the table, it can also swing parallel to the motion of the table with a very different and not commensurate period. The table itself can be made to vibrate perpendicular to its swing and, thereby, modulate the basic pattern of relative motion.

People use this exhibit in many different ways. Some just give the table a push as they walk by but then, so do I. Others make everything move every which way producing a noisy, unintelligible relative motion pattern. I enjoy doing that too. Many people very systematically let the table and the pendulum swing at right angles to each other, trying to reproduce the indicated circles and diagonal

lines of relative motion, learning about relative phases and amplitudes by trial and error. There are some visitors who know all about what the pendulums are "supposed" to show. They use the exhibit to instruct their friends and children - and I also use it that way.

This is a very good exhibit. I enjoy playing with it myself, and I enjoy showing it to you - no matter who you are; it is an exhibit for everybody. Many decisions went into its construction. It is versatile; visitors can find systematic things to do with it with relative ease; and one can obviously invent activities that are "out of context," clearly not part of any preconceived syllabus. The exhibit has other virtues as well. It is made entirely of hardware store parts: pipe, perforated angle iron, cable and turnbuckles, springs, etc. The hinging involves a short section of pipe rolling on two rods for the proper motion of the pendulum and a rocking motion from one rod to the other for the playful motions. The main defect in the exhibit is that, although there is elegance in the design, there is virtually none in the craftsmanship. Perhaps it was built in too much of a hurry.

In contrast to the relative motion pendulum, our exhibit demonstrating the magnetic force on a wire carrying a current is a very poor one. We placed three exceptionally large permanent magnets to have a common poleface, making a horizontal rectangular magnetic field, 10 inches deep and 2 inches high, with a gap of about 2 inches. A thick wire carries about 250 amperes, triggered when a visitor steps on a mat switch. The wire is hinged so that a straight length of wire can move up and down through the magnetic field. When the current is turned on, the wire pops up through the field, and the visitor who tries to push the wire down feels the large, springlike force of opposed magnetic fields. One can even "feel" the current because of the imperfectly smoothed direct current. A good deal of thought went into the design and execution of the exhibit, and it forms an important link in a series of exhibits on electromagnetism. But it shows only one thing. When I demonstrated the piece to one of our staff members, she said, "The lid of my



The Motor Effect exhibit

garbage can pops up when I step on the foot lever, too."

This exhibit is a traditional science museum demonstration. It may even be a little better than most, because the magnet and the wire are out in the open and not behind glass. I frequently use the exhibit as a prop for teaching electromagnetic phenomena, but I never play with it as I walk by or show it to friends who visit the Exploratorium. It is not for me - it is not for you, it is for nobody. No side effects branch from the main phenomenon that it demonstrates. It just does what it is supposed to do; there is no way to make it misbehave. It does not even contain any redeeming features of beauty or whimsy. Too much was designed out of the exhibit. In order to let people feel how strong the force is, the magnet was made strong; it would, therefore, have been dangerous to leave any loose pieces of iron around. The wire is large and stiff in order to carry the 250 amperes without growing hot. It is a single twisted bundle of wires and not a loose collection of flexible ones

In the Exploratorium's Bernoulli Blower the air stream from a powerful blower supports a light-weight ball, and museum visitors can feel the forces on the ball and watch it move as the air-stream is changed. They can also do "completely irrelevant things," says Dr. Oppenheimer - a fact which worries him less that the problem of making the Blower exhibit "link more intersecting chains of ideas."

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because a loose collection would have gone every which way and become tangled on the polefaces. We were too timid (or not clever enough) to use such a messy array of wires. We used a permanent magnet rather than a variable electromagnet because we thought the exhibit would thereby be conceptually more obvious. Thus, one by one, we designed out any and all the features that might have made the exhibit worth spending some time with. We converted the tree into a telephone pole.

