

## Quest of a Broken-Wing Butterfly

Dear Sophie,

Congratulations on making the pit orchestra for the spring Wizard of Oz concert! I know how excited you must be – and should be – very impressive to have made it as a freshman!

We should make the story clear to your cousins, Jake and Lauren – it is such a good example. By “the story” I mean starting last spring when you were so disappointed about not being selected for one of the two open spots for cello in Honors Orchestra. It would have been easy for you to give up and do other things.

Your determination, continuing to practice – including your free period at school, in the room next to the music director’s office – and playing with feeling, was surely what led to the director inviting you, after all, to join Honors Orchestra – and now the pit orchestra.

Sophie, that tenacity and hard work are going to be needed during your lifetime, not just by you, but by a huge number of people, if the remarkable life on our planet is to continue to flourish. Humanity needs that life, the millions of other species, which we must fight to preserve for today’s young people and future generations. I need your help to make that story clear.

Let’s start with the tale of our favorite insect, the incredible Monarch butterfly.

Remember five years ago when you and Connor helped me dig up milkweeds on Frogtown Road, where they would have been mowed, and transplant them near the fence on the south side of the horse field? It seemed to be a good idea. Planting milkweeds would help the Monarchs and at the same time help you and our other grandchildren appreciate how remarkable nature is.

My own interest had been spurred by my climate research, especially the indications that many species will be threatened by climate change, if humans cause more extreme climate variations. Children should not be made to worry about such problems -- growing up already has enough challenges for kids. However, a nature project helps children spend more time outdoors, a useful break from all the electronic stuff.

The Monarch butterfly is so special -- as light as a feather, but it can fly 100 miles or more in a day. It needs to be able to fly fast, because it lives as far north as central Canada in the summer, but it migrates south and hibernates for the winter in a mountainous area in central Mexico. Thousands and thousands of Monarchs will blanket a single fir tree, hanging dormant all winter, until warm spring sunshine wakes them up, telling them it is time to head north.

By the time the overwintering generation of Monarchs reaches the southern United States, they are exhausted. The female butterfly looks for a milkweed on which she will lay her eggs. She



**Figure 1. The broken-wing female Monarch on our butterfly bush.**

may travel a bit further along the trek north, but her life is nearing its end and she is obsessed with starting the next generation. Her children will carry on the migration.

The annual roundtrip, from Mexico to Canada to Mexico, requires three or four generations. Remarkably the great or great-great grandchildren, even if a storm drives them far off course, are able to find their way back to their ancestral home in the small area of fir trees in Mexico.

Unfortunately, the Monarch population is declining rapidly. A few decades ago Anniek and I could see a dozen or more Monarchs at the same time on our property in Pennsylvania. But in recent years we could see only one or two butterflies at any time on our 7½ acre farm.

The main reason for Monarch decline is probably the widespread use of herbicides, especially Roundup, which kills all weeds including milkweeds. Milkweeds are the only food that can be eaten by Monarch larvae (caterpillars). That's the reason we began planting milkweeds.

Our milkweeds produced a few dozen larvae most years. Pinhead-sized Monarch eggs hatch into tiny larvae, which munch on milkweeds for two weeks until reaching their maximum size, about two inches long. Then they abandon the milkweed, crawl off in a seemingly random direction, and, perhaps when good and tired, find a place to attach themselves, hang upside down, and curl up in a j-shape. Miraculously, each larva seems to “melt” and “rearrange” itself, changing into an acorn-sized green chrysalis, which has a hard shell (exoskeleton) but is initially soup-like within. Enzymes break down the muscles that the caterpillar had used to crawl, as the butterfly will need very different muscles to fly. Some of the butterfly parts, including the wings, antennae, compound eyes, and reproductive organs actually were present in the larvae but only as tiny clusters of cells. These cells rearrange and grow in the chrysalis. Inner layers of the exoskeleton dissolve and provide nutrients to the developing butterfly. As the shell becomes thinner,



**Figure 2. Larvae devouring the milkweeds.**

orange wings can be seen through the chrysalis shell. After two weeks the Monarch is ready to unfold its wings, bursting the thin remaining shell.

In 2011 we were ready to do our share to aid the Monarch migration and life cycle. We planted a butterfly bush and alongside it milkweeds that Connor started with seeds in pots in the spring. We saw several Monarchs that summer, but for a few weeks in August there was just one flitting about our patch. I could tell it was the same butterfly, because she had a broken wing (Fig.1).

