

Front-End Evaluation

SUGAR FROM THE SUN
for
Garfield Park Conservatory Alliance

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EXECUTIVE SUMMARY

Overview

The Garfield Park Conservatory Alliance is developing *Sugar from the Sun*, a project consisting of a 5,400-square-foot exhibition intended to help children and their families explore photosynthesis. This immersive exhibition will use real plants to delve into the process that plants use to manufacture sugar (food energy) from the sun (light energy).

Selinda Research Associates (SRA) conducted a front-end evaluation as part of the exhibit development process. The first phase examined what was known in the research literature about the public's understanding of photosynthesis and also about creating successful immersive experiences. The second phase of front-end evaluation, and the focus of this report, assessed visitors' understandings of the scientific concepts presented, determined potential visitors' perceptions, connections, and experiences with the topics, and identified challenges and potential entry points.

This evaluation was grounded in naturalistic methodology (Lincoln & Guba, 1985). The primary data collection method for this study was depth interviews, combined with an activity serving to map visitors' concepts about photosynthesis. Respondents for this study were purposively selected (Miles & Huberman, 1994). Interviews were conducted with four West Side community members (Garfield Park, Humboldt Park, Austin, and Lawndale) as well as casual groups visiting the Conservatory. Selection criteria also included a mix of gender, ethnicity/race, group composition, and age. In all, we interviewed 31 groups for a total of 94 respondents. Interview times ranged between 20 and 45 minutes. Interviews were transcribed and analyzed using inductive constant comparison (Lincoln & Guba, 1985).

Summary of Results

Plant Perceptions & Connections

- Respondents' perceptions and connections with plants were wide-ranging, encompassing personal memories, aesthetic connections, affective associations, and even connections with broader environmental concepts. The most significant aspect of this range of connections was that these associations were respondents' primary explanations for why plants were important.
- Respondents primarily thought of plants' importance in terms of how plants affect people as individuals, then secondarily in terms of how plants fit into the environment. Most did *not* think about plants' importance from a scientific viewpoint.
- Respondents' connections stemmed primarily from their *everyday experiences* with plants. This is especially important, because it points to the fact that visitors' primary point of reference to plants will be grounded in daily and common experiences with plants rather than more abstract concepts. Respondents' knowledge that plants provide for people's physical



needs (e.g., food) might serve as a potential entry-point for discussing the importance of plants in sustaining life on earth.

Photosynthesis

One way of understanding the range of visitor understandings and conceptualizations about the topic is by representing them on a knowledge hierarchy. The photosynthesis knowledge hierarchy developed for this consists of six levels:

Level 0: Don't know what plants need to live.

Level 1: Plants need sun and water to live.

Level 2: Plants need sun, water, and carbon dioxide to live.

Level 3: Plants have a process in which they take in water, sun, and carbon dioxide, and produce oxygen and sugar.

Level 4: Plants have a process in which they take in water, sun, and carbon dioxide, and produce oxygen and sugar. This sugar is used by the plants as well as people.

Level 5: A more complete understanding of photosynthesis, including an understanding of the chemical processes involved.

- The lower levels of the hierarchy represent incomplete understandings of the topic. At these levels, conceptions about what plants need to live emerge, but visitors placed at these levels have no conception of photosynthesis per se. It is not until Level Four in the hierarchy that a clear understanding of the core concept of photosynthesis (i.e., plants make sugar as their own food) emerges.
- At lower levels of the hierarchy, respondents focus on things *plants need* to stay alive (e.g., sun, water) in practical, concrete ways, based on everyday experience with household plants.
- At higher levels of the hierarchy, respondents focus on the *process* by which plants take what they need and convert it to something they can use. The orientation is more academic, abstract, and based on concepts they read or heard about in school.
- While school exposure to the topic seems to help move people up the hierarchy—generally, students who had recently studied the topic were at a level four understanding, with few adults at this level—people shift their emphasis away from the scientific understanding of photosynthesis once they get away from school their days toward a more concrete (rather than abstract), practical (rather than academic) mental model grounded in their everyday world.
- Moving people up the hierarchy will likely involve more than supplying information; it will require helping them change *how they relate* to that information. For example, do ways



exist to help visitors think of photosynthesis in practical terms, even when they are thinking about an abstract process?

- Findings also indicate that one cannot assume adults know the term “photosynthesis” and that children do not. One challenge will be to develop interpretation allowing adult group members to guide their family’s interactions although parents may have little academic knowledge of the topic.

Sugar

- Respondents’ major associations with sugar were either to table sugar or sweet things such as candy. These preexisting conceptions will be challenging, because the topic of photosynthesis requires visitors to think about sugar in ways different than their current understanding. While using certain sweet economic crops as a “hook” for the exhibition is a good starting point, the team will need to be careful about inadvertently reinforcing visitors’ preconceptions. It will be critical to help visitors understand what plants do with sugar—that this substance, produced through photosynthesis, is a building block for everything else that plants (and humans) need to live and grow.

Perceptions of Garfield Park Conservatory

- Respondents ascribed, and appreciated, a number of qualities about the Conservatory, including its aesthetics, uniqueness (particularly for a large city), and ability to inspire awe and wonder. Respondents most often indicated being able to relax, “escape” the city, be in a beautiful place, and enjoy plants as reasons to visit the Conservatory. While many respondents believed GPC to be an educational place, and appreciated that aspect of it, this was not the main reason most visited the Conservatory.
- Though GPC staff questioned whether significant differences would exist between community respondents and other casual Conservatory visitors, we found no major differences related to the main themes explored in this study, including in their overall reactions to GPC upon visiting. While community respondents’ perceptions of the Conservatory were generally positive, one interview raised some important questions about how improvements at GPC actually benefited the community (as opposed to other populations). A thorough exploration of GPC and community issues was well beyond the scope of this study, whose focus was on the exhibition being developed. We recommend that GPC undertake a separate study focusing specifically on broader community issues.

Immersion at the Garfield Park Conservatory

- Findings indicated that several strong aspects of the Conservatory foster and maintain feelings of immersion for respondents; many of these aspects correlate well with existing research. Key immersive qualities identified included creating a feeling of being in a particular time and place, engaging all the senses, fostering a sense of discovery, allowing for contemplation, and being in environments that feel authentic (i.e., the Conservatory rooms and plantings do not feel false or contrived).



- Because visitors come to see a living collection (“real plants”) in a Conservatory, the need for authenticity and realism may be more important than in a traditional museum gallery, where visitors may have different expectations about immersive environments.

The full report discusses our findings in detail as well as their implications for exhibition development. The report also includes recommendations.



INTRODUCTION

The Garfield Park Conservatory Alliance (the Conservatory) is developing Sugar from the Sun, a project consisting of a 5,400-square-foot exhibition designed to help children and their families explore photosynthesis, a fundamental biological process. The exhibition, to be constructed in the Conservatory's Sweet House, will use real plants to explore the process that plants use to manufacture sugar (food energy) from the sun (light energy).

The primary goals of this exhibition are to:

1. Convey that plants use air, water, and sunlight to make sugar
2. Heighten visitors' appreciation for plants

Visitors will be immersed in a natural environment in which actual plants, air, water, and light are used to demonstrate food production by plants. The exhibit will be divided into four areas, one of which will be devoted to a product of photosynthesis (sugar) and will highlight plants within the Conservatory's plant collection. The other three areas, featuring the building blocks of photosynthesis—air, light and water—will show how those elements are taken in and processed through a plant's roots and leaves. At the center of the exhibit will be an interpretive area focusing on the sun, the energy source for photosynthesis.

The primary intended audience for this exhibition is families with middle school-aged children (fifth through eighth grades). While Sugar from the Sun is intended to serve families from Metropolitan Chicago, the Conservatory is placing special emphasis on reaching out to the West Side neighborhoods immediately surrounding the Conservatory (Garfield Park, Humboldt Park, Austin, and Lawndale). The exhibition, therefore, is expected to incorporate cultural elements that will help visitors of diverse backgrounds connect what they see and do at the Conservatory to their own lives. In addition, the Conservatory will include bilingual text in take-home material and may include it in exhibit elements as well.

Evaluation Overview

As part of the early planning for this project, Selinda Research Associates (SRA) conducted an initial front-end evaluation consisting of an exploratory literature review. This review was conducted in order to ascertain: a) what the research says about the public's understanding of photosynthesis in general, b) how the general public understands the four components of photosynthesis—air, water, sunlight, and sugar—on which the exhibit will focus, and c) what is already known about creating successful immersive experiences.

The second phase of front-end evaluation (the focus of this report) examined potential visitors' understandings of and connections with the scientific concepts presented. The specific goals of this evaluation phase were to:

- Assess visitors' understandings about the scientific concepts presented.
- Determine visitors' perceptions, connections, and experiences with the topic(s).



- Identify appropriate bridges between visitors and proposed content. That is, determine ways to help visitors connect with the exhibit topic so they can better understand the concepts presented.

Early in the project, the Conservatory and SRA evaluation team collaboratively developed a topical framework (see Appendix A) to guide the initial data collection. This framework outlined the issues to be explored during the study and provided a focus for conversation with respondents.

Methodology

This evaluation was grounded in naturalistic methodology (Lincoln & Guba, 1985). Naturalistic inquiry uses a systematic approach for collecting and analyzing data in real-life settings, as opposed to setting up laboratory-style experiments in which particular hypotheses are tested. It is a rigorous approach to understanding experiences in the natural context in which they occur. The goal of naturalistic methodology is to provide a holistic understanding of an exhibition or program from a variety of perspectives. Data are collected and analyzed throughout the study, and this analysis continually informs the data collection process.

One strength of naturalistic evaluation is that unanticipated findings emerge from the data, often in respondents' own words. This type of inquiry also allows the researcher to follow up on threads and themes that characterize how respondents think about and react to particular topics and concepts.

Methods

The depth interview was the primary data collection method used in this study. Depth interviews, which are open-ended, allow visitors to talk about the topics in their own words and without predetermined ideas about outcomes. Depth interviews yield rich information and a deeper understanding of how visitors think about the topics being studied.

As part of depth interviews, we developed a concept-mapping activity to focus part of our conversations with visitors. For the activity, we provided respondents with graphics (e.g., tree, apple, raindrops, sun) and select words (e.g., air, plant food, soil, in, out, sugar) and asked them to arrange these on a magnetic board in whatever way made sense to them. (See Appendix B for a list of words and graphics used. Appendix C provides examples of respondents' arrangements.) Respondents were instructed that they did *not* have to use all the pictures or words and could also add new ones if they liked. After respondents indicated they had completed their arrangement, we asked them to talk about their magnetic board, often probing particular ideas they expressed. This allowed us to gain an understanding of their conceptions of topics we wished to explore for this study.





Figure 1. Example of activity designed to illuminate respondents' understandings of photosynthesis. Respondents were provided with specific graphics and words, and were also given markers to add any additional images or words they wished to the image they created.

We interviewed 31 groups (a total of 94 respondents). Interview times ranged between 20 and 45 minutes. All interviews were conducted at Garfield Park Conservatory and were recorded for later analysis.

Respondents

In selecting respondents, we used purposive sampling (Miles & Huberman, 1994). In purposive sampling, each respondent is handpicked for certain characteristics. The goal of this sampling technique is to talk with respondents as different from each other as possible in order to elicit the widest possible range of responses. Understanding the experiences of a broad range of visitors is particularly important in museums because these institutions are concerned with reaching multiple audiences, intergenerational groups, and traditionally underserved populations.

Depth interviews were conducted with casual groups visiting the Conservatory as well as with respondents from four West Side communities (Garfield Park, Humboldt Park, Austin and Lawndale). Additional selection criteria for this study included:

- **Age:** Some groups that included a range of ages, and where one or more group members are middle-school aged or older.
- **Group composition:** As wide a range of groups with varying makeup, such as family groups, adult-only groups, teen groups, etc.
- **Gender:** As even a mix as possible of females and males.



- **Race/ethnicity:** As wide a range as possible of varying racial/ethnic groups, with a focus on African-American, Latino, and Caucasian respondents.

Casual visitors were invited to participate in interviews during their visit to the Conservatory. Garfield Park Conservatory staff recruited community respondents in order to ensure the surrounding communities were included in our sample. Prescheduled interviews with community members took place at the Conservatory. For detailed information on respondents, see Appendix D.

Data analysis

Interviews were transcribed and analyzed using *inductive constant comparison* (Lincoln & Guba, 1985). In inductive constant comparison, each unit of data is systematically compared with each previous data unit. This allowed researchers to continually identify, develop, and refine categories of data and patterns as they emerged.

Limitations

As is true with any evaluation, there are limitations to this study. When conducting an evaluation study using naturalistic methodologies, it is standard practice to continue collecting data until a *state of redundancy* is reached. Redundancy is the point at which no new information is gleaned, despite repeated attempts to elicit additional findings. We were able to reach redundancy on the core issues explored in this study. Time limitations and resources, however, prevented us from reaching redundancy on some aspects of the study. Specifically, we were not able to fully explore respondents' conceptions of specific terms (such as "producer" and "consumer") that may potentially be used in interpretations. This can be explored further in formative evaluation.

This study included a robust sample of community respondents from the four targeted communities. Due to recruitment challenges, however, the sample did not include Spanish-speaking community members as originally planned. In formative evaluation, inclusion of families who are bilingual or Spanish dominant will be important.

In addition, this study did not focus on broad community issues and relationships between Garfield Park Conservatory and the four targeted neighborhoods. While the evaluation provided some information about community members' perceptions of GPC, further research is recommended.



RESULTS

The following section discusses the main findings and implications of this study. In naturalistic evaluation, we describe the range of experiences rather than the percentage of people that acted or thought a certain way. Because respondents were purposively selected, it is inappropriate to report the percentages of respondents who felt a particular way. Instead, we identify which views were more commonly held and which were more idiosyncratic.

Throughout this report, we have included comments from interviews—when appropriate—to illustrate various points. It should be understood that the number of quotes selected is not representative of the number of respondents expressing a particular sentiment. When selecting quotes to use, we chose ones which were clearly stated and that illuminated a *range* of participants' perspectives.

Plant Perceptions and Connections

One aspect of this study focused on understanding the ways in which respondents connected with plants. Connections and perceptions of a topic are particularly important to understand, because they provide a general map of the range of the ways visitors relate to a subject. Identifying connections can be valuable in understanding where visitors are starting from and can often illuminate potential entry-points for the exhibition.

In our interviews, we gave respondents an opportunity to talk generally about their top-of-mind associations with plants and probed about the importance of plants. We found that respondents related to plants in a variety of ways, each of which is discussed in the subsections below. We noted that individual respondents often had one or more of these types of connections with plants. In other words, these are not mutually exclusive ways of relating to plants. In addition, the intensity of respondent reactions and the depth of their connections to plants varied. In this section, we describe the range of types of connections expressed by respondents.