Although the best exhibits commonly link several intersecting chains of ideas, this property is not essential. The Bernoulli Blower is a case in point. Here, a large blower has a truncated rubber highway marker mounted on top of it. The air stream supports a light-weight volley ball. The Bernoulli effect is strong enough so that one can feel an appreciable inward force if one tries to pull the ball out of the stream. People tap the ball and watch it oscillate in the stream; they partially cover the orifice with a hand or direct the stream to one side; they remove the ball and try to throw it so that it is caught by the stream. But they also do completely irrelevant things. Girls let their long hair stream up in the air current; kids hold their Tshirts over the orifice and let the air stream cool their bellies. Some people play catch with the ball either through or around the air stream. We lose about 25 balls a year - one per 20,000 visitors. If the ball is missing, people tear up bits of paper and see how these behave in the air stream. It is a pretty good exhibit, but we should build more links in this particular chain.

I cannot really say that I have noticed any difference in the way visitors to the Exploratorium behave on sunny and cloudy days. But for the staff and especially for me, and my feeling for you when you come to visit, whether the sun is turned on or not makes an incredible difference. This is because of the Sun Painting. I think it crucially important to have an exhibit of such scale and beauty. A beam of sunlight comes through a skylight from a sunfollowing mirror to illuminate the dusty gloom at the north end of the building. It strikes an angled flat mirror which sends it parallel to the floor into an array of vertical prisms; a multitude of vertical strips of mirror then pick up each individual spectral color, directing each color first behind and then onto an eight-by-fifteen-foot frosted screen. The exhibit demonstrates light scattering, prisms and mirrors and color, and sunlight. It is a brilliant abstract painting that shimmers and changes as people move in the light path and brush against the mylar mirrors behind the frosted screen. We have other exhibits of beauty, and without them the museum would be sterile and incomplete; but none are so fine as the Sun Painting. Not all the exhibits in the museum need to be of great beauty, but surely some must be, or the place would be for nobody.

An exhibit of the scale and beauty of the Sun Painting - the work of San Francisco artist Bob Miller - is ”crucially important" for a science museum, says Frank Oppenheimer. The scattering of sunlight through a series of prisms paints colors onto a giant screen - ”a brilliant abstract painting that shimmers and changes as people move in the light path and brush against the Mylar mirrors behind the screen," writes Dr. Oppenheimer.

The Benefits of Overkill

The attributes of exhibits that I have described - their beauty, their multiple linkages with different themes, the inclusion of extraneous possibilities for intervention and discovery have proved to be important to the overall effectiveness of the museum. There are other general practices that are important. In particular, when we make an effort to illustrate some process or behavior that is pervasive in nature (refraction, resonance, or sensory lateral inhibition, for example), this behavior is presented in many exhibit pieces. Each illustrates the same underlying process in very different contexts. For example, wave motion is a powerful abstraction that could not be perceived from any single type of wave. But the concept can take shape by observing the effect of light waves and water waves and sound waves, of waves on an oscilloscope, and waves in a string or a flat plate. Some of our exhibits on waves are grouped together as a sub-section in the museum. Many of them are scattered in various other topical sections of the museum.

Even phenomena less pervasive than waves need multiple and varied examples so visitors can develop an intuitive understanding. We have three exhibits on stroboscopic illumination, and plan several more. There are at least half a dozen on spatial and temporal beats, but we still need simpler and clearer exhibits on this topic. We have two dozen exhibits about the perception and mixing of color, and well over a dozen different ways to involve people in the basic phenomena of depth perception through binocular vision. One of the great virtues of museums stems from the

possibility that visitors can, by themselves, achieve a very satisfying understanding through abstraction from multiple and contextually different examples. Many museums fail to provide this possibility because they show only a single representative example of each effect or process.

