The Game Mechanics of Pokémon

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1 Introduction

Pokémon is one of the biggest video game franchises in history, having sold over 200 million games since its launch in 1996. Some of the best known games are the main RPGs in the series spanning across five generations with a sixth one on the way. These games have consistently shown that the Pokémon world has many complexities, even in the days of the Game Boy when cartridges could only hold up to 1 megabyte of data on them.[1] This class will discuss many of the aspects of the Pokémon games, such as finding them, catching them, training them, breeding them, and battling with them.

2 Finding Pokémon

Anyone who has played Pokémon knows that there are many ways to find wild Pokémon, such as searching through tall grass, wandering around in caves, and surfing on the ocean. Also, some Pokémon can only be found in certain areas, and some species are rarer than others.

2.1 Encounter Rates

Every area has a table of Pokémon that can be found in that area.[2] This table also contains what levels the Pokémon appear at and the odds that any random encounter will be of a certain species. For example, here is the table of encounter rates for Kanto Route 24 in FireRed:

Species	Levels	Rate
Caterpie	7	20%
Metapod	8	1%
Weedle	7	20%
Kakuna	8	4%
Pidgey	11-13	15%
Oddish	12-14	25%
Abra	8-12	15%

Games from Generations II, IV, and V keep track of the time of day, splitting a 24-hour period into three parts: morning (4 a.m. to 10 a.m.), daytime (10 a.m. to 6 p.m.), and nighttime (6 p.m. to 4 a.m.). This allows different Pokémon to appear at different times of day. For this, there are separate tables for each part of the day, as with Sinnoh Route 203:

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[1]As an even more impressive story, the contents of Pokémon Gold and Silver originally filled the cartridge when the game was only halfway done. Satoru Iwata, the president of Nintendo, personally compressed the data to fit into the cartridge. That's why Kanto was included in the game—there was that much space left when he was done!

[2]These tables can be found on websites like Bulbapedia (http://bulbapedia.bulbagarden.net/).

Species	Morning		Daytime		Nighttime	
	Level	Rate	Level	Rate	Level	Rate
Starly	4-7	35%	4-7	35%	4-7	25%
Bidoof	5-7	15%	4-7	25%	5-7	15%
Kricketot	4	10%	–		5	10%
Shinx	4-5	25%	4-5	25%	4-5	25%
Abra	4-5	15%	4-5	15%	4-5	15%
Zubat	–		–		4	10%

2.2 The Mystery Behind MissingNo.

MissingNo. is probably one of the most famous video game glitches of all time, notably because of its ability to duplicate the sixth item in the player's bag. The process[3] of performing this item duplication trick is as follows:

1. Place the item you want to duplicate in the sixth slot of your bag. Rare Candies and Master Balls are popular choices.

2. Talk to the old man in the northern end of Viridian City and have him show you how to catch a Pokémon.

3. Fly to Cinnabar Island, and Surf along the east coast until you encounter a MissingNo.

4. Your sixth item has now been duplicated.

This takes advantage of a programming quirk present in the games. When you enter an area, the table of wild Pokémon available is stored in a data buffer, which the game accesses for random encounters. However, when you talk to the old man, the player's name is stored in this data buffer. Normally when you enter another area, this data buffer is overwritten with valid Pokémon data. However, the programmers forgot to associate the east coast of Cinnabar Island with valid Pokémon data, so it just uses whatever was in the table beforehand. Therefore, in the process described above, the game will try to read the hexadecimal values of your name as Pokémon data, which can cause the game to see unexpected values. MissingNo. is the result of seeing an unexpected value.

But why does this process duplicate your sixth item? The reason for this involves how the game keeps track of which Pokémon you have seen. When you see a particular species Pokémon for the first time, the game sets a certain bit in memory to 1. For MissingNo., this bit happens to be the highest order bit of the memory address that contains the quantity of your sixth item. If you set this bit to 1, you increase the quantity of your sixth item by 128 (or leave it unchanged if it is already at least 128).

2.3 Finding Mew

Due to another bug, it's possible to encounter Mew in the wild in Gen I games.[4] Here's one way to do it:

1. Before you begin, make sure you have not yet defeated the Jr. Trainer in the grass on Route 24 and the Youngster with the Slowpoke on Route 25. Also, you'll need a Pokémon that knows Teleport.

2. Heal at the Cerulean Pokémon Center so you can Teleport back there.

3. Approach the Jr. Trainer and press START at the exact same moment as when the exclamation point would appear.

4. From the menu, use Teleport. If you do it right, you'll see the exclamation point appear as you're teleporting out. You'll end up back at the Pokémon Center.

5. Go to Route 25 and battle the Youngster, making sure you avoid the other trainers if you haven't battled them.

6. Battle the Youngster. Make sure you approach him by walking along the northern edge, or else the trick will not work.

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[3]This trick only works in Pokémon Red and Blue.
[4]No, it doesn't involve looking under the truck.