Aesthetic Connections

A recurring theme in respondents' comments centered on the aesthetics of plants. Respondents often mentioned the visual beauty of plants (particularly flowers), the range of colors of plants (including green), and their smells. Respondents often cited aesthetics as one reason they valued having plants in their homes or neighborhoods.

They make the house beautiful. EF202-2

I just like them because they're pretty. They make things look better. CG612-1

Like flowers, plants, they make our life more beautiful.... More beautiful. EF617-2

They look nice. They sometimes make a room feel cozier if you have plants. EG626-1

The first thing that comes to mind for me when it comes to plants is just beauty. Something that's pleasing to see. And to smell. Plants that grow beautiful smelling flowers. BC703-2



Restorative Associations

While respondents' immediate associations with plants were often about their beauty and sensory appeal, their connections with them went much deeper. Respondents also commented that they valued plants because of their restorative nature. They often told us that being around plants made them feel relaxed and seemed to recharge and rejuvenate them.

[Plants] calm people down like when they're mad or something—the different colors from them. They're relaxing. BC606-2

I have a little, like, window box right outside my room with plants in it and stuff. And it's kind of nice...because my bed is right next to my window and it's nice to just kind of lie there and before I go to sleep. I mean, it smells really good. And it's just kind of nice just to sit there and read and listen to music and look at the plants and be able to smell that and then I can just go to sleep right away. You know...it would be different... if it was, like, something artificial keeping us alive. Like some big plant that was pumping out air or something. I just—it's just so different and it wouldn't be as—it just wouldn't be natural and it would be like everything was man-made. CG522-3

Some respondents told us that plants had a healing effect as well. Because plants are alive, they serve as a reminder that life is all around. This theme often recurred when respondents discussed how they feel when they visit the Conservatory.

For me, being [in] an atmosphere like this [the Conservatory] is extremely healing because there's life all around me. Things are growing, things are alive, and that's just so healing for me to be in an atmosphere like that. CG522-1

Spiritual Connections

Appreciation for the beauty and restorative nature of plants sometimes extended to what we might categorize as a spiritual perspective. The variety of plants and the way they grow seemed to inspire a sense of wonder and awe.

One of the things that really struck me was how...little [the plants] were and how detailed. It was really, really amazing to see that. BCC523-2

This sense of awe, however, was not limited to an appreciation of plants' physical characteristics. Instead, the fact that plants are living things inspired some respondents to think about broader questions of life. For some, plants embodied “being alive” and the connection to life itself, including the possibility of a deep (though perhaps mysterious) connection between plants and human life.

I think plants are just really a necessity. Just for human existence and maybe that—some people might think that's pretty extreme, but I think they provide a lot more than what we're aware of. And people are not as in touch with what plants provide us spiritually



and emotionally and physically that we're aware of. So I think it's in the people's interest for us to have plants around us. CG522-1

This connection was sometimes extended to nature itself. This teen, for example, talked about the importance of being in nature in this way:

We go out to the West Coast a lot. And I love being out there because we go camping. And, I mean, I'm not surrounded by big buildings and, I mean, I like the city a lot, but (inaudible) it's really nice to get out and, you know, just see nature. People think it's stupid but I think it's really important. I mean it's...it really is what keeps us alive. CG522-3

Still other respondents made direct connections between plants and their spiritual beliefs of God. One respondent, for example, after learning about the cacao tree commented:

You know it broadens your horizons when it comes to what God has created. EF617-1

Others expressed both a sense of amazement at nature in general and for a plant's growth process.

People say that like nature they're inspired to believe in God and...it's so pretty. BC523-2

I just wonder how did God create—how did He—what materials did he put in... that makes a beautiful thing. I mean, like, this tiny little seed grows humongous. Like, how did He do that? How did He make such beautiful plants? EF617-2

Memories of Plants

Another thread in conversations centered on respondents' memories about particular plants they grew up with. These memories were either of gardens or particular plants in their own (or a family member's) backyard, or in a part of the country in which they had grown up.

Because my great-grandmother loved plants, and flowers in her garden and stuff. Well, she planted roses all the time. She always planted roses. I remember those. And she had, like, tulips. BC703-2

I'm from the West Coast, so to be able to go into the fern room it seems—I kind of feel like I'm back home. My parents live at the base of the Olympic Mountains and so you're over in the woods, there, and there [are] ferns everywhere. EF523-2

Sometimes memories about plants revolved around using particular plants for food and also seemed to be associated with family stories.

Respondent #1: We had some kind of flowers [in our yard]. My brother—I thought it was a—just a flower but it was actually honey. It was a honeysuckle.



Interviewer: Oh, could you eat it?

Respondent #1: Yes...It tastes like real honey.

Respondent #2: They were back in the bush all the time.... Whenever someone came over, they went to the back and sucked on the honeysuckle. BC424-2

There were some sort of plants that we used to eat. It was, like, a green bean. EG626-1

One thing I know that my husband told me is that when he was a kid he says he always remembers his grandmother. When we're the backyard, and I'm weeding, he says he remembers his grandmother using a certain kind of weed I was pulling out; she used it to make tea. That was really weird, but I will never forget that one, because I remember smelling it and thinking it smelled awful. BC703-2

Caretaking: Plants and people

A striking theme that emerged from the interviews was the degree to which respondents appreciated plants' need for care as well as the beneficial effects this can have on the people who care for plants. Some of the most vivid stories about plants emerged from respondents conversing about how they, or more often how someone close to them, cares for plants as a hobby.

Respondents who had tried growing their own plants or who had a relative who grew plants avidly understood that plants grown at home require a commitment of time and effort to grow successfully. The successes of those who have a "green thumb" made lasting impressions on respondents.

I don't have a green thumb. I have a hard time keeping them alive. But my mom...my mother lives on a second floor and she doesn't even put curtains on her windows because she wants the plants to get as much light as they can, which is why I think her plants [live]. I mean, people that have plants that have died will take them to her, and for some reason she'll get them to live again. But I think that it's because of the abundance of sunlight that comes into her living room and dining room that the plants are able to live so well. BC703-2

Some respondents talked about how plants need people to care for them. Sometimes respondents reported a tendency among avid plant hobbyists to anthropomorphize their plants. Plants were sometimes seen as having feelings and responding to human interaction.

Respondent #2: The thing I'd explain to somebody is, like, plants need care and love and I think that if someone is talking to an eight-year-old or seven-year-old, I would [talk about]...how you take care of plants. You take care of them. You feed them. You, like, stay there when it's dying, or something like that. CG424-1

My mom believes that...she has a relationship between herself and her plants. Like she talks to them. Because you know she says that that's good for them. And she feels that they understand. I swear it's a crazy idea but she feels that the plants understand. She



actually like sometimes she'll get me to get the kids to go over and help her clean them. BC703-2

Interviewer: Okay, and why do you think that was? What do you think that talking to plants would make them grow?

Respondent #1: Like, paying attention to it. Water it every day. Put it in the sun and let it grow about two weeks. Feed it. Don't let it just sit there being lonely and have the leaves all falling off. CG424-1

Those who related taking time and effort to cultivate plants (either in gardens or even in their apartments) explained that they gained satisfaction from watching their plants grow. One plant hobbyist explained:

Respondent: I consider myself sort of, like, horticulture-like inclined. Because in the backyard, I put some milkweeds that somebody had down the street and I put a couple of pods in and they're growing. Because I'm going to see if it will attract some monarch butterflies and a couple of them did fly over in the area.

Interviewer: So what is it you think you like about working with plants?

Respondent: To see them grow. BC703-1

Taking care of plants also provided a sense of accomplishment and was a source of pride for some respondents. For example, one group we interviewed talked about how the father in the family received a trophy for having the best garden in the neighborhood.

The other side of caring for plants was the positive effects respondents saw for those doing the caretaking. They talked about the ways plants gave people something constructive to do, how they could ease a person's loneliness, and simply make them happy.

Functional Perceptions of Plants

Plants were also seen as being important because they provide for people's physical needs. A top-of-mind reason for plants' value was that plants provide food for people to eat, followed closely by oxygen for people to breathe. Respondents also mentioned a variety of other physical needs that plants fulfill, such as providing medicine, wood, and paper.

As a food source, plants were primarily seen as a direct source of edibles, but some respondents indicated awareness of plants as part of a larger food chain.

And we couldn't get—and the animals couldn't get—any food, so that means we couldn't get any meat or fish or eggs. Or, you know, food from animals. So each one of us helps the other. We give off energy to plants that give us the energy; the plants give energy to the animals to live so that we can eat the animals. BC606-1

Respondents viewed plants not only as being a source of oxygen, but also in some cases as being an "air purifier."



A lot of people think ozone, air, [that] there's always going to be air, but if you breathe it all up, you know, eventually it's going to be gone. Like if you put yourself in a locked room where no air can come in (inaudible) and you start breathing it up, pretty soon it's going to get hot and fill up with carbon dioxide. If you have a plant in there that you can keep, then it's going to be fine. BC424-1

Because if we didn't have plants, we could never get the oxygen that we need to breathe on the earth. BC606-1

Some respondents were also aware that plants can be a source of medicine.

Like the eucalyptus plant; that helps in the breathing because of whatever it's made of that comes off of the plant. I think that helps you breathe for people with asthma. EG626-1

Environmental Connections: How plants fit in the cycle of life

The idea that there is an interrelationship in nature among plants, people, and animals emerged repeatedly in our interviews. For example, after completing the magnetic board activity, one respondent said, “we've defined the cycle of life (cg52202).” Other respondents expanded upon this idea in various ways:

And basically the tree is dependent on the person, the person is dependent on the tree. You can't have one or the other. And they're all kind of dependent on nature, yeah, because the person is dependent on the tree, then he's also dependent on nature because that's what the tree depends on. CG522-3

Respondent #1: Well, right now, we're all dependent on one another. It's true. It's a cycle, we are.

Respondent #2: If one thing dies then everything else dies. BC502-3

Respondent: Okay. If there wasn't [any] sun there will be no plants. And if there would be no plants there won't be no animals.

Interviewer: Now why is that? What is the connection between the plants and the animals?

Respondent: Because usually, it's like a food group. A food group. That first it comes from sunlight, then it goes to these plants. Then it goes to animals and usually some other animal. EF617-2

I mean, because trees play a big part in human existence. So it keeps life moving, flowing. So that's my original thought. And that I love trees. Like I appreciate. I'm glad, you know. When I'm alone, I hug trees. Because I'm real grateful for what they do for us. CG522-1



Some respondents also indicated awareness of specific ways that plants contribute to the environment—for example, by providing shelter for animals or preventing erosion.

They're houses to animals. BC502-2

They're important for the insects. A place for them to be able to make honey and things like that and a place to stay and nutrients and food for their bugs. Little insects. BC703-

Respondent #1: And they hold water. Hold back soil.

Respondent #2: Yeah, they don't make—they prevent erosion. BC502-2

Conversations sometimes led to a discussion of environmental issues where some respondents expressed concern about the ways human activity affects plants. One respondent, for example, commented that overdevelopment meant fewer green spaces. Another respondent group expressed their unease this way:

Respondent #1: We used to use paper plates all the time and stuff. But I'm really like—my thing is, how many trees are being cut down to actually—just so that we can use a paper plate when we can wash our own plates.

Respondent #2: I always think of paper. I'm like, oh my God, look at all this paper in the store. So much paper wasted, though.

Respondent #1: Yeah, because we use it for folders, for napkins...

Respondent #2: For everything.

Respondent #1: Paper towels, paper plates, paper cups. And so don't you think that they think it's more convenient for us because we don't have to wash dishes, which is a good thing for me but—but it's really taking away a lot from our rain forest, the trees. So, I mean, I think it would be a good thing to learn about recycling for the benefit of the trees in the world.

Respondent #1: I think we should recycle more.

Respondent #2: Yeah. I recycle newspapers and stuff like that. But I think that, and we've cut down on the—well, we don't—we only use paper plates for parties. Like the kids' birthday parties or something. But we don't use them any more for dinnertime or anything like that, because that's a big concern for me. BC703-2

Cultural Connections

As we analyzed data, we also examined the extent to which respondents saw plants as especially significant to their culture. In some ways, the particular stories about growing up and uses of specific plants could be considered part of respondents' individual family culture. In our sample, respondents did not identify any particular plants as being especially linked to cultural heritage or identity. There were indications, however, that for some visitors, plants may elicit connections to the countries where they or family grew up. The few respondents we talked with, for example, who are recent residents to the United States had connections and memories to plants that grew in their country of birth. One group was particularly animated about plants they saw at the Conservatory that reminded them of plants in India, where they had grown up.



Interviewer: So you made a connection that way [to plants in the Conservatory you saw]? Which kind of plants...?

Respondent #1: Hibiscus.

Respondent #2: Banana, coconut.

Respondent #3: Cocoa, coffee. Ginger.

Respondent #1: Even some of the palm trees. What is this little one? Verbena. EF523-1

Negative Associations

While respondents had very positive perceptions of and connections to plants, we noted that a few children expressed a fear of plants. Fears were expressed in a variety of ways. For one respondent this fear seemed to be a result of being aware that some plants are poisonous to people (through their leaves, fruit, or thorns), but not having a complete understanding of the potential effects of these plants and also not knowing how to identify such plants. For example, one child tried to move away from leaves that were brushing against her when she was walking around the Conservatory because of a fear of poison ivy, which she indicated could make someone ill or perhaps even be fatal.

For children in one group, the fear stemmed not from plants themselves, but from the insects such as the bees and yellow jackets attracted to plants in their backyard. Their father explained that this was the reason his children did not want to be around dense plant growth.

Still another child expressed dismay when his mother explained that sugar comes from a plant, fearing that it would be dirty:

Adult: Sugar comes from the sugar cane.

Child: What's a sugar cane?

Adult : It's like big stalks of trees.

Child: Sugar comes from trees?

Adult: It's like a big bunch of—big—, like, trees. That's where it comes from.

Child: Blecch. I hope it's clean.

Adult: It's clean, believe me. They go through a lot of processes to get it like it's supposed to be. BC626-1

It should be noted, however, that this child also reported learning at the Conservatory that people could get sick from eating some plants, but did not appear to express the knowledge in negative emotional terms.

Curiosity about Plants

During conversations we also probed to find out what about plants might pique respondents' curiosity. We identified three areas:

- By far, respondents' primary questions about plants were about how to grow them successfully.

How to keep [plants] alive without doing a lot of work. EG626-1



How to keep [plants] alive....What type of bed is good for what plants? EF708-2

How to preserve them in the—you know, in your house. I know you need to water them but sometimes you can overwater them. BC703-1

- Respondents also expressed interest in the names of plants, both around the Conservatory and sometimes in areas near their homes.
- Interesting uses for plants (e.g., as medicine) was also a topic of curiosity for some respondents.