Near the end of August there were more than a dozen small larvae chomping away on the milkweeds when I drove off to Washington (where I was arrested and spent several hours sweating in the back of a paddy-wagon with my hands uncomfortably padlocked behind me – that’s another story, to be explained later). It was almost a week before I returned to the farm, which, in the meantime had been pummeled by high winds and a deluge from the remnants of tropical storm Irene. Our rain gauge had overflowed at six inches.

I presumed that neither butterfly nor larvae could survive that storm. But, to my surprise, I found one butterfly flitting about – the same broken wing female! Evidently she had decided that our meager milkweed patch and butterfly bush were going to be her final resting place. And her children too had survived. They would need to complete the journey to Mexico.

By then the milkweeds were being stripped by the ravenous larvae, which were mostly in their final stage (Fig. 2). I put a bench behind the milkweed patch with a long plank on it, where the larvae could attach themselves to proceed through their miraculous chrysalis stage.

The caterpillars began to disappear, but they studiously avoided forming a chrysalis any place I could find. I began to wonder if they had been eaten by a predator, even though I know that they



**Figure 3. Newly-emergent Monarchs, each beside its popped chrysalis, waiting for their wings to dry.**

are poisonous to birds (that’s probably why Monarch larvae eat milkweeds, to make themselves poisonous, and it’s the reason that some other butterflies have evolved to look like Monarchs – they are faking out birds, who have been trained to avoid awful-tasting Monarchs).

Two weeks later, in our nearby privet hedge, two bright orange spots appeared (Fig. 3). Simultaneously two newly emergent butterflies were hanging upside down, seemingly exhausted by their breakneck trip from the land of the “worms”, waiting for their new-found wings to dry.

Soon one of them, a male, began steadily crawling up the privet sprig. He sat motionless at the apex for several minutes. Then, while holding on to the sprig, he beat his wings several times, and finally set sail to heights of 20-30 feet, flying once all around the yard before returning to land on the butterfly bush (Fig. 4a), where he presumably was gathering nourishment for a long trip. The female soon launched herself, landing first on a spent wildflower (Fig. 4b).

How did they know to flap their newfound wings and to fly to the butterfly bush for a drink of nectar? When I came back an hour later, they were both gone, presumably on their way to Mexico. How did they know they should go, and how to get there? Their brain weight to body weight ratio is much smaller than in humans, and their body weight is only half a gram.

Surely these remarkable insects operate on instinct, but what a complex program they follow! The September babies, unlike their parents, who became sexually active within days, somehow



**Figure 4. Male (left) and female Monarchs after first landings on butterfly bush and wildflower.**

“know” that they must save their energy for the trip to Mexico; they remain juveniles until the following spring. Perhaps the reduced autumn sunlight or lowering temperatures cue them that they are of the generation that must complete the journey to Mexico and hibernate for the winter.

Including the dormant hibernation period, the overwintering generation lives seven to eight months. After the warming sun wakens them in the spring, they begin the northward migration with the objective of laying eggs on milkweeds. Subsequent generations live about 2-6 weeks as butterflies, so, including the 4 weeks of the egg and larva stages, the entire lifetime of a summer Monarch is about 6-10 weeks. Butterflies in the long-lived generation that returns to Mexico are great-grandchildren or great-great-grandchildren of those that left Mexico the prior year.

In 2012 I wrote an article ([Butterfly Report + Jeremiah, the Frog](#)) reporting that the number of Monarchs arriving in Mexico for the 2011-2012 winter was 30% less than the previous year. I hypothesized that the drop in butterfly population may have been in part related to the extreme drought in Texas and Oklahoma that year.

After putting that article on my website I received a message from Cuauhtemoc Saenz-Romero, a Mexican scientist. Fig. 5 shows Dr. Saenz-Romero's two-year-old grandson looking up at millions of hibernating Monarchs. Saenz-Romero reports that the fir trees are under stress, as shown in Fig. 6, because of persistent drought in this region in recent years. This tree damage and illegal logging in this butterfly reserve area have contributed to the Monarch decline. This persistent drought seems to be a consequence of shifting climate zones and intensification of regional climate extremes associated with global warming, as I will discuss in another letter.