7. Return to Cerulean City. On your way, the pause menu will randomly appear. Exit it, and you'll get thrown a battle with a wild Mew.

You can see the glitch in action at `http://www.youtube.com/watch?v=J6hU-f_Q8Vk`.

The reason for this glitch on a high level is that the game is confused about what state it is in. The exclamation point appearing indicates that the game thinks it's about to enter a battle. However, since you're Teleporting, you're clearly not about to battle. As you proceed through these steps, the game continues to be confused, and due to how Gen I games determine wild encounters, a Mew will appear.

2.4 The Repel Trick

If you know what Pokémon are available in a certain area and at what levels they appear, then you can easily take advantage of the Repel Trick to find certain Pokémon. Repels are items that prevent you from encountering wild Pokémon that are at a lower level than the first Pokémon in your party. For example, if you have a level 20 Pokémon in the first position, you will not encounter any wild Pokémon that are level 19 or below.

2.4.1 Example 1 – Pokémon Mansion, Blue

Suppose you are in Pokémon Mansion in Blue version and you want to catch a Fire-type Pokémon. Here is the table of wild Pokémon for this area:

Species	Levels	Rate
Vulpix	34	10%
Ponyta	28-34	40%
Grimer	30-32	40%
Muk	37	4%
Koffing	30	5%
Weezing	39	1%

Normally, you would have a 50% chance of encountering a Fire type. These aren't bad odds. However, they may not be ideal if you were doing a Nuzlocke run,[5] where you can only catch the first Pokémon you see in any area. However, you can easily increase these odds using Repel.

Suppose you put a level 33 Pokémon in the first position in your party. This eliminates all Grimers, all Koffings, and 5 out of 7 possible levels for Ponytas. Therefore the encounter rates for Grimer and Koffing drop to 0%, and the encounter rate for Ponyta drops to $\frac{2}{7}$ of 40%, or around 11%. After normalizing the rate percentages to add up to 100%, we get this:

Species	Levels	New "rate"	Normalized rate
Vulpix	34	10%	38%
Ponyta	33-34	11%	43%
Muk	37	4%	15%
Weezing	39	1%	4%

Your odds of encountering a Fire type are now 81%, which is much better.

2.4.2 Example 2 – Trophy Garden, Diamond/Pearl

Another example can allow you to score valuable held items. Here is the table for the Trophy Garden:

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[5]A Nuzlocke run is a run through a Pokémon game with two additional rules. First, you may only catch the first Pokémon you see in any area. Second, if a Pokémon faints, it is considered dead and must be released or permanently boxed as soon as possible. Some people choose to make webcomics highlighting points of their run. The original one can be found at `http://www.nuzlocke.com/pokemonhardmode.php?p=1`. It's a great read.

Species	Morning		Daytime		Nighttime	
	Level	Rate	Level	Rate	Level	Rate
Staravia	16-17	20%	16-17	40%	16-17	20%
Kricketune	16-17	10%	16-17	10%	16-17	30%
Roselia	16-17	30%	16-17	30%	16-17	30%
Pichu	16	30%	16	10%	16	10%
Pikachu	18	10%	18	10%	18	10%

If you use Repel with a level 18 Pokémon in front, then all wild Pokémon encounters will be Pikachus. Furthermore, if this Pokémon also has the Compoundeyes ability, then the chances of finding a Pikachu holding a Light Ball[6] increases. (This isn't a huge increase; the odds go from 5% to 7.5%. However, every little bit helps.)

3 Catching Pokémon

When you actually find a wild Pokémon, you can try to catch it. It's obviously easier to catch Pokémon with lower HP or with a status ailment. Let's look at how the mechanics of this work. We'll first talk about the mechanics of games in Generations II and beyond.

3.1 Catch Rates and Modified Catch Rates

Every Pokémon species has a *catch rate* that indicates how easy it is for a Pokémon to be caught. The highest catch rate any Pokémon has is 255, which is held by common Pokémon such as Patrat or Bidoof. The lowest catch rate any Pokémon has is 3, which is held by most legendaries.

However, there are other factors that go into how likely one is to catch a Pokémon, including how much HP the Pokémon has left, what kind of ball you're using, and any status ailment the wild Pokémon has. Therefore we must compute a *modified catch rate m*. In Gens III and IV, the formula for the modified catch rate in terms of the wild Pokémon's catch rate c is:

$$m = \left(1 - \frac{2}{3} \cdot \frac{\text{current HP}}{\text{max HP}} \right) \cdot c \cdot b_{\text{ball}} \cdot b_{\text{status}}$$

If $m \geq 255$, the Pokémon is automatically caught. Otherwise, the probability of capture is approximately $\frac{m+1}{256}$.