Overall, respondents' perceptions and connections with plants were wide-ranging, encompassing personal memories, emotional associations, and even connections with broader environmental concepts. The most significant aspect of this range of connections was that these associations were the reasons that respondents gave as primary reasons for why plants were important.

It is also important to recognize that respondents primarily thought of plants' importance in terms of how plants affect people as individuals, then secondarily in terms of how plants fit into the environment. Most did *not* think about plants' importance from a scientific viewpoint.

Another striking aspect of these connections was that they illuminated the fact that respondents' connections stem primarily from their *everyday experience* with plants. Respondents' stories and comments were often grounded in memories from childhood or from experiences with family, from their experiences growing gardens (or knowing someone who did) and from their own emotional response to plants. This is an especially important finding because it points to the fact that visitors' primary point of reference to plants will be grounded in their daily and common experiences with plants, rather than in more abstract concepts. We discuss this concept further in the Photosynthesis section.

Given that respondents based their connections to plants on their everyday experience, it is perhaps not surprising that respondent curiosity about plants related largely to the very practical question of how to grow plants more successfully (rather than more abstract or scientific questions). Finally, our findings suggest that the recognition that plants provide for people's physical needs (e.g., food) might serve as a potential entry-point for discussing the importance of plants in sustaining life on earth.

Photosynthesis

Assessing respondents' understandings about photosynthesis and its components played a major part in this study. As discussed in the methods section, we used a magnetic board activity to focus discussions and illuminate respondents' conceptions. In the interviews, we probed a number of topics, including conceptions of photosynthesis in general (e.g., attitudes, understanding of the photosynthesis process) as well as specific components of the process (e.g., water, sun, air, sugar). This method allowed us to uncover respondents' mental models about the topic.



In the topical framework for this evaluation, we broke questions into discrete sections, first of understandings of photosynthesis in general and then about specific components. We used this strategy to ensure that all pertinent aspects of the topics would be addressed in the study. Of course, in the real world, one does not compartmentalize as such, but instead, aspects of a topic are integrated into one's overall conceptions or mental model about a subject. Therefore, instead of treating aspects of photosynthesis as discrete sections, we present them here as holistically as possible, describing the various perspectives and levels of understandings or concepts about photosynthesis.

Understandings

In our analysis and discussion of respondents' conceptions of photosynthesis, we used a knowledge hierarchy—a technique for presenting the range of respondents' understandings about a certain topic within the context of the intended exhibition goals (Perry, 1989). A knowledge hierarchy usually describes six or seven levels of understandings that characterize a range of respondents' conceptions about a topic, usually by increasing levels of sophistication. A knowledge hierarchy does not identify the number of visitors in each category; rather, it describes the *range* of understanding about the topic as identified through the data. Illuminating the *range* of understanding, rather than emphasizing the numbers of respondents within each level, is especially desirable for institutions concerned with reaching multiple audiences. The knowledge hierarchy enables museums to recognize that they have at least some visitors at all levels and to understand those levels.

The photosynthesis knowledge hierarchy consists of six levels. The hierarchy's lower levels represent incomplete understandings of the topic. At these levels, conceptions emerge about what plants need in order to live, but visitors at these levels do not have a conception of photosynthesis per se. Only at Level Four in the hierarchy does a clear understanding of the core concept of photosynthesis emerge (i.e., plants make sugar as their own food). Below we discuss each level in detail. In addition, in Appendix E we provide a graphic representation of each level of the hierarchy.

Level 0: I don't know what plants need in order to live.

Level Zero on the hierarchy represents a lack of understanding about the basic aspects of what plants need to live. We found no respondents at this level. It is likely that even young children with some experience with plants (e.g., watching parents grow houseplants, growing plants from seed in pre-school) have formed some conceptions that plants need certain components in order to grow. In an evaluation for an exhibition on soil, for example, Perry and Garibay (1996) found that even younger children understood that plants need to be planted in soil in order to grow. Thus, only very young children, who have no experience with plants, would likely be at this level.

Level 1: Plants need sun and water in order to live.

Levels One and Two on the hierarchy indicate a basic, though highly incomplete, understanding that plants need certain components to live. Respondents at Level One identified both sun and water as key to plant survival, but lacked an understanding of exactly why plants need them.



While respondents at this level often discussed sunlight as a critical component, they had difficulty articulating how plants use it. Some respondents at this level equated a plant's need for sun with a need of people, saying that both need sunlight to live.

Interviewer: What if they didn't have the sun? What would happen to the plants?

Respondent: It would die. EF502-2

Interviewer: What happens if I take the sun out of the picture?

Respondent 1 (Child): It would be dark. (laughter)

Respondent 2: Everything would die....My sister, she went to Norway. At certain times of the year, they only have one hour of sunlight. So they have a high suicide rate because people get really depressed because they don't have any sunlight. So you need sunlight. EG626-1

Respondent: The sun helps [a plant] too if it doesn't get too hot....If the sun gets too hot, it can kill it [the plant].

Interviewer: Now how do you think they use sun? How do plants use sun?

Respondent: It's the light up there. I believe the light from the sun, if it's not too hot, makes the plants grow. CG612-1

Interviewer: Okay, What do you think would happen without the sun?

Respondent: The plant would die and people would die...Everything dies.

Interviewer: Would die because what?

Respondent: Because it would get too cold. EF522-1

Others at this level sometimes equated sun with energy and speculated at a connection, but were unable to explain the relationship. For example, when asked what a plant or tree uses the sun for, one respondent at this level said,

And this [sun] is the energy and the energy shines on the plants to make it grow. And this is the rain that helps the plants grow. BC424-2

Other studies indicate that this may be a prevalent gap for some people. Bell (1985), for example, found that students in his study appeared to have little understanding of the function of the energy obtained from sunlight. They knew sunlight was a requirement, but did not know why.

A few people we talked to at this level also had misconceptions about how plants absorbed sunlight:

Interviewer: How do you think the sun, like, gets into the plant? Like, how do you think it takes it in?

Respondent: From the soil. BC606-2



While a basic understanding about the need for sun and water probably develops early due to experiences growing (or watching others grow) plants at home or at school, these understandings can often be incomplete, and some experiences can reinforce misconceptions. For example, Smith and Anderson (1984) indicated that:

Incomplete experiences can lead to misunderstandings about the role the sun plays in plant growth. As a result of an experiment where grass seeds were grown in the dark, most members of a fifth grade class concluded that plants don't need light to survive, although light does help make plants healthier. These conclusions were based on the observations that the seeds did grow in the dark—they even grew taller—but they were an unhealthy yellowish color (Smith & Anderson, 1984).

Respondents at Level One of the hierarchy also knew plants needed water to live, but usually did not know why. A few speculated that water helps plants stay hydrated, but could not expand on the subject and tended to talk about it in general terms. A typical comment about why plants need water is reflected in this statement:

[Water] helps it [the plant] grow. And makes it healthy. EF502-2

It is important to note that while respondents at Level One identified water and sun as critical to plant growth (and sometimes soil), their mental models did not include air as a basic need for plants. For example, when asked what a plant needs to grow, a respondent replied,

It [a plant] needs soil and it needs water. And it needs sun. BC424-2

This finding is consistent with previous studies on what students understand about plants:

Most fifth graders in a Michigan classroom identified sun, water, and soil as the basic needs of plants—but few seemed to know about plants' need for air. (Smith & Wesley, 2000).

Level 2: Plants need sun, water, and carbon dioxide in order to live.

People at Level Two on the hierarchy were similar to those at Level One, but they also added air to the equation, stating that plants needed carbon dioxide to survive.





Figure 2. This image illustrates how sun, water, and CO₂ are identified as necessary to plant survival. At this level, however, components are seen as “things” plants need, rather than components that are part of a process.

An important aspect of respondents’ mental models at this level was the concept of an “exchange” of carbon dioxide and oxygen between plants and humans.

And then a person eats the apples and his oxygen goes to the trees. I mean his oxygen comes in, he breathes out carbon dioxide, the tree breathes in carbon dioxide and out oxygen. EF522-2

They [plants] need carbon dioxide. We need the oxygen.... They need carbon—we breathe out carbon dioxide and they give us oxygen. BC703-2

The initial idea was here’s the tree and here is the human. The human releases carbon dioxide. And the plant takes that in and releases oxygen in return for the human. CG522-3

The few respondents at this level who did not discuss the carbon dioxide/oxygen exchange stated that plants needed air as people do—to help them grow, make them “stand tall,” etc. Mostly however, the carbon dioxide/oxygen exchange process was a prominent component of the Level Two understanding.

Many conversations with these types of respondents revolved around the reciprocal relationship between plants and humans, taking in one type of gas and giving off another. Respondents at this level tended to have strong notions about the interdependence of plants and people because of humans’ need for oxygen to live. This association also often led to respondents discussing how at least one major reason for plants’ importance was their benefit to humans.

Quality of air would be really poor if there wasn’t any [plants] at all. BC703-2





Figure 3. The pervasive conception about the exchange of oxygen and carbon dioxide between plants and humans is illustrated in this image.

The oft-repeated discussion about the carbon dioxide/oxygen exchange was so prevalent, in fact, that it seems to be a widely held notion. Based on our interviews and earlier literature review on photosynthesis, we believe that most adults fit into this category. A national study by the National Science Board (2004), for example, found that almost 90% of American adults agreed with the statement, “The oxygen we breathe comes from plants.”

Research also indicates, however, that students do not easily understand the role of various gases on plants. Haslam & Treagust (1987) found that younger secondary students, in particular, were easily confused about the roles various gases play in photosynthesis. For instance, about a quarter of the younger students agreed that plants give off more carbon dioxide in sunlight, while nearly equal numbers agreed that oxygen was used to make food.

The exhibit, therefore, must still stress and clarify these processes for younger visitors. Further interpretation will help parents talk about oxygen and carbon dioxide to their children (and to help everyone stay clear about which gas is which).

It is important to note that those at Level do not equate a plant’s need for sun, water, and carbon dioxide with photosynthesis. Sun, water, and carbon dioxide are instead seen as discrete components rather than interrelated parts of a process.

In addition, at this level, the question of why plants produce fruit was not connected to photosynthesis. When we asked why plants produced fruit, respondents at this level could not able to speculate why this might be. These respondents tended instead to recall that fruit is a food people eat. In fact, respondents at this level did not associate sugar with plants at all, or, at most, associated it with sugar cane and table sugar. (See the Sugar section for further discussion). For example, one couple was confused about whether apples had sugar in them:

Respondent 1: Sweet apples [have sugar].

Respondent 2: But that don’t mean its sugar. Have you ever had a sweet apple?

Respondent 1: Have you ever had a bitter one?

Respondent 2: That don’t mean it’s— it was bittersweet. EF617-1



Level 3: Plants have a process in which they take in water, sun, and carbon dioxide, and produce oxygen and sugar.

Respondents at Level Three on the hierarchy understood both the inputs and the outputs of photosynthesis. Nevertheless, they still had a sketchy understanding and did not necessarily directly relate these “inputs and outputs” to the photosynthesis process. People we talked with at this level articulated the same understandings of sun, water, and carbon dioxide as those on Level Two, but also discussed sugar as an output, usually in the form of fruit that humans eat.



Figure 4. This family group focused their conversation on things plants need to “survive,” mentioning sun, water and air (as well as soil) as key components. Sugar was identified as something sweet found in the apples produced by the tree and eaten by people.

The following quotes illustrate the focus on sugar in the form of fruit.

Interviewer: And you’ve got sugar on there. What’s that about?

Respondent: Well I think that’s on the apple, which sustains the human. BC523-1

We get sugar from fruits and natural sugars. I think vegetables too [are]...plant products. BC502-1

Respondents at this level also seemed to recognize that some process takes place “inside the plant” with these inputs/components, although their conceptions were incomplete.

Interviewer: Like, how do you think it [the plant] makes the sugar?

Respondent: By going through the stems and they spread out to the leaves. BC606-2

[Plants produce sugar] Through the root system and through the watering of the plant mixed in with the various chemicals in the plant from process of the photosynthesis, breaking it down and adding it to the water. Which...I believe it’s—like also helps the



leaves and the seeds and the fruit be produced. Obviously again that's going to be seen in the fruits that we eat, such as apples and oranges, watermelons, and things like that, you know. That's the sign that the sugar that was in the actual branches, or in the vine itself, or the trunk of the tree is being used to make this particular fruit. BC703-1

Our analysis indicates that while these respondents included sugar in their mental models, they did not seem to understand that plants make their *own* food (i.e., that the plant uses the sugar). Instead, they seemed to equate sugar with something sweet that humans often benefited from in the form of fruit. In other words, respondents at this level did not understand that the production of sugar was photosynthesis and equated sugar as only being in fruit.

Level 4: Plants have a process in which they take in water, sun, and carbon dioxide, and produce oxygen and sugar. This sugar is used by the plants as well as people.

Respondents at Level Four on the hierarchy understood that plants make their own food and could usually give a basic definition of photosynthesis.

It's [photosynthesis] very important.... [it's how] plants actually make their food. EF523-1

And it [the plant], like, makes the carbon dioxide into sugar. BC523-2

And then the air, which we should have another one [more arrow on the magnetic board] over here, because the trees and all the plants, when they make their food, they take our carbon dioxide, which is what we breathe out when we exhale, and they turn that into their food as well with water and light from the sun.... When the trees are done making their food, then they release air. BC424-1

Respondents at this level had a good basic understanding of photosynthesis and could explain the broad aspects of the process. They were unclear, however, on the actual molecular process involved. Generally, we found that students who had recently studied the topic in school were mostly the ones at this level of understanding. In contrast, we saw few adults at this level. That is not to say that all students had a basic understanding of photosynthesis, but rather, that those with recent exposure were able to recall specifics and had a more complete mental model. In our interviews, we found in general that the more time that had passed from when a respondent learned about the topic in school, the less likely that she or he had a basic understanding of the process. (The exceptions, of course, are adults in specific fields of study that utilize these concepts.)

Level Four respondents also had a more sophisticated understanding of sugar than those at lower levels of the hierarchy. Respondents at this level saw sugar as a source of energy for plants. For example,

Interviewer: And so where does the sugar end up in the plant?

Respondent: All throughout it, I think. BC523-2



Interviewer: You talked about the trees producing sugar.

Respondent: I know that it's a part of the—it's called photosynthesis, right? That effect where at some point the sugar—the sugar is made in the leaves or in some part of the tree that nourishes—provides the nourishment for the rest of the tree. CG522-1

Sugar—I think it's produced in the leaves of a plant. BC502-3

Some respondents were still confused, however, about what the “sugar” in photosynthesis was—is it glucose or fructose that plants produce? Respondents sometimes discussed how complex a sugar plants produce, the difference between different types of sugar, and which types of sugar people use. For example, one group had the following discussion:

Respondent 1: I really don't understand the full process, but I know that sucrose is a mix of fructose and glucose and if you suck on sucrose, which is in most of your foods, then...