Saenz-Romero and his colleagues conclude that these trees may not survive if global warming increases. They discuss possible "assisted migration" of Monarchs, which would involve planting fir species at higher altitudes where the trees may be more viable. However, they conclude that, if the most extreme projections of fossil fuel use occur, it may be necessary to find higher mountains for fir tree survival. In such case, assisted migration may be a great challenge.



**Figure 5. Monarchs being observed in oxamel fir trees in Mexico. Monarchs of Eastern North America overwinter on these trees at altitudes between 2.9-3.4 km at latitudes between 19°N and 20°N in the Trans-Mexican Volcanic Belt (Saenz-Romero et al., *Forest Ecol. & Manag.*, 275, 2012).**

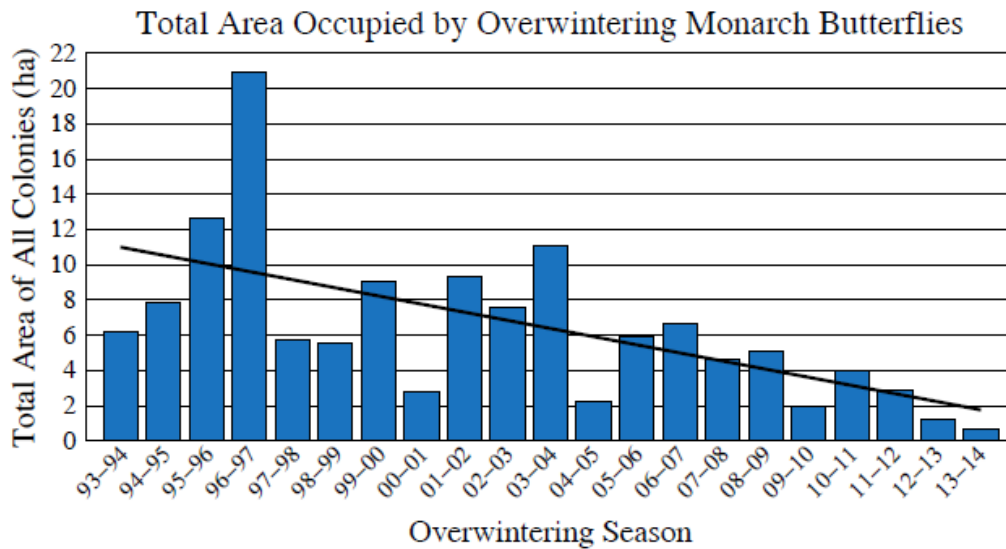
The threat to Monarch survival may be much more immediate. The number of Monarchs making it to Mexico can be estimated from the area covered by the trees they occupy, because they cluster close together to help survive possible freezing winter temperatures. The area covered in the 2012-2013 winter was barely more than one hectare<sup>1</sup>, the smallest of any year in which the area was measured, about 60% less than the year before (Fig. 7).



**Figure 6. Drought-stressed fir trees in Butterfly Reserve. Photo: C. Saenz-Romero**

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<sup>1</sup> A hectare, abbreviated ha, is the area of a square 100 meters on a side, i.e., 10,000 square meters. A hectare is lightly less than 2½ acres.



**Figure 7. Monarch population is estimated by the area of the colonies in which they cluster together for their winter hibernation.** (Graph updated from Brower et al., *Insect Conser. & Diver.*, 5, 95, 2011).

The reduced number of Monarchs in the 2012-13 winter presumably was due in part to the widespread, extreme drought of 2012 in the central United States. Therefore, because drought was less severe in 2013, there was hope for a rebound of the Monarch population. A single female can lay 500 or more eggs, so big population rebounds are not unusual (Fig. 7).

However, that hope was short-lived. Now I am afraid that the Monarch population, at least of eastern North America Monarchs, may be in a state of collapse. Perhaps these Monarchs have reached the dreaded “committed to extinction” status. Let me explain the reason for that concern, and then we can consider what information is needed for a better evaluation.

In the spring of 2013 Connor, Jake and I planted more milkweeds by the butterfly bush, which has grown to six feet tall with lots of purple flowers. So it should attract any Monarchs that happen by on their long trip to Mexico, coming down to refuel and perhaps even lay some eggs. I checked the bush and milkweeds every day that I was home. For most of the summer there was not a single Monarch, no evidence of eggs, no leaves munched by hungry caterpillars.