A Different Drum to Demonstrate Resonance

The basic problems of exhibit design are not solved by the general considerations that I have outlined. Each effect, each idea, each way of conceiving some aspect of nature requires a topic-specific design. One sees the need for an exhibit - that is, one is aware of a crucial link that is missing at the beginning or middle or end of some topical chain. The need may become apparent while teaching our aides or in conducting some of the formal classes here. Frequently this need festers for a year or more before someone on the staff or a visitor suggests a reasonable way of forging the link. In the meantime one continues to fabricate less crucial links in the chain.

For example, we have been developing many exhibits on optical and acoustical resonance, but we have not figured out how to show, clearly and convincingly, what goes on when a non-resonant device, like a bow, excites a resonant violin string. We are getting closer. We increased the weight of the rope that is stretched across the 120 feet of the museum so that when the visitors jerk the rope they can feel the reflected pulse pull on their hand a moment later. We have a series of different length glass pipes, each of which responds, like a seashell held to the ear, by selecting and resounding a characteristic note out of the ambient noise of the museum. We have a 400-pound pendulum that visitors can put in motion only by pulling repeatedly and at the proper time on a cord that is very weakly attached to the pendulum by a small magnet. We are building an Aeolian harp. All of these exhibits work around the edge of the basic phenomena, but we still do not have anything to show how the rubbing of a bow or the hissing of a stream of air is converted into a sustained tone in a musical instrument.

We are planning other links in this resonance chain. We know roughly how to demonstrate the resonance absorption of yellow light by sodium vapor, but we have not yet managed to develop this important exhibit. On the other hand, we have not yet decided how to convey what is going on in a resonant electrical circuit. Perhaps, after we have built more links in an electrical phenomena chain, a method for this particular demonstration will occur to us. There are no general prescriptions for exhibit design that will solve this problem. Yet it is precisely on the success in finding such solutions that the quality of science museums depends.

Addiction to Individual Discovery

A museum's logistics force its staff to have flexible teaching strategies. Conducting a group tour is impossible. It is also impossible, even if one wished, to insist that visitors work with the exhibits in a prescribed order. In a crowded museum, the visitor may not be able to progress to the "next step" because other people are in the way. Even people who come together take separate paths and0 then call to each other, "Hey, come look at this!" When staff members are frustrated by our visitors' tendency to this kind of "Brownian motion," I urge them to look back and remember how many different kinds of patterns and circumstances in their own learning were wonderful like the variety of my mountain walks.

The character of our visitors' exploration of the museum is the main reason for our having aides - we call them Explainers - moving around the floor, stopping to play with or fix one of the exhibits. (Any attempt to repair an exhibit invariably draws an eager group.)

The difficult problem for the staff is how to show our visitors the path leading to the broader vistas and the sense of unity and coherence that one would like them to perceive and which, to a large extent, they would like to find.

The remarkable feature of the process of individual discovery, whether of detail or of generality, is that the first taste of success can be addicting. For some obscure reason we, as teachers, are committed to turning on addicts. But potential addicts are not programmable; one never knows who they are or when they are vulnerable. We argue among ourselves: if we do not tell people what they are supposed to find, many will leave with a sense of frustration, but a few will have become addicted to finding more than anybody knew was there. How many frustrated people is one addict worth? Since there is no going back if one gives away too much, we tend to lean toward the more radical answer to this arguable question. And we do have a large number of addicts who come back for more.

For the many who feel somewhat frustrated because their curiosity has been aroused but not satisfied, we have persuaded ourselves that we can enrich the museum experience by preparing written, take-home material related to our exhibits. In addition, we should be able to make short topical television programs which use our exhibits as props. The broadcast programs would not be for national distribution but would help people who had visited the museum and who planned to return. We also sell relevant books and reprints in the museum store. This reliance on take-home written material may seem to be a cop-out from the task of designing better exhibits. There is, however, no valid reason for rejecting the abundant use of language, especially if the language is based on the kind of broad experience that people can find in the Exploratorium.