Respondent 2: [it] comes from fructose.

Respondent 1: And they take the glucose straight in its energy and the fructose is broken down into glucose, which is broken down into energy. BC502-2

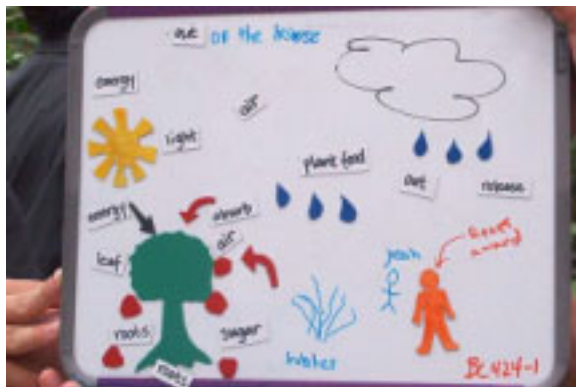


Figure 5. One of the respondents who created this image explained, “So sugar we put by the tree, because the tree is producing its own food—which is what all plants make—and there is a product called glucose which is similar to sugar.” People “reap the rewards” when we eat fruit.

Throughout the various levels of the hierarchy, confusion reigned about what exactly this sugar was. In our literature review, we noted,

Most of the research papers we read talked about plants producing either food or carbohydrates—children's understanding of sugar production was not a major focus of this research. We found one warning in the work of Barker & Carr (1989a). They described the results of experiments where students tested leaves for starch under various conditions, and concluded that: “Pupils found the anticipated conclusion, that plants contain starch and/or sugar difficult to reconcile with their everyday experiences....



(Except for nectar and sugar-cane) plants patently do not taste sweet (Barker & Carr, 1989, p. 42)."

Our results also indicated that respondents did not have a basic understanding of sugar as it relates to photosynthesis. Instead, respondents' conceptions of sugar were more closely associated with table sugar and candy. We discuss this further in the Sugar section of this report.

We also noted that some Level Four respondents mentioned that chlorophyll was involved in the process of photosynthesis. For example,

It [the plant] uses the energy from the sun and green plants use the chlorophyll as kind of the little chemical power plant and the carbon dioxide and water are only parts of it. And in the process, it uses the energy to split the carbon dioxide. It releases the oxygen from the plant. The plant doesn't need it. That's just a byproduct. And it breaks it down and uses the carbon and the energy to form sugar. BC502-2

Interviewer: How do you think the plant makes the sugar? Like you've got light and you've got water and carbon dioxide.

Respondent 1: I think it's chlorophyll... Chloroplast—I think they take in the sunlight and they turn it into sugar.

Respondent 2: I think the chloroplast is in the leaf along with the chlorophyll.

Respondent 1: And if you've seen it under the microscope, it's, like, these little green cells. They look like this. And they're just all around....

Interviewer: And so the chloroplasts, they take in which part again?

Respondent 1: Sunlight.

Interviewer: Sunlight. And what do they do with that?

Respondent 1: I think they turn it into sugar.

Respondent 2: They combine all the elements and they get it to sugar. BC523-2

While these respondents were beginning to indicate some understanding of this process, we noted that most only had a vague idea of the role chlorophyll played in photosynthesis.

Level 5: A more complete understanding of photosynthesis, including an understanding of the chemical processes involved.

A Level Five understanding of photosynthesis, as discussed in the literature, would require a change in terminology from the ways respondents at previous levels talked about the process. In addition, it would require thinking in terms of chemical reactions and cycles.

People at this level of the hierarchy would tend to:

- Think in terms of photosynthesis as plants fixing energy, rather than making sugar.
- Write chemical equations to show the interrelationships.
- Talk specifically about glucose (or, more generally, carbohydrates) as the initial product of photosynthesis, and talk about the synthesis of starches and other biochemical products.



- Compare and contrast the chemical process of respiration with photosynthesis and consider the materials (such as carbon) being cycled.

We found no respondents at this level of understanding. We speculate that science educators on the secondary and college levels, who might use this exhibit, would be at this level of the hierarchy.

The range along the hierarchy

As one looks through the levels along the hierarchy, it is important to note that:

- Those at the lower levels of the hierarchy tend to focus on *what plants need* to stay alive in ways that seem practical, concrete, and based on everyday experience with household and garden plants.
- Those at higher levels tend to focus on the understanding of the *process* by which plants take things they need and convert them to something that they can use. The orientation is more academic and abstract and is based on things learned in school rather than based on everyday experience.

This seems to imply that helping someone move up the hierarchy requires more than just supplying information—one would also have to *help shift how the person relates* to that information. Our findings about the effects of school learning are a case in point. While school classes on particular topics help to move people up the hierarchy, as people move away from their school days, they tend to shift their emphasis away from the scientific understanding of photosynthesis to a more concrete (rather than abstract), practical (rather than academic) mental model grounded in their everyday world. (The reader might recall that in the section on plant connections, we noted that respondents’ associations and connections with plants were also grounded in everyday experiences with plants.)

Thus, it may be important to find ways to help visitors think about photosynthesis in practical terms, even when they are thinking about an abstract process. Is there, for example, a way to show visitors that understanding photosynthesis can help them raise healthier plants, grow better tasting tomatoes, or even improve understanding of human nutrition?

As the Garfield Park team moves forward in the exhibit development process, it is important to keep in mind the purpose of the learning hierarchy developed from this study. A learning hierarchy is useful in mapping out and understanding the *range* of visitors’ conceptions about photosynthesis. It is *not* intended to suggest that the exhibit team should gear the exhibition toward one particular level that visitors should achieve. On the contrary, the hierarchy illuminates the fact that there will be at least some visitors at all levels of the hierarchy. The goal, then, is to find ways to engage visitors, regardless of what level they enter, and, through their experiences at the exhibition, help them develop a deeper or more meaningful understanding of and/or connection to the topic.



Photosynthesis: Associations and Attitudes

We were also interested in understanding respondents' associations and perceptions about the term "photosynthesis" and the topic itself. We saw some disconnect between understanding the term *photosynthesis* and understanding the concept. While people at Level One generally had no understanding of the term *photosynthesis*, and those at Level Four had a good (but incomplete) understanding of the term, some people who knew the term didn't always give the correct definition or only had a vague idea of what it all involved. Others who had a good understanding of the concept did not always recall the term. One person, for example, with a Level Four understanding of the process thought it was called the nitrogen cycle instead of photosynthesis (as illustrated in the figure below).



Figure 6. This respondent indicated that plants absorb light, which triggers chlorophyll as part of the photosynthesis process. She added that the process involves sun light, water, and a release of oxygen, and produces carbohydrates (simple sugars). This respondent said she thought this process was called the nitrogen cycle.

This finding implies that exhibit designers cannot assume that even those visitors with more familiarity with the process will actually equate it with the correct term.

As might be expected, respondents made unique associations about photosynthesis based on their backgrounds, education, and personal experiences. A film historian, for example, who had a basic understanding of photosynthesis as a scientific process related it to his own work:

*Like the motion photographers in the late 19th century were photosynthesizing images.
Like the development of cinema or animation. EF522-2*

Despite the idiosyncratic nature of respondents' personal associations with photosynthesis, some common associations and attitudes emerged during our interviews. The most common association respondents made with photosynthesis by far was that it reminded them of something



they learned in school or science class. Some children, usually elementary- or middle-school-aged, said they had recently studied it. One child explained,

Respondent: I think that I knew that [the word photosynthesis].... I forgot the word but I know what the formula is, really.

Interviewer: But you knew the formula. Okay. Where did you hear that formula?

Respondent: In Columbus School, we have this kind of new book of science. EF617-2

Adults were more likely to say they related it to science and remembered hearing about it in school—even if they couldn't recall the specifics. For example,

*I probably did [hear about photosynthesis in school], but it's been a while. (laughs)
EF708-2*

Well, I think it's kind of like between sort of interesting but also kind of like, "learned it in school" and sort of forgot about it. I mean when I go outside and I'm like—just normally breathing, I don't think about photosynthesis and how that affects me. But sometimes I do. It's just not as often. I think I forget about the stuff that we learned in school a lot. CG522-3

[I heard about photosynthesis] Several times....starting in grade school up through high school. EF523-2

Surprisingly, a few respondents actually related the term to TV, since that is where they had heard the term before—though even these associations were generally related to science class. For example,

Respondent 1: That's [the word "photosynthesis" is] from [the TV show Full House].

Respondent 2: We were just watching Full House.

Interviewer: Were they talking about that on Full House?

Respondent 1: She [a character on the show] just had a science test. BC523-1

[I heard the term "photosynthesis" on] TV shows, like a TV show that we saw at school. They talk about a lot of different things. We learned a lot from those shows. EF708-2

Some respondents, especially those with a better understanding of photosynthesis, talked about how photosynthesis reminded them of growth, life, energy, and/or the process of plants living.

Green. I think of green.... Green plants, the process.... Well, the breaking down of carbon dioxide. BC523-1

*I think my first thought is just life. Photosynthesis is a process that keeps life moving.
CG522-1*



Many respondents, however, did not seem to make any associations with photosynthesis. These respondents, who typically had little knowledge about the process of photosynthesis, said either that they had not heard the term before or could not remember anything about it. For example, one respondent said,

I've heard of it [the term "photosynthesis"], but I don't know what it means. BC626-1

During these interviews, some adults were embarrassed or uncomfortable when asked about the topic.

Interviewer: When you heard the word photosynthesis...what was your reaction?

Respondent 1: Oh no, science!

Interviewer: [Later in the interview.] Honestly, you heard the word, you thought "Oh no, science!" Why did you say [that]? Were there questions that popped into your mind?

Respondent 1: Well, no. I kind of—plants are not my forte. So...I have a garden. I know it needs water and sun... EF522-1

As we noted earlier, middle school-age or high school-aged children generally had a more academic understanding of photosynthesis than adults.

Associations and attitudes regarding photosynthesis have a number of implications for the exhibition. It is important that the exhibition not assume that adults know the term "photosynthesis" while children do not. The team must also be cognizant that some adult visitors may feel embarrassed or intimidated by their lack of knowledge. Visitors who do not know the term or who may feel unsure about their understandings should not be made to feel uninformed or "talked down to." One challenge is to develop interpretation allowing adult group members to guide their family's interactions even though parents may have little academic knowledge about the topic.

Moreover, the exhibition must overcome the idea that photosynthesis is an esoteric concept to be learned in science class and then forgotten. By showing the importance of photosynthesis to everyday life, and ultimately to human survival, the exhibition could help visitors see the process as more than an abstract or scientific word far removed from their experiences.

Plant Food

As we talked with respondents about the topic, we also examined their conceptions of the term "plant food." We found that the term was confusing to many respondents, regardless of whether they were at Level One or up through Level Four. (The term "plant food" seems to be a layperson's term for fertilizer.) One respondent, for example, who indicated an interest in horticulture explained:

Interviewer: So what kind of stuff would be plant food?

Respondent: Okay, plant food. Let's see, we have nitrate and potash. BC703-1



Others equated the term with what *plants* provided *people*. That is, fruit is plant food for people!

The apple [is plant food]. It's like eating a part of a plant. Like plant food. Everyone thinks about food for the plant. But I'll say, like, "Oh I'm really hungry for plant food."
EF522-2

Interviewer: And what about plant food?...Tell me what you were thinking when you put that there.

Respondent 1: It's more like the apples.

Respondent 2: Plant food. That comes from the plant. BC703-2

Some respondents identified light and water as plant food. For example,

Interviewer: Why did you put plant food on there?

Respondent: Because I think you need a little plant food to help it grow. First it needs water and food to live.

Interviewer: So what would be an example of plant food?

Respondent: Water is definitely plant food. I don't know if you would consider the seeds plant food, but I know you have to plant that to get some food. I don't know of any others.
BC626-1

These findings are consistent with studies we cited in the literature review:

- Many children describe water as food for plants sucked up by their roots; most of these students considered the soil to be the source of the plants' food (Smith & Wesley, 2000).
- Most primary students, and many secondary ones, stated that food stored and used by green plants was obtained from the soil, through the roots (Simpson & Arnold, 1982).
- Plant food might be considered water, fertilizer—plant food—or anything else taken in from the outside, including air (Bell, 1985).
- Even the term “energy” for plants, instead of the term “food,” still has potential to confuse. For example, many respondents in this study equated the sun with providing “energy.” This seems to be a fairly common conception. Boyes & Stanisstreet (1991) found that 93% of first-year British undergraduates said that they were sure plants got their energy from the sun. However, respondents were allowed to choose more than one energy source: 31% of these same students *also* agreed that plants got energy from the soil, 28% thought plants got energy from water, and 20% thought plants got energy from air.



Because of the confusion surrounding the term “plant food,” it is important to think through potential interpretive strategies for this concept. Depending on the direction of the exhibition, and how interpretation is weaved through, it may be worth developing a unit that confronts these confusions directly, discussing what food really is and how it comes from for both plants and people.

In the rest of the exhibit, however, it may pay to avoid using the term “plant food,” which might activate or reinforce people’s misconceptions. Rather than focus on the term itself, it is probably much more important for the exhibition to emphasize and help visitors understand what plants *do* with the sugar they produce.

The Role of Soil

In the magnetic board activity, many respondents placed the word “soil” in their arrangements (often by tree roots). While the topic of soil, per se, was not the focus of this study, we did use this opportunity to explore visitors’ conceptions about soil in relationship to photosynthesis and helped illuminate respondents’ mental models about plant food.

Not surprisingly, the most prevalent conception about soil found among our respondents was that plants needed it to grow. Even respondents at Level One of the photosynthesis-understanding hierarchy said that soil was essential to plant growth, even if they didn’t quite understand why. One respondent group said:

Respondent1: It’s [the soil is] food for the tree to grow.

Interviewer: Okay. It helps the tree grow. So how does it get this plant food?

Respondent1: By water.

Respondent2: Like, the tree eats the soil up. CG612-1

Many respondents at all levels of the hierarchy went on to indicate that soil provided nutrients to plants.

If the soil is rich, they get the nutrients they need to grow better. BC502-1

Well, the roots need nutrients—like food. They need different things to help them grow. EG626-1

Well, that’s true, that they get nutrients from the soil. BC606-1

As discussed in the Plant Food section of the report, some respondents considered the nutrients that plants absorb from the soil to be plant food. One respondent explained,

The plant food of the tree is the soil. The soil produces nutrients. EF617-1

Overall, respondents at all levels of the hierarchy had a fairly sketchy understanding of (and even misconceptions about) the part that soil plays in the photosynthesis process. For example, one respondent indicated that:

[The plant’s] roots are in the soil, and they absorb nutrients and the rain—and they produce sugar, which goes into the apple. EF522-2



A respondent with a Level Four understanding of photosynthesis speculated:

Interviewer: Do the soil and the nutrients play a role in the photosynthesis?