Here, b_{ball} refers to a bonus multiplier applied depending on what kind of ball you're using. For example, a Poké Ball has a multiplier of 1, a Great Ball has a multiplier of 1.5, and an Ultra Ball has a multiplier of 2.[7] b_{status} refers to a bonus given for a status ailment. It equals 1 if the wild Pokémon has no status ailment, 1.5 if it is paralyzed, poisoned, or burned, and 2 if it is asleep or frozen.

Generation II games have a similar formula, except the status bonus is added rather than multiplied. Paralysis, poison, and burn add 5 to the modified catch rate, and sleep and freeze add 10 to the modified catch rate.

3.2 Shake Probabilities

What really happens is that the game calculates a *shake probability* from the modified catch rate. The game then performs four shake checks, which are done to determine how many times the Poké Ball shakes before the Pokémon breaks free or the game tells you, "Gotcha! [Wild Pokémon] was caught!"

In Generations III and beyond, if p is the probability of capture, then the probability of passing a shake check is approximately $\sqrt[4]{p}$. Generation II uses a lookup table to associate the modified catch rate m and the shake probability s:

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[6]An item that doubles Pikachu's Attack and Special Attack stats when held.

[7]See http://bulbapedia.bulbagarden.net/wiki/Catch_rate#Pok.C3.A9_Ball_effectiveness_rates for a list of all ball bonuses. Note that the Heavy Ball doesn't multiply the catch rate; rather, it adds or subtracts a bonus or penalty. This affects the catch rate before multiplying by any other modifiers.

m	s	m	s	m	s	m	s
0-1	0.250	8-10	0.445	51-60	0.695	161-160	0.918
2	0.297	11-15	0.496	61-80	0.750	181-280	0.941
3	0.332	16-20	0.527	81-100	0.789	201-220	0.965
4	0.355	21-30	0.586	101-120	0.828	221-240	0.984
5	0.375	31-40	0.629	121-140	0.863	241-254	0.992
6-7	0.406	41-50	0.664	141-160	0.891	255	1.000

However, it turns out that these values of s closely correspond to $\sqrt[4]{\dfrac{m+1}{256}} = \sqrt[4]{p}$.

3.3 Generation V Additions

Gen V games have added two additional multipliers to get the modified catch rate. The first one is the Capture Power factor, an Entralink mechanic. Depending on which power is active, you can multiply the value of m by 1.1, 1.2, or 1.3. The second mechanic is the dark grass factor. When you encounter a Pokémon in dark grass, the HP factor is multiplied by another number depending on how many Pokémon you have caught:

Number caught	Multiplier
601-649	1.0
451-600	0.9
301-450	0.8
151-300	0.7
30-150	0.5
0-29	0.3

Gen V games also introduce the idea of a *critical capture*, which increases your chances drastically of catching a Pokémon by only performing one shake check. To check whether or not a critical capture has occurred, the game calculates the modified catch rate m above and multiplies it by a constant k:

Number caught	Multiplier
601-649	2.5
451-600	2.0
301-450	1.5
151-300	1.0
30-150	0.5
0-29	0.0

The game then generates a random number x between 0 and 255. If $x < mk$, then a critical capture occurs.

3.4 Generation I Mechanics

Gen I mechanics are much different. The idea of catch rates still applies, but the effects of HP level, the ball used, and status ailments has changed. To determine whether or not a wild Pokémon is caught, perform the following steps in this order:

1. If you use a Master Ball, the Pokémon is automatically caught.

2. Pick a random integer x between 0 and A inclusive, where A is 255 if you're using a Poké Ball, 200 if you're using a Great Ball, or 150 if you're using an Ultra Ball.

3. If $x < 25$ and the Pokémon is asleep or frozen, the Pokémon is caught.

4. If $x < 12$ and the Pokémon is paralyzed, poisoned, or burned, the Pokémon is caught.

5. If x is greater than the catch rate of the wild Pokémon, the Pokémon breaks free.

6. Pick a random integer y between 0 and 255 inclusive. Calculate $z = \dfrac{255}{B} \cdot \dfrac{\text{max HP}}{\text{current HP}}$, where you are looking at the HP of the wild Pokémon, and where B is 2 for a Great Ball, 3 otherwise. If $z \geq y$, the Pokémon is caught. Otherwise it breaks free.

This method has some unusual properties:

- The effect of reducing HP diminishes on Pokémon with lower catch rates, and the effect of inflicting a status ailment diminishes on Pokémon with higher catch rates.

- Reducing the wild Pokémon's HP below half of its maximum value does not improve the chance of capture with Great Balls. For other balls, the threshold is $\frac{1}{3}$ of the maximum value.

- In some cases, Great Balls perform better than Ultra Balls. This is generally the case with Pokémon above 50% HP and no status ailment.