We are careful not to be overly wordy in the signs that accompany the exhibits, but, in fact, we have not adequately solved the problems associated with exhibit graphics. Too many words can be intimidating and can discourage people from trusting their own ability to explore and find things out for themselves. It is also true that words can be used to fool people into believing that they have been enlightened. For example, concerns about consumer protection have led to legislation that requires the ingredients to be specified on medicinal labels. As a result, the disinfectant spray, Bactine, for example, has an unenlightening label that reads: "Alcohol 3.17 per cent, Methylbenzethonium chloride, isooctylphenoxypolyethoxyethanol and chiorothymol." Why should not this information be given in a pamphlet explaining which ingredient serves as bacticide, which as fungicide and which as deodorant? It could even explain why these particular organics are effective, painless, and commercially profitable. Museum curators invariably complain that the public does not read. But I see no reason for a museum to cater to the fact that many people have been put off language by the way it is so deliberately used with dishonesty in commercial and political life.

At Ease with Trivia in a Non-Trivial Place

The Exploratorium is a good museum because of the care and thoughtfulness with which the exhibits have been conceived, designed, and assembled. But many of the people who visit us stress, and perhaps exaggerate, the importance of the general ambience of the place. Some aspects of this ambience may be essential to our purposes. The remarkable spaciousness of the Palace of Fine Arts hall is certainly unique. It is also vital that we do not fragment the space with walls that define subject matter boundaries. Since we want visitors to explore and invent in a way to which they are unaccustomed, we avoid the usual plethora of written and verbal commands as to how they should behave. We also resist making rules whose sole purpose is to reduce the amount of work or decision-making required of the staff.

The most important aspect of the ambience of the Exploratorium may stem from the fact that visitors are never subjected to judgmental discomfiture. They do not feel compelled to decide whether they are supposed to learn something from an exhibit or merely to enjoy themselves. If they stand before an exhibit and say, "Gosh, my eight-year-old child could do that," this remark is made approvingly. It is not the familiar disparaging or derisive statement

that is heard in an art gallery. Nothing in the setting, label, or symbolism suggests to the visitor that he must decide whether an exhibit is truly great art or great science or an outstanding intellectual achievement of the human mind. It is in this one respect - and only in this one - that we may conceivably fool people, because many of the things they look at really do reflect the extraordinary quality of somebody's achievement and imagination.

Even in this respect, though, I doubt that we really fool people. They are certainly aware that the Exploratorium is not a trivial place. But we do nothing that would make people feel uncomfortable with non-triviality; else why do so many teachers bring students, why do so many students bring back their parents and families and friends? And why would those few adults who come alone invariably express regret that they do not have their children or grandchildren with them?

I suspect that everybody - not just you and I genuinely wants to share and feel at home with the cumulative and increasingly coherent awareness of nature that is the traditional harvest of scientists and artists.

The exhibits that we have designed, the thematic emphasis on perception and the general atmosphere of the Exploratorium, go a long way toward making this sharing possible for an indescribably diverse population. There is a great deal left to do and learn in order to complete what we have started. As we mature it also seems ever more important to us that we learn how to integrate what happens here with learning and enjoyment that takes place at home, in the city and country, and in schools. In the meantime, it is wonderful and rewarding to just wander around the floor, watching, listening to, and occasionally talking to the visitors. Perhaps each of us is in some way everybody, and the surest way to delight others is to find what is a delight to ourselves and to the people we are fond of.

“Discovering the Exploratorium is like stumbling into the belly of a giant whale where some mad scientist has found a home,” writes its director, Frank Oppenheimer. The museum’s unlikely home is the cavernous Palace of Fine Arts in San Francisco, originally created for the 1915 Panama Pacific International Exposition. In 1969 Dr. Oppenheimer set out to create there an institution that would make science and technology more accessible to the public – “a place where people could not only learn, but participate.” Now the asphalt floors feel the footsteps of 400,000 visitors a year, and the concrete walls resound to a public invited in “to touch, pound, open, pull on, look through, listen to, screech at, and climb through.”