Respondent 1: Oh I'm sure that in the leaf, you know, they get the nitrogen, right? Our plants take up nitrogen.

Respondent 2: Through the roots.

Respondent 1: I'm sure. It's all connected. And...it does eventually wind up in the leaves.
BC502-3

Other misconceptions regarding soil heard from respondents included that sunlight gets absorbed through soil and that nutrients in the soil come from water.

While we were unable within the scope of this study to explore respondents' conceptions of nutrients in more detail, our findings regarding soil, plant food, and ideas about photosynthesis suggest confusion around such terms as "plant food," "nutrients," and even "energy." Based on the data, the word "nutrient" might mean different things to people when they are thinking about plant fertilizers rather than the food humans eat. In exhibition interpretation, it will be important to use care in what words are used and to be clear about what the term refers to as well as who the "nutrients" are for (i.e., plants or humans). This should be an important focus of formative evaluation.

Sugar and "Sugar from the Sun"

In our discussions of the knowledge hierarchy, we discussed the ways in which respondents conceived of sugar in relation to photosynthesis. We noted that while this understanding emerges at Levels Three and Four, these mental models were still incomplete. In this section, we expand the discussion to include overall conceptions about sugar. Findings indicated that:

- Respondents' top-of-mind association with sugar was with either table sugar or sweet things, such as candy.

Interviewer: What comes to mind when I say the word "sugar"?

Respondent 1: Candy.

Respondent 2: Sweets. BC606-2

Respondent 1: [When I hear the word "sugar"] I think of the product, you know, I have to eat all the time.

Respondent 2: The white stuff in the bag. CG522-2

Sugar makes me think of ice cream. BC502-3

- Some respondents associated the topic with sugar cane or the process of making refined sugar.

It made me think of Hawaii.... I've been there. The C&H plant is there.... C&H Sugar.
BC523-1



You know, when you first think about how sugar is made, I automatically think sugar cane. But I think that there's different kind of sugar, so I think that, like granulated sugar, the sugar we use for baking...that maybe comes from sugar cane. But most of it comes from sugar cane, but maybe a small portion of it comes from fruits or something. BC703-2

Interviewer: Well, when you hear the word "sugar," what first comes to mind?

Respondent: Sweet cane. EF708-2

- The strong association with sweetness and sugar meant that many respondents believed that sugar is only in "sweet" parts of a plant or in fruit.

But some plants make like a nectar.... That insects use and pollinate. Right? Nectar is like a--they're making some sort of...sweet. BC502-1

Like why the plant makes sugar?...Sort of like the pollen where bees would want to come for pollinating it. Bees would be attracted to the sweet part. BC606-1

The sugar is in the fruit. EF523-1

Interviewer: If I were to ask you if you would take the word "sugar" and put it someplace on the picture, where do you think it would go?

Respondent: [On the] Apple.... Because it's sweet. EF708-1

Given the predominant association of sugar with sweet products such as candy and even fruit, it is not surprising that our research found that the exhibition's title, "Sugar from the Sun," caused confusion with most of our respondents. When asked what they thought of on hearing the phrase "Sugar from the Sun," most respondents speculated about sugar being something sweet. For example,

I don't know the process but I mean on a—when there's a summer that's particularly cloudy, or bad weather, the fruit that's produced by the—like, plants, will not be as sweet. So—and I don't know the process. It's part of photosynthesis. BC502-3

Sugar from the sun? I'm just assuming that that means we need the sun to make—to help plants grow to get our food from. EF502-2

A more common response to the title, however, was simply that the phrase was unclear and made no sense. For example,

I don't really understand how it makes sense. I mean I could understand if I knew about it, but I don't. CG522-3

I'd think "Sugar from the sun!" You're crazy. My sugar comes from South America." That's what I would say. CG522-2



In their initial conception for this exhibition, the team hypothesized that focusing on sugar could help avoid some of the confusion of terms by which photosynthesis is traditionally explained, such as “food” or “producer.” Our findings indicate, however, that respondents’ strong associations with sugar as something sweet, such as candy, will also be challenging, because the topic of photosynthesis requires visitors to think about sugar very differently than they currently do. In addition, while using certain sweet economic crops as a “hook” for the exhibition is a good starting point, the team will need to be careful about inadvertently reinforcing visitors’ preconceptions.

Our findings strongly suggest that it will be critical to help visitors understand what plants *do* with the sugar. It is important to help visitors understand that this substance, produced through photosynthesis, is a building block for everything else that plants (and humans) need to live and grow. The process, rather than simply conveying the fact that plants produce sugar, is essential. If the team cannot get that point across, then the “Sugar from the Sun” approach will likely leave people feeling confused about the title and main point of the exhibit.

A way to think about this exhibition’s “big idea”: “Plants use energy from the sun to make sugar, then use that sugar to make everything else they—and humans—need to live and grow.” This approach would address the sweetness dilemma, as well as the challenges of addressing the concept of “plant food.” It might also make photosynthesis seem more relevant, because of the link to human nutrition; starting with sugar, plants make all the food that humans need to survive.

The team could consider playing off visitors’ preconceptions and introducing economic crops that people would not associate as being sweet, explaining that they, too, use sugar. (While hot peppers, for example, are not sweet, they do use sugar). This element of surprise and fun may be useful in engaging visitors. Of course, that approach still must emphasize what plants *do* with the sugar (i.e., *how* they use it). It will be critical to test approaches in formative evaluation.

Finally, given the interest (and confusion) from some respondents about the type of sugar plants make in photosynthesis, the team may want to consider a component discussing the different types of sugar (e.g., glucose, sucrose, fructose) and/or the four sources of sugar that humans get from plants:

- Maple sugar, made by intercepting sugar as it was being transported from one place to another.
- The sugar in sweet fruits.
- The plant parts used to make table sugar and sugar for candy: sugar cane, sugar beets, corn syrup, whatever.
- Honey, which is made from flowers, another place where plants concentrate sugar.

These examples can help show that sugar really is widely distributed throughout plants, even if most plant parts don’t have enough sugar to taste sweet to human tongues.



The Garfield Park Conservatory Experience

To better understand the mindset and context under which participants visited, we also explored their perceptions of Garfield Park Conservatory. We were especially interested in the way they described the Conservatory and how they discussed their experiences there.

General Perceptions

Our findings indicate that respondents—both those from surrounding neighborhoods as well as those from other communities—generally had positive perceptions of the Conservatory and valued many aspects visiting Garfield Park Conservatory. Visitors particularly enjoyed seeing many different types of plants as well as the experiential nature of their visits, which we discuss in detail later in this section.

Though GPC staff questioned whether significant differences would exist between community respondents and other casual Conservatory visitors, we found no major differences related to the main themes explored in this study, including in local visitors' their overall reactions to GPC.

Several community respondents told us that they had been coming to the Conservatory for many years. A few respondents, for example, relayed that they had visited the Conservatory regularly as children with their parents and now come back on their own. Those who now had children remarked that they brought them as well. Community respondents sometimes also mentioned that they liked that the Conservatory was family-oriented—a place where they could bring their children.

Some community members who, prior to this study, had never been to the Conservatory told us they were happily surprised at what they found at GPC and indicated they never knew what was available at GPC.

I never realized [the Conservatory] was like that....I had no idea [it had] the plants and all. It's really nice. I enjoyed it. CG612-1

I think—I've never seen it. It's unbelievable to me. Well, I didn't know they grow flowers inside like that.... [It's] beautiful. EF708-3

Some local respondents, including those who had visited the GPC before, noted a possible lack of awareness about the Conservatory in their communities.

I don't know if too many people over there [in my neighborhood] know about the Conservatory. BC703-2

[The Conservatory] is new for me...I'm telling you, I've been living here almost six years, since 1998, [and] I didn't know about this place. EF617-2

Respondent: I really don't think they're aware [of the Conservatory].... If you want to be for real, a lot of us don't go there.

Interviews: When you say the city, you mean downtown?



Respondent: Well, City Hall, the [local] Alderman's office.... And stuff is not really advertised in the community.... I don't think there is any advertising in our neighborhood around the Garfield [Park] Conservatory.... And especially in my neighborhood—you know, it's not a rich neighborhood as far as [money goes] and the Conservatory, they offer a lot of things that [are] free. BC626-1

While respondents' perceptions of the Conservatory were generally very positive, and new community visitors enjoyed their experience at GPC (sometimes indicating they would return), we did take note of one particular interview. In this discussion, a community respondent raised some questions about the degree to which improvements at GPC actually benefited the surrounding community. This respondent was a long-standing visitor of the Conservatory who began visiting as a child; her children are currently involved in GPC initiatives.

So coming down here and seeing the [Conservatory Kids] program and then with all the renovation that they've done and the programs that they brought over with Chihuly and the dinosaurs and all that and the advertisement that it's just booming.... And actually it was somewhat of a—to us in the community [there were] pros and cons to how they have addressed it. Because they took our train station at Homan and Lake and moved it down to Central and Lake. And it's quite a nice station as well. We didn't get that kind of [service before]. So it was like they're doing stuff [but] not for us.... Only it's not for the community.... We just happen to be here. And we'll benefit from it. But it wasn't because there was this tremendous concern about us. [Before Chihuly] we never saw this many folk coming in.... I mean to have a trolley from downtown come to the Conservatory, that was unheard of.... I do not totally disagree with it. I think it's been a good thing and it is a treasure in the neighborhood. EF617-1

It should be noted that no other community respondent expressed this view. Given the nature of these comments, however, the evaluation team determined it was important to raise this issue.

Given that that a thorough exploration of GPC and community issues was well beyond the scope of this study (our focus is on the exhibition being developed), our findings are necessarily limited. We recommend a separate study focusing specifically on broader community issues.

The Garfield Park Conservatory Environment

Respondents ascribed a number of qualities to the Conservatory and clearly appreciated it. Visitors enjoyed its aesthetics, uniqueness (particularly in a large city) and its ability to inspire awe and wonder. These characteristics were ones that respondents most often indicated as motivators to visit the Conservatory—respondents want to relax, to “escape” the city, to be in a beautiful place, and to enjoy plants.

Aesthetics

Respondents saw the Conservatory as a unique environment both for its collection and the building itself. Respondents often talked about the attractiveness of Garfield Park Conservatory, primarily because of the diversity and beauty of the plants.

Awesome. It's really beautiful. It's nice to see this in the city. BC523-1



There [are] beautiful flowers and beautiful plants. EF502-2

But the thing I like about this conservatory] is that the plants are a lot more colorful. They're really, really, really vivid. BC523-2

It's pleasant to look at. The outdoor gardens are beautiful to look at. Not too much decorating so that the plants don't get caught in the decoration. The plants are still the focus. But they arrange them in such a way that just makes it really pleasant to look at. CG522-1

A few respondents also commented on the structure itself and the uniqueness of the building.

I usually tell people that I like it here, first of all. And a lot of times the actual building itself I think is really impressive. Like just the age of the building. You don't get to hang out in structures like this all that often. CG522-2

Respite, Escape, and Relaxation

The importance of the Conservatory as a restorative place emerged as a prominent theme in our conversations and was expressed by many of the visitors with spoke with. Respondents talked about enjoying the Conservatory because it provided a calming place where they could relax.

I just like...to look at the different flowers in bloom and just walk through each room. I find it very peaceful. BC502-1

[This place is] relaxing, quiet. Peaceful. EF522-2

It was always very serene here. EF617-1

Whatever problem you have you can come here and you can be very happy...It changes everything. EF617-2

[The Conservatory] is very tranquil, calming. BC502-1

It takes you away from the concrete jungle. BC703-1

This sense of respite seemed to go beyond the mere beauty of the plants and seemed to fill a much deeper need. One respondent articulated it this way.

Respondent: [This place is] soothing to the soul.

Interviewer: What makes it that way?

Respondent: Green. It's warm, it's humid, it's alive. Everything is beautifully done. So I mean you have the most unusual plants. BC502-3



It's a healing place. It's a great place to be. For me being [in] an atmosphere like this is extremely healing because there's life all around me. Things are growing, things are alive and that's just so healing for me to be in an atmosphere like that. And being so close to the earth in this kind of way. Where it's intentionally being preserved. It's intentionally being cared for, [which] is a great thing. CG522-1

Adventure/Discovery

While the peaceful and restorative nature of their experience was very important to respondents, this did not mean that the Conservatory was necessarily seen as entirely passive. For some respondents, discovering new things about plants, or even noticing new plants, during visits was an important aspect of their Conservatory outings. Repeat visitors most often expressed this sentiment.

[The Conservatory is] very exciting and adventurous and there's always something new to see here. Like the other time I didn't notice that they had those little, they're like a fuzzy plant. And this time I noticed them. It was, like, a red plant. BC502-2

Well, each room is so much different than the other, and each time you come, something else is happening. Something else is in bloom or there's a different exhibit. You know—they change the exhibits.... But even the area like over here where you can, you know, you can see the food you eat—the vegetation. You know, see what a cocoa plant looks like. BC502-1

Imagination

For some respondents, a sense of discovery or adventure stretched into a more playful experience. Various Conservatory Rooms sparked their imagination, allowing them to visualize themselves in completely different places. Sometimes, visitors simply imagined themselves away from an urban landscape, in a more nature-filled setting. Other respondents talked about imagining themselves in specific settings or faraway places such as Hawaii or a rainforest.

We were talking about imagining if it was a real rainforest, and, like, they pointed out a spot where, you know, it was so dense in there. I said, but imagine it would be this muggy but you'd probably have bugs biting you all over [and] animals following you. BC703-2

This sense of immersion was very common. Respondents often referred to the Fern and Palm Rooms as two that most inspired them in this way. (We discuss the immersion experience in further detail in the next major section of this report.)

Learning

Since *Sugar from the Sun* is a different type of exhibition than those previously developed at the Conservatory, GPC staff wanted to understand how respondents view the Conservatory in terms of education. In this section, we report on how visitors saw GPC as an educational environment as well as on what “educational” might mean within the context of the Conservatory.



While many respondents believe Garfield Park Conservatory can be an educational place and appreciate the potential educational value of a visit, our research found that this is not a primary reason they come to the Conservatory.

Like reading all the names [of plants and where they] come from [is educational], but...the reason I come in the first place is more to relax. EF523-2

I think you could probably learn what grows on different trees and how big some of the trees are—the leaves—how big they get. I wouldn't just come here to learn. I mean, I would just be looking. BC606-2

Instead, the motivations for visiting, as discussed above, centered on relaxation, to escape the city, to be in a beautiful place, and to enjoy plants. This does not mean, however, that respondents did not appreciate the educational value of the Conservatory—rather, it was simply not their top-of-mind consideration.