4   Training Pokémon

Training is one of the biggest aspects of Pokémon. As you battle, your Pokémon get stronger. However, if you choose your battles smartly, your Pokémon can become powerful in all the right places.

4.1   Experience

As you battle other Pokémon, you gain experience. When you gain enough experience, you level up and become stronger. In Generations I through IV, the formula for how much experience points a Pokémon gets from making another Pokémon faint is:

$$\text{EXP} = \frac{b \cdot L_f \cdot a \cdot t \cdot e}{7 \cdot s}$$

The variables are:

- b is equal to the base experience of the fainted Pokémon, which varies from species to species. Generally, the harder it is to make a Pokémon faint, the higher its base experience is. For example, Blissey, having a ton of HP (up to 714 HP, the most any Pokémon can have), has a b value of 608, the highest b value of all Pokémon.

- L_f is equal to the level of the fainted Pokémon.

- a is equal to 1 if the fainted Pokémon was wild, or 1.5 if it was owned by a Trainer.

- t is equal to 1 if the winning Pokémon was caught by the user, or 1.5 if it was received in a trade. In Generations IV and V, where one can trade internationally via the Nintendo Wi-Fi Connection, the trade bonus is 1.5 for domestic trades and 1.7 for international trades.

- e is equal to 1.5 if the winning Pokémon is holding a Lucky Egg, or 1 otherwise.

- s is equal to the number of Pokémon that participated in battle.

Generation V adds a new concept: higher-leveled Pokémon gain less experience from winning against lower-leveled Pokémon. In Generation V, the formula is:

$$\text{EXP} = \left(\frac{b \cdot L_f \cdot a}{5 \cdot s} \cdot \left(\frac{2L_f + 10}{L_w + L_f + 10} \right)^{2.5} + 1 \right) \cdot t \cdot e \cdot p$$

This introduces two new variables:

- L_w is the level of the winning Pokémon.

- p is a variable depending on Exp. Point Power, a Gen V game mechanic associated with the Entralink.

4.2 Experience Groups

When a Pokémon reaches a certain number of experience points, it levels up. The exact times when a Pokémon level up depends on which of the six experience groups it belongs to. Here are the six different experience groups, along with the formulas for how much experience is required to reach level n.

4.2.1 Erratic Group

$$\text{EXP} = \begin{cases} \frac{n^3(100-n)}{50} & n < 50 \\ \frac{n^3(150-n)}{100} & 50 \leq n < 68 \\ \frac{n^3\lfloor(1911-10n)/3\rfloor}{500} & 68 \leq n < 98 \\ \frac{n^3(160-n)}{100} & 98 \leq n \end{cases}$$

Note: $\lfloor x \rfloor$ denotes the greatest integer less than or equal to x, and may be read as "the floor of x." For example, $\lfloor 3.14 \rfloor = 3$, $\lfloor 8.999 \rfloor = 8$, and $\lfloor -13.37 \rfloor = -14$.

Pokémon in this group start out growing slowly, but end up requiring the fewest number of experience points (600,000) to reach level 100. This group was introduced in Gen III, and contains 22 Pokémon.

4.2.2 Fast Group

$$\text{EXP} = 0.8n^3$$

This group grows consistently quickly. It was the fastest growing group in Gen I and Gen II, requiring only 800,000 EXP to reach level 100. There are 52 Pokémon in this group.

4.2.3 Medium-Fast Group

$$\text{EXP} = n^3$$

This group is the largest experience group of them all, containing 251 Pokémon. Pokémon in this group require 1,000,000 EXP to reach level 100.

4.2.4 Medium-Slow Group

$$\text{EXP} = 1.2n^3 - 15n^2 + 100n - 140$$

Despite its name, Pokémon in this group do grow faster than those in the medium-fast group up until level 67. This group is the second-largest group, containing 175 Pokémon, including all the starters and their evolution lines. Pokémon in this group require 1,059,860 EXP to reach level 100.

Interestingly, if you evaluate this function at $n = 1$, you get -53.8, which rounds to -54. Gen I and Gen II games stored experience points as a 24-bit unsigned integer[8], so this caused an integer underflow error. Therefore if a level 1 Pokémon in this group was to gain a small amount of experience, they would instantaneously grow to level 100.

4.2.5 Slow Group

$$\text{EXP} = 1.25n^3$$

The slow group was the slowest growing group in Gen I and Gen II. It contains 135 Pokémon, including many rare, legendary, and powerful Pokémon. And Magikarp, who is definitely not rare, legendary, or powerful. Pokémon in this group require 1,250,000 EXP to reach level 100.

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[8]This means that you can only express numbers from 0 to $2^{24} - 1 = 16777215$ inclusive. A negative number, like -5, would be represented as $2^{24} - 5$. Although there is no standard data type for 24-bit integers, it's likely that the programmers used bit-manipulating tricks to save precious memory. This case must have slipped through the cracks.