It was the same story for the milkweeds by the house, the ones that we planted between our front door and the lilac bush. Those milkweeds harbored more than a dozen caterpillars their first year and we found chrysalises behind the shutter, on top the window, and under the step overhang. This year: not a single Monarch, no evidence of eggs, no leaves munched by hungry caterpillars.

The milkweeds that Connor and you helped transplant from Frogtown Road to the horse fence five years ago, which turned yellow and barely survived the first summer, are now taller than the fence and I don’t need to carry pails of water over there anymore. But the same story for them: not a single Monarch, no evidence of eggs, no leaves munched by hungry caterpillars.



**Figure 8. Three of the Tiger Swallowtail butterflies; bottom one is female.**

Now I began to view these waiting milkweeds differently. Anticipation was replaced with an empty feeling. The milkweeds wilting in the hot summer sun were like the moldering wedding cake in *Great Expectations*. How silly, right? We were only being stood up by an insect.

Besides, the butterfly bush was well used. In early summer there were a few large yellow Tiger Swallowtails (Fig. 8). By mid-summer there were as many as 15 or 20 of them. Some of the females were brown, almost black. Some, male and female, had bright blue spots near their tail. Very nice looking, right? But somehow I did not like them much. The Tiger Swallowtails are larger than the Monarch, but they seem to be flimsy, many with tattered wings. Surely they could not fly thousands of miles, like the Monarch.





**Figure 9. First Monarch sighted in 2013.**

Then, on 14 August 1:17 PM, the first and only 2013 sighting of a Monarch in our yard (I saw three more in 2013 on edges of our property). She flew around the butterfly bush, landed on it briefly and then on a milkweed, where I took a photo (Fig. 9). She flew all around the yard a few times, at heights as much as 30 feet or more, all the way to the barn and back. She landed on the privet hedge several times and spent a lot of time sitting on the grass, seemingly resting. She came back to the butterfly bush and got in a confrontation with one of the Tiger Swallowtails, as they briefly whirled around each other. Why wouldn't she go back to the milkweeds and lay some eggs like the [broken-wing female](#)? Finally, after about two hours, she flew up over the pin oaks that border our property and was not seen again. Perhaps she didn't want to deal with the Tiger Swallowtails or maybe she just wanted to get on her way to Mexico.

When I went inside and enlarged the photo I saw that she was a he (Fig. 9), so there was no point to look for eggs on the milkweed or wait for caterpillars to appear. He looks weather-beaten, well-traveled - like Clint Eastwood in *Bridges of Madison County*. That made me wonder, how do the male and female Monarchs meet up? They don't seem to travel in pairs. They must produce new generations two or three times on the roundtrip from Mexico to Canada and back. That seems to depend upon chance encounters, which may explain this butterfly's behavior. He had learned immediately where the milkweeds and butterfly bush were located, so his circuitous search of the entire yard may have been spurred by the hope of meeting a female Monarch.

That raises a question: can the Monarch population be reduced to a level that the species becomes unviable, i.e., the species is committed to extinction? There are still millions of Monarchs, so you might guess that the species is not yet endangered. However, I suspect that the extinction threat for Monarchs is quite different from that for species such as the Whooping Crane, which I will discuss more in a moment. The birds stay in pairs or groups, and they migrate together, so there is potential for population recovery from even a small number. Based on the fact that most of my Monarch sightings in the past few years have been of single Monarchs and on my interpretation of the behavior of the male Monarch in our backyard in 2013, I wonder whether the population may have passed a tipping point beyond which it will

collapse. In other words, is the population now so low that there may be too few encounters between male and female butterflies to sustain the species?

This hypothesis might be tested by developing an appropriate mathematical model to calculate the change of Monarch population as a function of several quantities. Variables and parameters in the model must account for food availability on the Monarch flight path including effects of climate change. However, it is not easy to develop and test such a phenomenological model, and now events seem to be outpacing efforts to develop a quantitative understanding.

Data have just come in for the 2013-2014 winter. Monarchs reaching the wintering grounds in Mexico were only 56% as many as the prior year, which had been the record low number. This huge decline in Monarch population occurred despite improved weather conditions that should have resulted in an improved food supply along the flight path. The decline cannot be blamed on deforestation in Mexico, as the area of available fir trees exceeded the Monarchs' need.