Some respondents' conceptions of what constituted an “educational experience” were so grounded in formal school learning that they initially had difficulty with the notion of GPC as an educational place.

I feel that [the Conservatory] it's less than educational. It's more like sort of art. It's more of just an experience. EF523-2

Upon reflection, however, many respondents agreed that the Conservatory was educational, but tended to restrict their conceptions to the most formal aspects possible (such as carefully reading plant labels).

Well, I guess if people come and read the signs, like, I mean, those little signs that say what the plants are, and it says like a little bit about where they're from, I think, some of them do. And then if you stop and read that, then, yeah, it could be educational. But I don't come to learn about plants. CG522-3

I agree with it [the idea of the Conservatory as educational]. We read a lot of [signs]. BC703-2

Other respondents commented that the Conservatory provided opportunities to learn facts about specific plants.

I learned about a little kind of flower that was on this tree. I didn't know that there was a flower [to the cacao tree]. BC502-1

It was also interesting to talk to respondents about learning or educational aspects of the Conservatory. Some tended to focus on the *Giants: African Dinosaurs* exhibition as an example of what they saw as educational at GPC.



I know they started doing, like, exhibits here. Like, different exhibits that have been changing a lot. And I think that's actually pretty nice, because I remember coming before they were actually, like, really doing exhibits that much. I mean they might have been, but it wasn't as, you know, serious and I think it's—I think that the idea is pretty cool. I mean I think that could be educational. I mean, you could learn a lot about the—what is it, dinosaurs? Yeah, I think—I mean, that could be educational, more than you know, like, learning about the flowers or something like that. CG522-3

Still other respondents took a broader view of the educational experience at the Conservatory, citing the potential for learning on various levels. These respondents indicated that GPC is “educational” because it exposes visitors to new plants, or experiences with plants, and provides opportunities to learn plant names or other interesting facts about them.

I think it's educational in a different sense, though. Not in the sense of so much you're learning about where the plants are from.... But you're having a different experience. You know, most people at school don't get to see this stuff, and unless you, like, come to the field trip here, or somebody takes you here, or you figure out about it and get here yourself, you don't get to see this stuff. And it's educational in itself just being here, you know.... So it's like learning in a very broad sense of being exposed to different kinds of things. Experiencing a different place altogether. CG522

Instead of actually reading about [plants] you can actually see them and touch them. EF502-2

I would use...[the word] unique. And it is so different from what folks usually categorize as entertainment, because of the natural aspect of the place. It's not, you know, what you usually go [do] to be entertained. But it is entertainment. It's—how can I put it?...It's a learning experience. EF617-1

Our study found that in many ways, the plants themselves were clearly at the center of respondents' experiences and responses to the Conservatory. As respondents discussed with us their experiences and attitudes toward the Conservatory, we found many parallels between their reasons for valuing plants and the reasons they valued their visits. At the same time, what respondents seemed to value was not necessarily framed as a cognitive or scientific experience.

As respondents reflected on possible educational aspects of the Conservatory, many noted that a variety of ways to learn existed at GPC. Despite this fact, however, respondents focused to a large degree on their restorative, aesthetic, and affective experiences. Thus, the primary importance of these types of experiences to respondents is quite clear. As illustrated in some respondent quotes, they clearly valued the educational aspects of GPC, but were interested in visiting for other reasons. This suggests that the team will need to find ways to provide interpretation that extends visitors' learning about photosynthesis while at the same time ensuring that interpretation does not interfere with visitors' affective, restorative, aesthetic, and even immersive experiences. This should be a major focus of formative evaluation.



Immersion at the Garfield Park Conservatory

One key challenge for the exhibition is to create an immersive experience for respondents where the plants themselves “tell” the story of photosynthesis. As part of this front-end study, we wanted to learn what aspects of the Conservatory seemed most critical to fostering and maintaining a feeling of immersion. We were also interested in understanding the extent to which visitors valued the qualities that we might define as immersive.

Previous research (Bitgood, 1990) indicates that when visitors are immersed in an exhibit, they report that the exhibit accomplishes one or more of the following:

- involves or absorbs you
- creates an exciting experience
- creates the feeling of being in a particular time and place
- is realistic and natural
- makes the subject matter come to life
- focuses your attention
- is memorable

To help us understand respondents’ perspectives on immersion as it might play out at the Conservatory, we asked most visitors whether there was a particular room they especially enjoyed and if so, why. For respondents who regularly visited the Conservatory, we occasionally changed the question slightly, asking if they had a favorite room and what about it was special.

Visitors often named the Fern Room as a favorite, along with the Desert House and the Palm House. As respondents talked about these rooms, we noted that the ways they described them, or discussed their experiences in these various areas of the Conservatory, were similar to what has been identified in the literature about immersive experiences in museums. We identified several features that respondents verbalized as engaging qualities of these rooms:

Creates the feeling of being in a different time or place

Respondents often said that these rooms made them feel they were in a different place, or that transported them to another time. Some respondents, for example, commented that the Fern Room made them feel like they had stepped into a forest, or back in time to a different era before cities were built.

That area over there [points to the Fern Room]....Yeah, because you just step down.... And you sit there on the bench and you really could just be there. And it's like, “Oh, where am I?” CG522-1

Others talked of ways these rooms reminded them of places they had visited or different areas of the world.



I like the outdoors and I actually have done a lot of traveling in South America and in jungles and things like that. So for me it's—it sort of takes me to those places as well. BC502-3

[The Desert Room], it kind of seems like a different part of the country. I mean like... [if you were] down South. CG522-3

I think it is the palms [Palm Room]. I always, always associate palms with tropical places and, to me, vacations. I think it was how moist it was in there and how hot it was and muggy. BC703-2

For some respondents, the feeling of being transported elsewhere was not limited to a “real” place, but rather, to more of an “ideal” or imagined environment or place they enjoyed.

I like the way they've mixed in plants from different parts of the world all into one sort of Utopia jungle kind of thing. BC502-3

It's almost magical. It's real cool...It's amazing because you come in here...[and it's like] letting your imagination run free, sort of imagining. BC523-2

Feels authentic/real

While respondents enjoyed the sense of feeling transported to another place or time, they also expressed that the need for the experience to feel authentic—something not too “fake.”

There's nothing here that stands out as being artificial. Or as being like it's not supposed to be here. Everything fits so well. CG522-3

But it would be neat if [the new exhibit] room was more like the Fern Room, where you were, like, deeply involved in what was happening...But not in that fake sort of way, like they do at, like, zoos and stuff where you, like, walk through. CG522-2

Thus, the immersive quality has to be realized to enough of a degree that the experience feels *genuine*.

Interestingly, this call for authenticity does not necessarily mean that visitors did not realize these environments were, to some degree, artificial. Some respondents, for example, acknowledged that these rooms were landscaped places created by Conservatory workers. The respondents' point, however, seemed to be that the Rooms were created in such a way that nothing seemed out of place or artificial; the rooms even engaged their imaginations in ways that allowed them to feel transported elsewhere. Because Conservatory visitors come to see a living collection (“real plants”), the need for authenticity and realism may be more important than in a traditional museum gallery, where visitors may come with different expectations about immersive environments.



What *specific* characteristics of these rooms engrossed visitors in this way? We noted that visitors felt a need for multi-sensory aspects, fostering a sense of discovery, and providing areas where they could sit and reflect on what they saw or felt.

Engages all the senses

An important aspect of visitors' experiences in these rooms is that they provide a multi-sensory experience, engaging the "whole" visitor through sight, smell, and touch.

Many respondents said how much they enjoyed the rich smell of dirt and plants, which also seemed to contribute to the feeling of immersion.

It smells excellent in there [the Fern Room]. It smells really nice. CG522-2

The Fern Room smells like dirt. Yeah, which I kind of like. EF522-2

It's like if we can walk from Chicago into this, like, place that smells amazing and it's just like you're in a rainforest for a couple minutes. CG522-3

The sense of touch and the ability to engage physically with these environments were also particularly important. Some respondents said they enjoyed being able to touch the plants to get a better sense of them. For many respondents, walking through narrow paths (or, seemingly, no paths) or through "wild" areas increased their sense of immersion.

Like I said, the pathways, the little pathways they had. That made it more real. BC703-2

It's like—it's like there is no [obvious] path and it's, like, jungle around you. EF617-2

The sense of being surrounded by the collections, and the feeling that visitors were walking "through" the plants, contributed to the sense of immersion. Respondents often likened these experiences to actually "being in" the displays.

I think the Fern Room surrounds you the most. I mean it's—it's much smaller paths. It's not that you're [just] looking at things. EF522-2

It's just kind of, like, full of life, and that's really nice. How it feels, too. It's like you feel the mist and you can—and then you can also like—it's just—it surrounds you. CG522-3

It's like less that you're looking at displays and more that you're like in a display. CG522-2

Fosters a sense of discovery or adventure

The winding paths and small spaces, particularly in the Fern Room, also seemed to contribute positively to respondents' experiences. The winding paths and small places contributed to a sense of discovery; respondents did not always know what they might see next.



I remember it being more, like, narrow and claustrophobic and cluttered. And I really like that. CG522-2

And you go around the corner and then you see something new and you're like, whoa. And there are so many things that, like—visually it's like walking through—it's like walking through the rain forest (inaudible). Even though there are pods and like windows and stuff it's still like being with the plants. BC523-2

And plus, you always think something is behind everything along the way. EF617-2

Allows for contemplation

Some respondents also talked about the importance of having “private” spaces in which to take in their surroundings. These respondents mentioned the winding paths, which created a sense of separation from other visitors and sitting area within a room, as important features that added to their feeling of privacy. In the context of the Conservatory visit, this contemplative time seemed to add to respondents’ enjoyment and sense of immersion.

Overall, we found several aspects of the Conservatory that fostered and maintained a feeling of immersion for respondents. While many of these aspects correlate with existing research, the need for *authenticity* seems especially important to examine. Our findings about the experiences that respondents seek at the Conservatory, as well as the reasons why rooms such as the Fern Room were favorites, indicate that it is important to visitors to see **real** plants. They clearly want to be close to them and they especially enjoy the sense of realism created in these spaces. Our findings and previous research suggest that the following factors must be considered:

- Need to determine the “tone” of the exhibition’s immersive environment. For example, what “sense of place” does the exhibit want to convey?
- Manufactured components will need to be carefully determined so they do not detract from visitors’ experiences with the plants.
- Need to find ways to focus attention in keeping with an immersive tone (e.g., use of text to prompt mental imagery to encourage visitors to feel immersed).

The team will also want to keep in mind that research indicates that immersive exhibitions are experience-driven. As Bitgood (1990b) points out,

“Learning associated with immersion is more experience driven than it is information driven. Instead of emphasizing the acquisition of facts, concepts, etc., a more pervasive understanding of the subject is sought—one that includes the feelings of experiencing another time and/or place, curiosity, excitement, etc.”

An important consideration, therefore, is how the team expects this more experience-based environment to contribute to visitor understanding of photosynthesis. In what ways are content messages achievable with an immersive approach, and how will they be realized? What will constitute success? Finally, as discussed in this and the previous sections, the team will want to



consider and test interpretive strategies that not only maintain the immersive environment/experience but also provide ways for visitors to successfully access the content.



CONCLUSIONS

The heart of this study was an exploration of the ways people connect to and understand plants and plant processes. Among the specific questions we had when we embarked on this front-end evaluation: whether visitors had clear personal connections or associations with plants; to what extent visitors recognize the importance of plants; and what understanding visitors had of photosynthesis.

While respondents had a range of connections to plants and understandings about plant processes, we found they did, indeed, value plants on a number of levels. Respondents' perceptions and connections with plants were wide-ranging, encompassing personal memories, emotional associations, and even connections with broader environmental concepts. Perhaps most significantly, respondents said that these connections were their primary explanation for why plants are important. Respondents thought primarily of plants' importance in terms of how they affect people as individuals, and secondarily in terms of how plants fit into the environment. Most did *not* think about plants' importance from a strictly scientific viewpoint.

Nonetheless, it would be wrong to conclude that just because respondents did not first and foremost think about plants scientifically, they do not see the value of plants. It is the *nature* of respondents' connections and associations that can be most illuminating in understanding mental models about plants. Respondents' connections—and consequently the importance they ascribed to plants—stemmed primarily from their *everyday experience* with plants. Their stories and comments were often grounded in childhood memories or family experiences, from growing gardens (or knowing someone who did) and their own affective responses to plants. This is especially important because it points out that **respondents' primary point of reference to and value they ascribe to plants is grounded in their daily and common experience with plants, rather than in abstract concepts about plants.**

This notion is also reflected in our findings about respondents' understandings of photosynthesis. Respondents at the lower levels of the hierarchy tended to focus on *what plants need* to stay alive in practical, concrete ways based on everyday experience with household or garden plants. Those at higher levels had a more academic and abstract orientation, based on things learned in school rather than on everyday experience. We noted, in fact, that those at the higher levels of the hierarchy tended to have most recently been exposed to the topic in school. As people moved away from their school days, they tended to shift away from a scientific explanation of photosynthesis to a more concrete (rather than abstract), practical (rather than academic) mental model grounded in their everyday world. In addition, our findings about respondents' associations and attitudes about photosynthesis indicate that the exhibition must overcome the notion that photosynthesis is an esoteric concept to be learned in science class and then forgotten.

Thus, it may be **important to find ways to help visitors think about photosynthesis in practical terms, even when they are thinking about an abstract process.** For example, can the exhibit team find a way to show that understanding photosynthesis can help visitors raise healthier plants, grow better-tasting tomatoes, or even help in understanding human nutrition? By showing the importance of photosynthesis to everyday life, and ultimately to human survival, the



exhibition could help visitors gain a greater appreciation for the process, rather than merely seeing photosynthesis as an abstract scientific concept far removed from their experiences.

Other noteworthy findings about photosynthesis indicate that we cannot assume that adults know the term “photosynthesis,” and that children do not. In fact, the team should recognize that some adult visitors may feel embarrassed or intimidated by their lack of knowledge about the topic.

One challenge will be to develop interpretation that allows adult group members — especially those with little academic knowledge of the topic — to guide their family’s interactions. This should be one focus of formative evaluation.

In the initial exhibit concept, the team hypothesized that by focusing on sugar, they could avoid some confusion around words by which photosynthesis is traditionally explained, such as “food” or “producer.” Our findings indicate, however, that **respondents’ strong associations with sugar as something sweet (such as candy) provide a challenge because the topic of photosynthesis requires visitors to think about sugar in very different ways than they currently do.** In addition, while using certain sweet economic crops as a “hook” for the exhibition is a good starting point, the team will need to be careful about inadvertently reinforcing visitors’ preconceptions. **Our findings strongly suggest that helping visitors understand what plants actually do with the sugar is critical.** An explanation of the process, rather than just conveying the fact that plants produce sugar, is essential. Otherwise, the “Sugar from the Sun” approach will likely leave people feeling confused about the title and main point of the exhibit.