4.2.6 Fluctuating Group

$$\text{EXP} = \begin{cases} \frac{n^3(\lfloor (n+1)/3 \rfloor + 24)}{50} & n < 15 \\ \frac{n^3(n+14)}{50} & 15 \leq n < 36 \\ \frac{n^3(\lfloor n/2 \rfloor + 32)}{50} & 36 \leq n \end{cases}$$

Pokémon in this group start by growing very quickly, but grow more slower than normal as they level up. They require 1,640,000 EXP to reach level 100. This group was introduced in Gen III, and contains 14 Pokémon.

4.3 Another Way of Looking At It

These values, however, have some peculiarities. For many levels, Pokémon in the Medium Slow group actually need fewer experience points to reach a particular level than those in the Medium Fast group! This follows directly from the fact that $1.2n^3 - 15n^2 + 100n - 140 < n^3$ when $6 \leq n \leq 67$. (The full range is a little bit larger; the two sides are equal at $n \approx 1.96$, $n \approx 5.26$, and $n \approx 67.78$.) This is a pretty reasonable range for most Pokémon players; after all, when you battle the Elite Four and Champion, you don't really see any levels beyond the mid-60s. Some notable exceptions might be the rematch against Cynthia in Platinum, where her Pokémon are in the mid-70s, and Red in Gen II and the Gen IV remakes, whose Pokémon have levels in the 70s and 80s.

This suggests that we may want to think of a new model. Instead of focusing on how much experience it takes to reach level n, let's focus on how much experience it takes to get from level $n-1$ to level n. This can be done by taking one of the six experience functions f described above and calculating $f(n) - f(n-1)$. Mathematically, this is known as a *backward finite difference*. We will call these results *marginal experience functions*.[9]

We will just look at the marginal experience functions for the Fast, Medium Fast, Medium Slow, and Slow groups, since the marginal experience functions for the Erratic and Fluctuating groups are pretty ugly due to the numerous floor functions.

The marginal experience function for the Fast group is:

$$0.8n^3 - 0.8(n-1)^3$$
$$= 2.4n^2 - 2.4n + 0.8$$

The marginal experience function for the Medium Fast group is:

$$n^3 - (n-1)^3$$
$$= 3n^2 - 3n + 1$$

The marginal experience function for the Medium Slow group is:

$$\left(1.2n^3 - 15n^2 + 100n - 140\right) - \left(1.2(n-1)^3 - 15(n-1)^2 + 100(n-1) - 140\right)$$
$$= 3.6n^2 - 33.6n + 116.2$$

The marginal experience function for the Fast group is:

$$1.25n^3 - 1.25(n-1)^3$$
$$= 3.75n^2 - 3.75n + 1.25$$

If you were to compare the marginal experience functions of the Medium Fast and Medium Slow groups, you will find that they are equal at $n \approx 46.9$. Beyond this level, Pokémon in the Medium Fast group require fewer EXP to advance one level than Pokémon in the Medium Slow group. This is a slightly more acceptable way of looking at this, since it is almost certain that a trainer will bring his Pokémon beyond this level while training.

As an aside, you can save yourself a little bit of messy algebra by using the derivative, $f'(n)$, as an approximation to the marginal experience function. The answer won't change much. This would be a better model if levels were continuous (that is, if you could have any real-numbered level like $26\frac{1}{2}$ or $10 + \pi$), but it's not absolutely necessary in our case. I'm only mentioning this just so you can say that you can use calculus to discuss Pokémon game mechanics.

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[9]Here, "marginal" is borrowed from economics, where it refers to how much a function changes when you change its input by a small amount.

4.4 Stats

As Pokémon gain more experience, they level up, and their stats become stronger. Your stats are what ultimately determine how well a Pokémon does in battle (along with many other factors, which we will discuss later).

4.4.1 Base Stats

Every Pokémon has a set of base stats in six areas: HP, Attack, Defense, Special Attack, Special Defense, and Speed.[10] The higher your base stats are, the high your overall stats are. As an example, here are Krookodile's base stats:

HP	95
Attack	117
Defense	70
Special Attack	65
Special Defense	70
Speed	92

As another example, here are Pikachu's base stats:

HP	35
Attack	55
Defense	30
Special Attack	50
Special Defense	40
Speed	90

4.4.2 Effort Values

Effort values, or EVs, really define what it means to train Pokémon. Each Pokémon has six EVs, one for each stat. In Gens I and II there are only five EVs: HP, Attack, Defense, Speed, and Special. When you receive a Pokémon, it starts out with no EVs whatsoever. When you win a battle, in addition to experience points, you also gain EVs based on which Pokémon you made faint.