Thus the data support the hypothesis that the Monarch population may have crossed a threshold such that it cannot sustain itself. If that is true, it is inevitable that the magnificent migrating Monarch population of eastern North America will practically disappear.

If the Monarch population has crossed a threshold of viability, our broken-wing butterfly's quest was in vain. At least she will not know. Besides, with her milligram-sized brain, she didn't even understand what she was trying to do. She wasn't thinking: "I have to raise this brood, so they can fly to Mexico and sustain the species." It was all just her instinct, you know.

Anyhow, my conjecture about this threshold is only a hypothesis, based on a few observations in one backyard, and hopefully it is a wrong hypothesis. Hypotheses based on limited data are tested by looking at additional data or making more observations that have the potential to support or falsify the hypothesis. Perhaps conservation efforts to restore milkweed areas can still yield a rebound of Monarch numbers, thus falsifying this hypothesis.

If the great North American Monarch migration is exterminated, it will be a big loss to the summer landscape and a symbol of the crushing effect that we humans are having on nature as we "take over" the land. The Monarch is indeed a monarch of the insect world, deserving our respect. Survival of some Monarchs in Mexico, the southern United States, and other parts of the world will be small consolation. Yet that survival provides the possibility of reviving the great migration – but it's too early for that discussion, which will require another letter!

In any case, next summer we will prepare the butterfly feast as usual. I may try to chase away any Tiger Swallowtails to reserve the butterfly bush for Monarchs as well as the other butterflies and hummingbirds that appeared last year. I suppose I will relent in the future if the Monarch goes extinct or if its numbers rebound, but I may find it difficult to learn to like the Tiger Swallowtail, even though they probably bear no responsibility for the Monarchs' problems.



**Figure 10. Whooping cranes, the tallest North American bird.**

Whooping Cranes (Fig. 10) provide another perspective on potential for extinction. The population of this bird, the tallest in North America, was reduced to about 20 in 1940. When I was a boy it was easy to keep track of the number of Whooping Cranes, because a running tally was kept on the bottom of the front page of the Omaha World Herald. I had a paper route delivering the World Herald, and, being rather slow-paced, when weather permitted I would sit down on a stone wall on my route, checking the front page, including the count of Whooping Cranes that had successfully migrated to Texas or back north, in addition to the sports pages.

Iconic species have an advantage. Penalties, including possible prison time, were imposed for killing a Whooping Crane. There has even been a major effort to re-establish an eastern flyway with wintering in Florida. This endeavor has included captive breeding of birds and training the birds to migrate from Wisconsin to Florida with the help of ultralight aircraft (Fig. 11).

These efforts have succeeded in restoring the Whooping Crane population to about 300 migratory birds in the wild. It seems that the Whooping Crane has survived its brush with extinction. However, their population remains far below the estimate of more than 10,000 Whooping Cranes prior to the settling of Europeans in North America. Your chances of seeing a whooping crane are pretty slim, even if you are traveling in their part of the continent.

It's not enough to keep species just on the good side of extinction. One of the most impressive things in nature is massive wildlife numbers, whether it is a buffalo herd, a flock of flamingoes (not the plastic ones), or the migrating Monarchs upon arrival in Mexico.

Few species can expect the treatment received by the Whooping Crane. When an 18-year old boy who had killed a Whooping Crane received only probation, a \$1 fine, and court costs of about \$500, lawyers for conservation organizations objected to the leniency, stating that the cost of restoring Whooping Cranes was about \$100,000 per bird.

There are millions of species on our remarkable planet. Preserving these species on a one-by-one basis is not practical. Indeed, it is not possible, because there is a vast interdependency



**Figure 11. Whooping cranes being led to Florida.**

among the species, which humans will never be able to figure out entirely and replicate. We must learn to share the planet with the other species, preserving all or at least most of them.

Whooping Cranes provide an example of another important point. I just mention it now – we can explore it more later. A federal judge in 2013, during a continuing drought, ordered Texas officials to allocate water supplies to the world’s last wild flock of the officially endangered Whooping Cranes<sup>2</sup>. The birds would have been in jeopardy without this water pumped into their nesting area. The point illustrated is that a climate anomaly, regardless of whether it is human-induced or a natural climate fluctuation, has the potential to be deadly to a species on the brink of extinction, especially if that species has been pushed into a limited area.