The immersive environment of this exhibition will also be an important consideration. Our findings indicate that several strong aspects of the Conservatory foster and maintain a feeling of immersion for respondents, many of which correlate very well with existing research. In the context of a conservatory, however, the need for authenticity may be critical. Results indicated that respondents visiting the Conservatory especially valued seeing and being near real plants and enjoyed the sense of realism created in these spaces. In addition, the value respondents placed on their own affective, restorative, and aesthetic experiences should be considered. **One challenge, then, will be to develop an exhibit approach and interpretive strategy that maintain the experiences that visitors value (which are their primary motivation for visiting) and also allow visitors to successfully access the content and exhibit messages.** The team will need to decide how this more experience-based exhibit will contribute to visitors’ understandings of photosynthesis. In what ways are content messages achievable with an immersive approach, and how will these be realized? What will constitute success?

This study found that the plants themselves were clearly at the center of respondents’ Conservatory experiences. Thus, the exhibit team’s concept of focusing on components and elements inherent to conservatory spaces is a useful strategy. Building on the aspects visitors seem to value at the Conservatory, particularly direct experience with plants, is a solid start. This study also indicates that the team has an opportunity to build on respondents’ connections to plants and value they see in them (including the recognition that plants provide for people’s physical needs). One key, as discussed, will be to ground visitors’ connections to plants in practical, concrete, and meaningful everyday experiences.



RECOMMENDATIONS

Throughout this report, we have discussed implications of our findings and included several recommendations. In this section, we present our key recommendations.

- **Help visitors think about photosynthesis in practical, concrete ways rather than as an abstract process.** This is critical, because findings indicate that moving people up the learning hierarchy requires helping them shift the way they relate to information about photosynthesis. Is there a way to illuminate that understanding photosynthesis can help visitors raise healthier plants, grow better tasting tomatoes, or even learn more about human nutrition?
- **Do not gear exhibit content messages or goals to one specific level of the learning hierarchy.** The hierarchy illuminates the fact that at least some visitors will be at each level of the hierarchy. The goal, then, is to find ways to engage visitors regardless of what level they enter and, through their experiences at the exhibition, help them develop deeper, more meaningful understandings and/or connections to the topic. The hierarchy is *not* intended to suggest that the exhibit team should gear the exhibition toward getting visitors to one particular level.
- **Use visitors’ everyday, practical experiences and their connections to plants as entry points to messages.** Findings indicate that respondents’ primary reference points to plants, and connections to them, are grounded in everyday experiences (e.g., growing plants) rather than in more abstract concepts or scientific perspectives.
- **Consider using the fact that plants provide for people’s physical needs (e.g., food) as an entry-point to discuss plants’ importance in sustaining life on earth.** Since respondents primarily thought of plants’ importance in terms of how plants affect people, this may be a good approach. Of course, this should be tested in formative evaluation.
- **Focus on, and emphasize, what plants *do* with the sugar they produce.** Respondents’ strong associations with sugar to table sugar or sweet things, such as candy, will be a major challenge for this exhibition because the topic of photosynthesis requires visitors to think about sugar in very different ways than they usually do. This exhibit requires more than simply conveying that plants produce sugar. Instead, it is important to help visitors understand how plants use sugar as a building block for everything else that they (and humans) need to live and grow.
- **Revisit and revise the “Big Idea” of this exhibition so that it highlights how plants use sugar and the importance of sugar as a building block.** For example, a starting point could be: “Plants use energy from the sun to make sugar, then use that sugar to make everything else they—and humans—need to live and grow.”
- **Include economic crops that are not sweet to counter visitors’ preconceptions about sugar in plants.** While using certain sweet economic crops as a “hook” for the



exhibition is a good starting point, the team must not inadvertently reinforce visitors' preconceptions. Introducing economic crops that people would not associate as being sweet and explaining that they, too, use sugar may help address these preconceptions. (Of course, that approach still needs to emphasize what plants *do* with sugar.) It will be critical to test out approaches in formative evaluation.

- **Determine more clearly how the immersive approach will support this exhibit's messages.** Immersive exhibits tend to emphasize understanding a subject experientially, rather than focusing on the acquisition of facts and concepts. The team, therefore, should consider how they expect this more experience-based environment to contribute to visitors' understandings about the topic. In what ways are content messages achievable with an immersive approach, and how will they be realized? What will constitute success? What type of "tone" will be appropriate to sustain the immersive qualities desired while still conveying key information?
- **Test specific terminology in formative evaluation.** Confusion abounds in such terms as "plant food," "nutrients," and even "energy." Testing terminology in formative evaluation can determine the extent to which these terms can be used (or avoided). It may be helpful, for example, to avoid the term "plant food" (which respondents seemed to equate with fertilizer) and instead focus on the ways that plants use sugar
- **Test proposed interpretive strategies during formative evaluation.** Given our findings about how visitors understand the exhibit topic, and the research about immersive exhibitions, it will be critical to test interpretation in this exhibition. The team will specifically want to develop and test interpretive strategies that not only maintain the immersive environment/experience but also provide ways for visitors to successfully access content.



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APPENDIX A: TOPICAL FRAMEWORK

Sugar from the Sun Topical Framework April 2004

This topical framework is blueprint for the front-end study, outlining the issues to be explored. A topical framework contains the questions that will be answered in this phase of the evaluation (rather than the actual questions that we will ask respondents). It is a living document that will continue to evolve throughout the study as new questions emerge from data collected.

In this phase of evaluation (front-end), the main focus is on examining visitors' connections to and understandings of the scientific concepts presented. A secondary focus is on respondents' perceptions of immersion at the Conservatory within the context of the Sugar from the Sun Exhibition.

Plants

Connections

1. What are respondents' top-of-mind associations to plants?
2. To what extent, and in what ways, do respondents understand the relationship between plants and the food they eat?
3. What personal connections do respondents have to plants (e.g., memories, gardening, folk medicine) and how strong are the connections?
4. To what extent, and in what ways, do respondents see plants as particularly significant to their heritage or culture?
5. What piques respondents' curiosity about plants? What causes them to ask more questions?

Knowledge

1. To what extent, and in what ways, do respondents recognize the importance of plants? How do they articulate these perspectives? What words do they use?
2. What are respondents' understandings about plants as living organisms and about what plants need to live (i.e., air, sun, water)?
3. What associations do respondents make between plants and air, sun, and water?
4. What are respondents' understandings about how plants grow?

Photosynthesis

Connections and Awareness

1. What are respondents' associations with photosynthesis? What words do they use to describe it?
2. In what ways, and to what extent, are respondents interested in photosynthesis?



3. To what extent, and in what ways, do respondents see photosynthesis as part of their lives?
4. To what extent, and in what ways, do respondents see photosynthesis as critical to life itself?

Understandings

General

1. To what extent can respondents explain the process of photosynthesis? What words do they use?
2. Are respondents able to identify the key elements of photosynthesis (air, water, sun)?
3. What misconceptions emerge?
4. What questions do respondents have about photosynthesis?

Sugar

1. What associations do respondents make to the word “sugar”?
2. What conceptions do respondents have about the relationship between plants and sugar?
3. What connections do respondents make between sugar and photosynthesis?
4. Where do respondents think sugar comes from?
5. How do respondents explain why plants produce fruits?
6. How do respondents respond to the phrase “sugar from the sun?”

Water

1. What conceptions do respondents have about water’s role in plant growth?
2. What do respondents think would happen to plants without water?
3. What conceptions do respondents hold about water’s role in photosynthesis? How do respondents think plants capture, transport, and use water?
4. To what extent, and in what ways, do respondents understand that water molecules can be rearranged to form other substances?
5. To what extent, and in what ways, do respondents understand that water is composed of molecules that are broken down and rearranged in the process of photosynthesis?

Sun

1. What conceptions do respondents have about the sun’s role in plant growth?
2. What do respondents think would happen to plants without sun?
3. What are respondents’ conceptions about the sun’s role in photosynthesis? How do respondents think plants capture sunlight?
4. What are respondents’ conceptions about light as a form of energy? To what extent, and in what ways, do respondents understand that energy can be transformed or that it can be stored?

Air

1. What conceptions do respondents have about how air is used in photosynthesis?



2. What do respondents think would happen to plants without air?
3. How do respondents think plants take in and use air?
4. In what ways, and to what extent, do respondents think that plants impact the air we breathe?
5. To what extent, and in what ways, do respondents understand that air is composed of molecules that are broken down and rearranged in the process of photosynthesis?

Exhibition Context

Conservatory

1. What terms do respondents use to describe the Conservatory? What is the nature of those associations?
2. To what extent, and in what ways, do respondents associate the Conservatory with nature or naturalistic environments? How is this connected to respondents' general perceptions of nature?
3. What is most memorable to respondents about their experiences at the Conservatory? What do respondents seem to value most?
4. How do they respond to the idea of educational exhibits at the Conservatory?

Immersive Environments

1. To what extent, and in what ways, do respondents value an immersive environment at the Conservatory?
2. What aspects of Conservatory seem most critical to fostering and maintaining a feeling of immersion?



APPENDIX B: MAGNETIC BOARD COMPONENTS

Magnetic Board Activity Words and Graphics Used

Words

- Air
- Carbon Dioxide
- Roots
- Water
- Sugar
- Plant Food
- Leaf
- Light
- Energy
- Oxygen
- Nutrients
- Soil
- Release
- Absorb
- In
- Out
- Transpire
- Consumer
- Producer

Graphics

- Tree
- Sun
- Water drops
- Person
- Apples



APPENDIX C: MAGNETIC BOARD EXAMPLES

Magnetic Board Conceptual Mapping Examples

The activity developed for this study was intended to focus conversations with respondents to help us gain insight into their conceptions about photosynthesis. While fully interpreting images require simultaneous analysis of the interview transcript, below we provide some select images with explanations (in addition to those presented in the body of the report) as examples of respondents' conceptions.

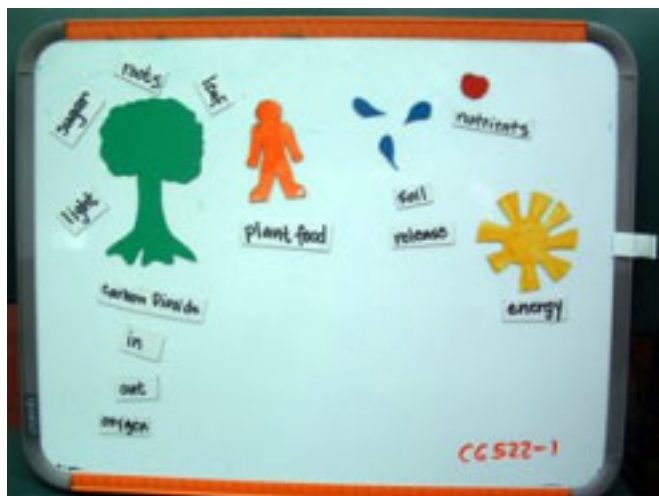


This group of respondents focused on sun and “energy.” They indicated that sun light helps the tree grow and that “the energy comes from the sun and the water” and then goes to “us” (humans). The person, they indicated, was on the receiving end of this process because they ate the fruit from the tree. As one respondent, stated, making a circular motion of the board, “all this is energy for our bodies. Energy is something that helps us when we need to run.” The word “sugar” near the tree trunk seemed to represent sap or maple syrup, which they had difficulty integrating into their primary explanation of the image.

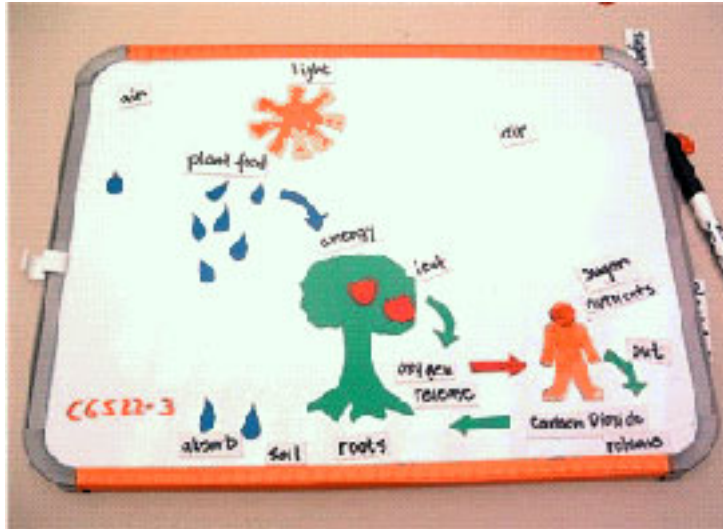




This mother and child group worked together. The 11 year-old-boy's primary focus was on the oxygen/carbon dioxide process. He explained that plants give off oxygen, which humans need and, in turn, people give off CO₂. The adult talked about a "cycle" where plants absorb light and break apart CO₂ and "spit out" O₂ as a byproduct, and produce sugar for them to grow (and which also produces fruit). The role of water was seen as more of an isolated component plants need to live rather than as part of the photosynthesis process.



This respondents' focus was on the benefit plants provide for people and vice versa. Making four distinct columns, this respondent first discussed the tree, focusing on the oxygen/CO₂ exchange. The phrase "plant food" under the human figure represents people gardening and providing "nourishment" to plants through that activity. In other words, humans are caretakers. The apple is nourishment from trees.



This group emphasized the interdependence of plants and humans. Human release carbon dioxide, which plants use and plants, in return, release oxygen. Trees produce fruit which provides nutrients for people. While this group indicated that they remembered from school that plants need CO₂ as part of photosynthesis, they could not recall why. They did recall that sun and water are necessary for photosynthesis.



Respondents were two girls, 12 and 13 respectively. The main theme that emerged from the discussion of this image was the notion of “cycles.” These respondents said there is a “carbon cycle, an oxygen cycle and a water cycle.” They stated that everything is interdependent and “locked” into each other. These respondents talked about the “circle of life.” Much of this group’s thinking seemed to be influenced by an environmental science class they were taking.



tree. The mother interjected, saying that even though sugar is not really good for us, we need it and get it from plants. He explained that the sugar he was referring to in the image was not the same and that it is “the kind the plant needs so that the tree can stay a little longer.” The tree, he explained, gets this sugar when sunlight hits the leaves.



This image, created by a family that included a middle school child, a high school respondent, and two adults emphasized the components plants need to live as well as some benefits to humans. They stated that the four figures represented their family walking through the park and stopping to look at an apple tree. The tree, they explained, needs water, air, clean soil, and oxygen to grow and produce apples. The word “sugar” referred to the apples, which they stated were sweet.