In Generations I and II, the winning Pokémon gains EVs in each stat equal to the base stats of the fainted Pokémon. For example, causing a Pikachu to faint would give the winning Pokémon 35 HP EVs, 55 Attack EVs, 30 Defense EVs, etc. The maximum number of EVs one could have in any particular stat is 65,535.

Generations III and beyond have a different EV system, each Pokémon has an EV yield, which is loosely connected to its base stats, as Pokémon that are strong in a particular stat tend to yield EVs in that stat. For example, Pikachu's EV yield in the newer games is 2 Speed EVs, and Krookodile's EV yield is 3 Attack EVs. Every Pokémon yields either 1, 2, or 3 EVs, and they may yield EVs across different stats (for example, Torterra's EV yield is 2 Attack EVs and 1 Defense EV). The maximum number of EVs one could have in any particular stat is 255, and the maximum number of EVs one could have over all stats is 510.

One way to help grow EVs is through the Pokérus, a rare symbiotic virus introduced in Gen II that infects 3 out of 65,536 Pokémon. Once infected with the virus, Pokémon gain EVs at double the normal rate. This virus goes away after a few days, but the positive effects remain. Make sure you spread the Pokérus as soon as you get it!

Another way is through EV-enhancing items, like vitamins such as Protein or Iron. In Gens I and II, each vitamin increases a particular EV by 2560, up to 25600. In Gens III and beyond, each vitamin increases an EV by 10, up to 100 and provided that the total EVs do not exceed 510.

You can also use certain held items, like the Power Lens or the Power Band, to help increase EVs in exchange for halving Speed in battle. Each of these items add an additional 4 EVs to a particular stat after every battle, including the fallen Pokémon's EV yield. For example, the Power Lens is associated with the Special Attack EV. Better yet, if you have the Pokérus, the effects of these held items also double, yielding a whopping 8 EV bonus!

Another type of item that can be used to increase EVs is the Wing, introduced in Gen V. These can be found at the Driftveil Drawbridge or Marvelous Bridge, and each one increases a particular EV by 1. For example, the Health

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[10]In Generation I, Special Attack and Special Defense were combined into one stat, Special.

Wing increases your Pokémon's HP EV by 1. They work similarly to vitamins, only they can be used to increase EVs all the way up to 255.

We discuss more ways you can fine-tune EVs in the section marked "EV Training."

4.4.3   Individual Values

Individual values, or IVs, are fixed values that influence a Pokémon's stats. Like EVs, there is an IV for each stat. Unlike EVs, they cannot be changed. IVs behave like a Pokémon's genes. When you breed two Pokémon together, they pass some of their EVs down to their offspring. In Generations I and II, IVs range from 0 to 15. In Generations III and beyond, IVs range from 0 to 31.

In general, IVs are slightly harder to calculate for Pokémon than EVs, which can easily be counted directly. However, there are several ways you can calculate IVs directly. One such way in Gen IV games is to initiate a Wi-Fi battle and scale your Pokémon team to level 100. If you do this, and if you know your Pokémon's EVs, then you can use the appropriate stat formula in section 4.4.5 to calculate IVs.[11]

4.4.4   Natures

Generation III introduced Natures. Every Pokémon has one of 25 different natures. Twenty of them affect stats by increasing one by 10% and decreasing another by 10%:

		Decreased stat				
		Attack	**Defense**	**Speed**	**Sp. Atk.**	**Sp. Def.**
	Attack	–	Lonely	Brave	Adamant	Naughty
	Defense	Bold	–	Relaxed	Impish	Lax
Increased stat	**Speed**	Timid	Hasty	–	Jolly	Naïve
	Sp. Atk.	Modest	Mild	Quiet	–	Rash
	Sp. Def.	Calm	Gentle	Sassy	Careful	–

The other five natures are Bashful, Docile, Hardy, Quirky, and Serious. They do not affect stats.

Interestingly, these stat modifiers also determine what flavors of Pokéblocks or Poffins Pokémon like or dislike. Each stat corresponds to a flavor: Attack corresponds to Spicy, Defense to Sour, Special Attack to Dry, Special Defense to Bitter, and Speed to Sweet. The stat that is increased determines which flavor a Pokémon likes, and the stat that is decreased determines which flavor a Pokémon dislikes. For example, a Naughty Pokémon's favorite flavor is Spicy, and its least favorite flavor is Bitter.

4.4.5   Formulas

All this information gives us formulas for determining a Pokémon's stats.