Sophie, Monarchs and Whooping Cranes provide examples of humanity’s interaction with other life on our planet. In another letter I will discuss several more species. For most species that are in trouble, the trouble is not mainly climate change. Humans affect nature in many ways including introducing exotic species into new areas, overharvesting species that we use as food, using large areas to grow a single crop, over fertilizing crops, and using excessive pesticides and herbicides. We can summarize this simply by saying that humans are taking over most of the planet without sufficient regard for the value that nature has for everyone.

Although climate change is not the principal stress affecting most species, if climate change continues to increase it will be the combination of shifting climate zones with other stresses that will cause massive extinctions. Fortunately, actions needed to stabilize climate are consistent with actions that reduce the stress on other species, and climate stabilization and species preservation are both in the best interests of humanity.

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<sup>2</sup> [Texas Is Ordered to Supply Water to Crane Habitat](#) March 12, 2013 Wall Street Journal

I do not imply that the actions are easy. On the contrary, such fundamental matters as global population and poverty must be addressed, and thus, too, the need for abundant, affordable, clean energy. What I mean is that a path can be discerned that simultaneously addresses climate and survival of species. Furthermore, as we can discuss later, the required actions make sense for multiple reasons and are not painful to society overall.

I have no doubt that we are capable of solving these problems. In the vision of biologist Ed Wilson our present extreme abuse of the planet is temporary, causing a bottleneck this century for species. Most of the species will be able to pass through this bottleneck, if we take the actions that allow us to stabilize climate and do a better job of sharing the planet with the other life. And sharing the planet is necessary for our own good, as well as theirs.

I know this letter is already long and introduces several topics, so I will finish it. However, I want to close with a few important points.

First, this is no doom-and-gloom story. We live on the most marvelous of planets, with a spectacular array of life. It doesn't matter whether we call it Creation or Nature. We are blessed, we are fortunate, to have the opportunity to preserve this splendor of life for future generations. We must not miss that opportunity or fail to see the nobility of the task.

Remember last summer when I gave a talk in the backyard of a friend's house on Long Island? Jake, Lauren and baby Eric were in bed or getting in bed, but you and Connor were in the audience. There were so many people, and lots of questions, so I did not notice Connor, but, at the end, Oma saw that tears were rolling down his cheeks – you know how sensitive Connor is.

Oma told Connor not to worry about such things, that grownups were working on the problems, and grownups would fix the problems. As usual, Oma knew the right thing to say. It worked well – Connor was fine the next day and does not seem to have mentioned anything about it.

Youngsters unavoidably will hear the news at times. So if the Monarch population crashes, that can't be kept a secret. Star Wars, one of Connor's favorite stories, has a relevant example. Remember how Yoda, the Jedi Master, bowed his head when he felt, through "the Force", that people on a distant planet had succumbed to the evil Empire? A setback should be felt as a loss, but it should only increase our resolve, not discourage us.

The statement that grownups are working on the problems and will fix them is gut-wrenching, it gnaws on me because I am one of the adults who should have been fixing the problem. I am in a position to understand the situation as well or better than almost anyone. It seems impossible for me to get a full night's sleep, because all the elements of the story are continually swirling in my head. However, I have not, nor has anyone else, communicated the full story nor even the key portions of it well enough to lead to the needed actions. The tragedy is that the needed actions

make good sense in many ways, including economic sense, and they would benefit today's adults, as well as young people, future generations, and nature.

What has been communicated fairly well is the present state of urgency. Global climate, the average weather, changes slowly and the public does not easily notice climate change, because it is masked by large weather fluctuations. Paradoxically, the slowness of underlying climate change creates urgency. Slowness is caused by the great inertia of our deep oceans and thick ice sheets. The inertia implies that more climate change is "in the pipeline" even without further atmospheric change. And we will put still more change into the pipeline, because we can't instantly stop burning coal, oil and gas, which are the biggest cause of climate change.

Climate changes over decades. Major changes of energy systems take decades. Loss of species and possible recoveries occur over decades, as illustrated for Whooping Cranes and Monarchs, even though Monarch population trends are masked by short-term fluctuations, just as the weather masks climate trends.