APPENDIX D: RESPONDENTS

Grp. Code	Resp. Code	Age	M /F	Zip Code	Grp. Size	Grp. Type	Ethnicity /Race	Times to GPC	Occupation	GPC Member
CG424-1	A	13	F	60615	3	School group	African American	1	student	no
CG424-1	B	13	F	60615	3	School group	African American	2-4	student	no
CG424-1	C	14	F	60615	3	School group	African American	1	student	no
CG424-2	A	9	F	60623	9	Mentoring group	African American	5-9	student	no
CG424-2	B	7	M	60623	9	Mentoring group	African American	2-4	student	no
CG424-2	C	13	M	60623	9	Mentoring group	African American	2-4	student	no
CG522-1	A	39	F	60624	4	Extended family	African American	10+	not indicated	no
CG522-2	A	25	F	60647	2	Friends	White	1	database work	no
CG522-2	B	29	M	60706	2	Friends	White	5-9	computer programmer	no
CG522-3	A	15	F	60618	2	Friends	White	10+	student	yes
CG522-3	B	15	F	60625	2	Friends	White	2-4	student	no
EF424-1	A	14	M	60623	9	Mentoring group	African American	2-4	student	no
EF424-1	B	14	M	60623	9	Mentoring group	African American	2-4	student	no
EF424-1	C	12	M	60623	9	Mentoring group	African American	not indicated	student	no
EF052-1	A	36	M	60612	2	Friends	White	10+	teacher, student, actor	no
EF052-1	B	36	F	out of state	2	Friends	White	1	playwright	no
EF052-2	A	36	F	60659	5	Family	Latino	1	not indicated	no
EF052-2	B	7	F	60659	5	Family	Latino	1	student	no
EF052-2	C	9	F	60659	5	Family	Latino	1	student	no
EF052-2	D	11	F	60659	5	Family	Latino	1	student	no
EF0522-1	A	11	M	60552	3	Family	Asian	1	student	no
EF0522-1	B	41	F	60552	3	Family	White	1	not indicated	no
EF0522-1	C	30	M	60552	3	Family	White	1	not indicated	no



Grp. Code	Resp. Code	Age	M /F	Zip Code	Grp. Size	Grp. Type	Ethnicity /Race	Times to GPC	Occupation	GPC Member
EF0522-2	A	28	M	60622	3	Friends	White	1	film student	no
EF0522-2	B	28	F	60622	3	Friends	White	1	film teacher	no
EF0522-2	C	28	F	out of state	3	Friends	White	1	not indicated	no
EF0523-1	A	27	F	61606	3	Friends	East Indian	1	engineering student	no
EF0523-1	B	27	M	61606	3	Friends	East Indian	1	engineering student	no
EF0523-1	C	27	F	out of state	3	Friends	East Indian	1	engineering student	no
EF0523-2	A	22	F	60657	1	Single visitor	White	1	teacher w/ Americorps	no
BC424-1	A	15	M	60625	2	Friends	Asian	2-4	student	don't know
BC424-1	B	12	M	60630	2	Friends	Latino	1	student	don't know
BC424-2	A	6	F	out of state	3	Family	African American	2-4	student	no
BC424-2	B	30s	F	out of state	3	Family	African American	2-4	not indicated	no
BC424-2	C	50s	F	60617	3	Family	African American	10+	teacher	don't know
BC502-1	A	50s	F	60707	2	Family	White	10+	not indicated	no
BC502-1	B	55	M	60707	2	Family	White	10+	catering	no
BC502-2	A	51	F	60615	2	Family	White	10+	not indicated	no
BC502-2	B	11	M	60615	2	Family	White	10+	student	no
BC502-3	A	40s	F	60517	6	Extended family and friends	not indicated	1	substitute teacher	no
BC502-3	B	13	M	60517	6	Extended family and friends	Asian	1	student	no
BC502-3	C	30s	F	60647	6	Extended family and friends	East Indian	1	int'l marketing	don't know
BC502-3	D	40s	M	60640	6	Extended family and friends	White	5-9	int'l marketing	don't know
BC523-1	A	35	F	60612	3	Family	White	1	not indicated	no
BC523-1	B	37	M	60612	3	Family	White	2-4	not indicated	no
BC523-1	C	12	M	60612	3	Family	White	1	student	no



Grp. Code	Resp. Code	Age	M /F	Zip Code	Grp. Size	Grp. Type	Ethnicity /Race	Times to GPC	Occupation	GPC Member
BC523-2	A	12	F	60615 or 60637	6	Family and friends	White	1	student	don't know
BC523-2	B	13	F	60615 or 60637	6	Family and friends	White	1	student	don't know
BC523-2	C	8	F	60615 or 60637	6	Family and friends	White	1	student	don't know
BC606-1	A	11	M	60630	4	Family	Latino	2-4	student	no
BC606-1	B	43	M	60630	4	Family	Latino	2-4	sales	no
BC606-1	C	13	M	60630	4	Family	Latino	2-4	student	no
BC606-1	D	40s	F	60630	4	Family	Latino	2-4	not indicated	no
BC606-2	A	64	F	60623	6	Extended family	African American	10+	retired nurse	no
BC606-2	B	14	M	60623	6	Extended family	African American	10+	student	no
BC606-2	C	13	F	60623	6	Extended family	African American	10+	student	no
BC606-2	D	15	M	60623	6	Extended family	African American	10+	student	no
BC626-1	A	24	F	60644	5	Family	African American	5-9	secretary	no
BC626-1	B	9	M	60644	5	Family	African American	5-9	student	no
BC626-1	C	7	M	60644	5	Family	African American	5-9	student	no
BC703-1	A	47	M	60624	3	Family	African American	5-9	cleaner	no
BC703-1	B	11	F	60624	3	Family	African American	5-9	student	no
BC703-1	C	40s	F	60624	3	Family	African American	5-9	not indicated	no
BC703-2	A	29	F	60707	3	Family	Latino	1	homemaker	no
BC703-2	B	13	F	60707	3	Family	Latino	1	student	no
BC703-2	C	10	M	60707	3	Family	Latino	1	student	no
EG626-1	A	30s	F	60651	3	Family	African American	1	not indicated	no
EG626-1	B	13	M	60651	3	Family	African American	1	student	no
EG626-1	C	9 apprx	F	60651	3	Family	African American	1	student	no
EF0612-1	A	11	M	60644	9	Family	African American	1	student	no



Grp. Code	Resp. Code	Age	M /F	Zip Code	Grp. Size	Grp. Type	Ethnicity /Race	Times to GPC	Occupation	GPC Member
EF0612-1	B	6	M	60644	9	Family	African American	1	student	no
EF0612-1	C	4	F	60644	9	Family	African American	1	not indicated	no
EF0612-1	D	13	M	60644	9	Family	African American	2-4	student	no
EF0612-1	E	8	F	60644	9	Family	African American	1	student	no
EF0612-1	F	3	M	60644	9	Family	African American	1	not indicated	no
EF0612-1	G	14	M	60644	9	Family	African American	2-4	student	no
EF0612-1	H	39	F	60644	9	Family	African American	2-4	not indicated	no
EF0617-1	A	47	F	60624	3	Family	African American	2-4	pastor	no
EF0617-1	B	16	M	60624	3	Family	African American	2-4	student	no
EF0617-1	C	13	F	60624	3	Family	African American	2-4	student	no
EF0617-2	A	43	F	60651	2	Family	White	1	homemaker	no
EF0617-2	B	10	M	60651	2	Family	White	1	student	no
EF0708-1	A	50's	F	60624	7	Family	African American	1	none	no
EF0708-1	B	10	M	60624	7	Family	African American	5-9	student	no
EF0708-1	C	31	F	60624	7	Family	African American	1	not indicated	no
EF0708-2	A	44	F	60644	5	Family	African American	1	not indicated	no
EF0708-2	B	16	F	60644	5	Family	African American	2-4	student	no
EF0708-2	C	13	M	60644	5	Family	African American	2-4	student	no
EF0708-2	D	12	F	60644	5	Family	African American	2-4	student	no
EF0708-2	E	8	F	60644	5	Family	African American	1	student	no
EF0708-3	A	34	F	60651	4	Family	African American	1	cashier	no
EF0708-3	B	30's	M	60651	4	Family	African American	1	not indicated	no
EF0708-3	C	15	M	60651	4	Family	African American	1	student	no
EF0708-3	D	9	F	60651	4	Family	African American	1	student	no



APPENDIX E: LEARNING HIERARCHY

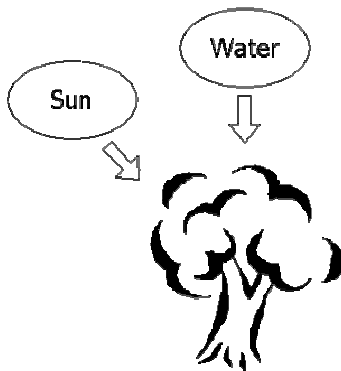
Graphic Representation of the Photosynthesis Learning Hierarchy

Level 0: Don't know what plants need to live



- Lack of understanding about basic aspects of what plants need to live.
- No respondents at this level.
- Potentially only very young children who have no experience of plants would be at this level.

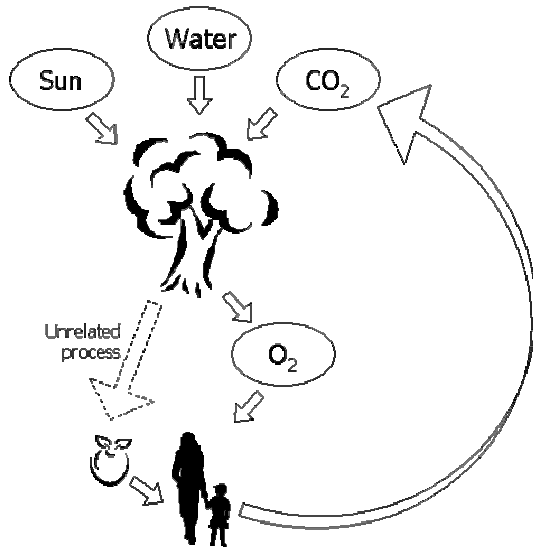
Level 1: Plants need sun and water to live



- Sun and water seen as critical to plant survival.
- Lack of understanding of the reasons (*why* plants need them).
- At this level, air was not part of respondents' mental model.

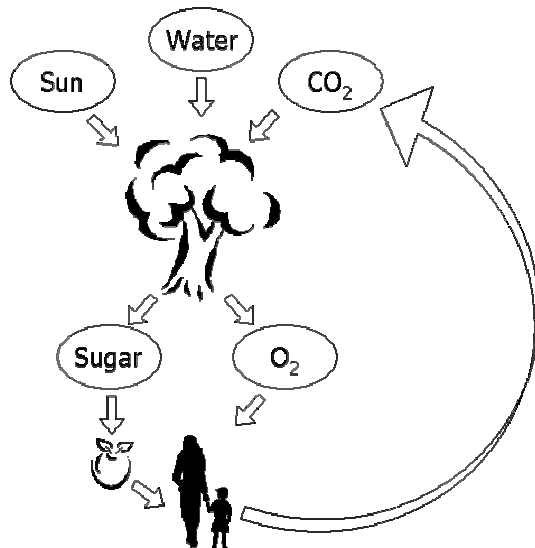


Level 2: Plants need sun and water and carbon dioxide to live



- Air is added as a component of what plants need to live.
- "Exchange" of oxygen and carbon dioxide between plants and humans.
- Mental model at this level is about discrete components rather than a process.

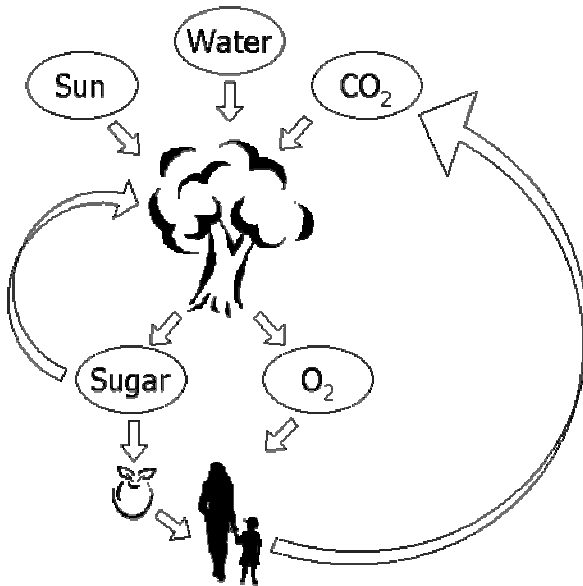
Level 3: Plants have a process in which they take in water, sun, carbon dioxide, and produce oxygen and sugar.



- Sugar is seen as part of "output" of photosynthesis.
- Though sugar is part of this mental model, respondents at this level do not see sugar as something a plant uses.
- At this level, respondents recognize a process that takes place "inside" the plant, but understanding is incomplete.

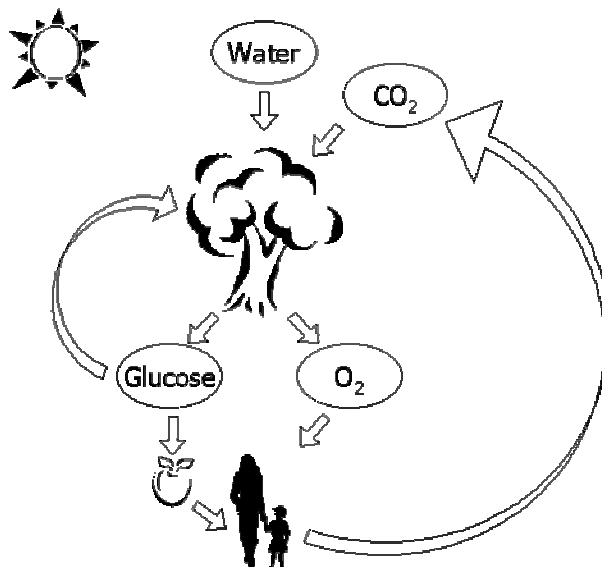


Level 4: Plants have a process in which they take in water, sun, and carbon dioxide, and produce oxygen and sugar. This sugar is used by the plants as well as people.



- Mental model includes the concept that plants make their own food.
- Sugar as a source of energy for plants.
- Confusion about what the sugar in photosynthesis is.
- Some vague notions about chlorophyll present.

Level 5: A more complete understanding of photosynthesis including the chemical processes involved.



Includes understanding of underlying chemical equations

- No respondents at this level
- At this level would expect to note change in terminology from previous levels:
 - > Plants fixing energy or fixing carbon rather than making sugar.
 - > Sunlight as driving a process rather than as a component or ingredient.
 - > Understanding of some chemical equations rather than interrelationships between components.
 - > Understanding of role chloroplast and chlorophyll play.
 - > Talk about glucose as initial product and also discuss synthesis of other sugars, starches, etc.
 - > Compare and contrast process of respiration with photosynthesis.
 - > Talk about materials involved in photosynthesis (like carbon) being cycled.