In Gens I and II, the formulas are:

$$\text{HP} = \frac{(\text{base} + \text{IV} + \frac{\sqrt{\text{EV}}}{8} + 50) \cdot \text{level}}{50} + 10$$

$$\text{Other stat} = \frac{(\text{base} + \text{IV} + \frac{\sqrt{\text{EV}}}{8}) \cdot \text{level}}{50} + 5$$

In Gens III and beyond, the formulas are: -

$$\text{HP} = \frac{(2 \cdot \text{base} + \text{IV} + \frac{\text{EV}}{4} + 100) \cdot \text{level}}{100} + 10$$

$$\text{Other stat} = \left(\frac{(2 \cdot \text{base} + \text{IV} + \frac{\text{EV}}{4}) \cdot \text{level}}{100} + 5 \right) \cdot N$$

where *N* represents the Nature modifier, which is either 0.9, 1, or 1.1.

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[11]For other ways to calculate or approximate IVs, check out `http://www.smogon.com/ingame/guides/breeding_guide_part1`.

4.5 EV Training

Naturally, you can affect the way your Pokémon grows by making it battle only Pokémon with certain EV yields to cultivate particular stats. At level 100, EVs can account for 63 stat points, and that's before taking Natures into account. Therefore, I will now discuss some useful notes about EV training.

4.5.1 The Rule of 252

Looking at the Gen III formula, you'll notice that EVs are divided by 4. When the game performs this computation, it will round the result down, just like any other computer performing integer division. Therefore if you bring a Pokémon's EV above 252, those points will not affect its stats.

    If you're consciously EV training, then you will probably make sure that this will never happen. You might ensure an EV distribution of 252/252/6, which would yield a total of $\lfloor \frac{252}{4} \rfloor + \lfloor \frac{252}{4} \rfloor + \lfloor \frac{6}{4} \rfloor = 127$ stat points. However, if you maxed out two EVs to 255 instead, then you would earn a total of $\lfloor \frac{255}{4} \rfloor + \lfloor \frac{255}{4} \rfloor = 126$ stat points, so the loss isn't that big a deal unless you want to fully optimize your Pokémon.

4.5.2 The Box Trick

The box trick is a trick that can be used in Gens I through IV to change your Pokémon's stats without leveling it up. The idea is that you can deposit a Pokémon into your PC and then take it out again, only to have its stats increase.

    The reason behind this is that when a Pokémon is stored in the PC, the game only stores the numbers needed to calculate its stats (such as EVs and IVs) to save space. When a Pokémon is brought out into your party, the stats are recalculated and stored explicitly in memory. When you store and withdraw a Pokémon, you are forcing the game to update its stats, which it does not normally do after every battle or EV-changing item.

    One slight limitation is that in Gens III and IV, you cannot use the box trick to obtain EVs from battling with level 100 Pokémon. This is because EVs are awarded with experience points, and level 100 Pokémon don't gain experience points. However, vitamins and the like will still work.

    This trick does not work in Gen V because stats are always recalculated after every battle. However, in Black 2 and White 2, you can still continue to EV train level 100 Pokémon, provided that they don't have a total of 510 EVs yet. This is because EVs are awarded separately from experience points, so the EV updates will get registered.

4.5.3 Huge Boosts

Since stats are not recalculated after every battle in Gens I through IV, it's possible to get some humorous results while EV training. If you increase a particular EV by a lot during a particular level, the corresponding stat will increase by a lot when it levels up.

    Let's work out an example. Suppose you catch a Palkia at level 47. Assume it has a neutral nature and zero IVs, and that you want to cultivate its Special Attack stat. Since Palkia is in the slow experience group, we have $\lfloor 1.25(48)^3 \rfloor - \lfloor 1.25(47)^3 \rfloor = 8462$ experience points to work with before we level up.

    Suppose we feed it ten Calciums, bringing Palkia's Special Attack EV to 100. Next we make it hold a Power Lens. Then we battle wild Gastly in the Old Chateau, which appear with an average level of 14. Each Gastly will yield, on average, $\lfloor \frac{62 \cdot 14}{7} \rfloor = 124$ EXP, and each will yield 5 Special Attack EVs: one for Gastly's standard yield and four from the effects of the Power Lens. Therefore we can battle 31 wild Gastly before our Special Attack EV hits 255 while gaining $124 \cdot 31 = 3844$ EXP, which is not enough to level up.

    If we continue battling until we level up to level 48, how much will our Special Attack stat increase by? When we caught Palkia, its Special Attack stat was:

$$\text{Special Attack} = \left(\frac{(2 \cdot 150 + 0 + \lfloor \frac{0}{4} \rfloor) \cdot 47}{100} + 5 \right) \cdot 1 = 146$$

When we level up, our Special Attack stat will be:

$$\text{Special Attack} = \left(\frac{(2 \cdot 150 + 0 + \lfloor \frac{255}{4} \rfloor) \cdot 48}{100} + 5 \right) \cdot 1 = 179$$

This is an increase of 33 stat points! Had we not EV trained our Palkia, the Special Attack would only be 149. Seeing all your other stats increase by 2 or 3 points while one stat increases by 33 points looks very silly, but it still has a perfectly reasonable explanation.