The swiftness of the decadal time scale became clearer to me recently when I watched Lauren, your 4-year-old cousin, coloring pictures. It reminded me of when you were that age and colored or drew pictures for us. I dug out an old photo of you on the kitchen floor with your uncle Erik (Fig. 13). I suppose that seems like a long time ago to you. But aging adults like me know that 11 years seems more like a blink of the eye. We can also use 11 years as a unit to measure time in climate science and species change, at least for our present discussion.

Let's begin measuring time in 1981. It was already becoming clear then, as discussed in a paper I wrote for *Science* in 1981, that burning all coal would have unacceptable consequences. Within



**Figure 12.** Sophie's cousin Lauren, age 4, coloring a picture.



**Figure 13. Sophie, at age 4, drawing a picture for uncle Erik.**

one unit of time, one blink, 11 years, nations of the world agreed that actions must be taken to avert dangerous human-made climate change, emblazoned in the 1992 United Nations Framework Convention on Climate Change. Political leaders were being responsible, looking out for the rights of young people, future generations, and nature. Or so it seemed.

After two more blinks of time, 22 years, their words ring hollow. Actions of nations, even proposed but unconsummated actions, have been half-baked and ineffectual.

Indeed, it is worse than that. Despite knowledge that all the coal cannot be burned and carbon-rich unconventional fossil fuels, such as tar sands and tar shale, should not be developed, our governments have allowed every fossil fuel that can be found to be extracted. Governments even encourage and subsidize growing fossil fuel extraction.

Is this a simple story of chicanery? The fossil fuel industry and governments are the villains? An oft-repeated accusation is that the fossil fuel industry mimics the tobacco industry, which decades ago used unscrupulous means to deny the link between smoking and lung cancer. It is easy to find examples of fossil fuel industry denial of climate change. Also there are obvious cases in which people made wealthy by fossil fuels try to maintain their fortune by lobbying governments and buying or influencing media or the courts.

However, the analogy of tobacco with fossil fuels is not even close. Tobacco is a luxury and an addiction. Energy is essential to humanity. Fossil fuel energy aided elimination of slavery and lifted half of the world out of poverty. Abundant affordable energy is essential to eliminate remaining poverty and reduce humanity's heavy footprint on nature. What science tells us is that the energy must be carbon-free, if young people and nature are to have a bright future.

Our “captains of industry”, including the fossil fuel industry are hugely talented. They are part of the solution to the energy and climate problems, but our political system needs to give them the proper incentives instead of hamstringing them or pointing them in the wrong direction.

The story of why we have floundered and wasted 22 years has not been accurately reported. A large part of the blame for complete policy failure rests on the shoulders of people who recognize the reality of climate change and claim to be supporting needed actions. This is a story that needs to be told, because until it is understood we likely will continue to flounder.

Politicians, elected to serve the people, bear a large part of the responsibility for failure so far, and the blame falls heavily on both sides of the political aisle. Scientists, too, bear a large responsibility. It is not most of the individual scientists who are at fault, because they work in specialized fields – rather the scientific community as a whole and those scientists in a position to see the broad picture, but who have failed to communicate the situation well.

Sophie, we cannot waste another blink. No such margin remains. By the time of the next blink the world’s fossil fuel emissions must be rapidly declining. And to achieve that, the world must move promptly onto a different energy pathway.

The actions that are needed are not painful to the public. On the contrary, the results will be beneficial to almost everyone, as well as the other life on our planet. But the actions will not happen without a broader understanding of what happened during the past 22 years, which will help clarify what needs to happen now.

Sophie, I need your help. This is my last chance to try to make the story clear. I know it is strange to ask your help. Just yesterday, one blink ago, you were lying on our kitchen floor, learning to draw with great determination, and for more than five years you were our only grandchild, the apple of everyone’s eyes. Even now, as a high school freshman, you and your classmates did not put the world in its present situation -- but you have a lot at stake.

Put yourself in Connor’s shoes for a moment and think of it as Star Wars – but with the battle for our planet being fought on our planet, not on some distant world. I call it “Sophie’s Planet” because it will soon belong to your generation, young people all around the world. We must help them all understand what is at stake. Never get discouraged -- it is an incredible planet.

So my dear granddaughter, the angel who came into our lives 15 years ago, the baby who named me Bopa, I am counting on you to help make these letters clear. This is my first letter.

Love, Bopa