4.5.4   Join Avenue

Join Avenue is a location in Black 2 and White 2 that contains many shops, some of which allow you to modify your Pokémon's EVs. The Beauty Shop allows you to lower your Pokémon's EVs by set amounts, while the Dojo and Café allow you to increase your Pokémon's EVs by set amounts.[12] Doing this will cost quite a bit of money, but it can really help you to build a powerful team.

5   Personality Values

All this information about a Pokémon is stored within the memory of a game cartridge. Amazingly, all the information about a Pokémon, from its battle stats to its nickname, can fit within roughly 100 bytes. In fact, in Gen III games, the information used to encode any single Pokémon in your party is exactly 100 bytes. Those that have been boxed only take up 80 bytes due to redundant information. For more information, see the URL in the footer.[13]

One of the key things in the Pokémon data structure is the personality value, a 32-bit number that is randomly generated for each Pokémon. This was introduced in Gen III when the data structure was overhauled.[14] The personality value determines many different attributes of a Pokémon, as we will see. For the following examples, we will work with the personality value `11110101 01110011 10111111 00110011`.

5.1   Gender

With the exception of genderless Pokémon (including, but not limited to, most legendaries), every Pokémon has a certain probability of being male or female. To determine a Pokémon's gender, look at the last byte b of the personality value. If f is the probability that a certain species of Pokémon is female, then a Pokémon is female if and only if $b < 256f$.

For example, Machop have a 75% chance of being male and a 25% chance of being female. Therefore $f = \frac{1}{4}$, and a Machop is female if and only if $b < 64$. If a Machop had the above personality value, then we would have $b = (00110011)_2 = 51$, which is less than 64. Therefore this Machop would be female.

There is an unusual quirk in the Azurill-Marill-Azumarill line when it comes to gender. Azurill have a 75% chance of being female and a 25% chance of being male, while Marill and Azumarill both have a 50% chance of being either gender. This means that if the last byte of an Azurill's personality value is between 128 and 191, its gender will change from female to male when it evolves into a Marill.[15]

5.2   Abilities

From Generation IV onward, each species of Pokémon had two different abilities attached to it. (The Dream World in Gen V offers a third, hidden ability, but we won't talk about that.) For example, Stunky can either have the Stench ability or the Aftermath ability. To determine which ability it has, look at the least significant bit of the last byte of the personality value. In the case above, the last byte of `00110011` is `1`. This gives Stunky the second ability, which is Aftermath. Has this bit been a 0 instead, Stunky would have had the Stench ability.

5.3   Natures

Which nature a Pokémon has is determined by the entire personality value. If you take the remainder of the personality value when it is divided by 25, you can determine which ability the Pokémon will have by looking at the table below:

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[12]You can find out more specifics about Join Avenue at `http://www.serebii.net/black2white2/joinavenue.shtml`.

[13]`http://bulbapedia.bulbagarden.net/wiki/Pokemon_data_structure_in_Generation_III`

[14]You can easily see that the data structure was overhauled by noting that the mechanics of EVs and IVs are different. This difference also contributes to why you can't trade between older games and newer games, setting aside the absurd thought of connecting a Nintendo DS and an old Game Boy.

[15]LPer Chuggaaconroy provides a humorous explanation at `http://www.youtube.com/watch?v=F8WTNJl_j8k&t=9m40s`. In the beginning of the video he also talks a little bit about personality values.

		Decreased stat				
		Attack	**Defense**	**Speed**	**Sp. Atk.**	**Sp. Def.**
	Attack	–	1: Lonely	2: Brave	3: Adamant	4: Naughty
	Defense	5: Bold	–	7: Relaxed	8: Impish	9: Lax
Increased stat	**Speed**	10: Timid	11: Hasty	–	13: Jolly	14: Naïve
	Sp. Atk.	15: Modest	16: Mild	17: Quiet	–	19: Rash
	Sp. Def.	20: Calm	21: Gentle	22: Sassy	23: Careful	–

No effect				
0: Hardy	6: Docile	12: Serious	18: Bashful	24: Quirky

For example, our chosen personality value yields $(11110101\ 01110011\ 10111111\ 00110011)_2$, which equals 4118003507, which leaves a remainder of 7 when divided by 25. Therefore this Pokémon would have a Relaxed nature.

5.4 Shininess

Introduced in Generation II, shiny Pokémon are Pokémon that are of a different color than normal. Those who have played a Generation II game or one of their remakes have probably seen a red Gyarados in the Lake of Rage. It turns out that any species of Pokémon can be shiny; the odds of this, however, are rather low, approximately 1 in 8192. Whenever you run into a shiny Pokémon, you *will* freak out.[16]

In Generation II, shininess was determined solely by IVs. A Pokémon is shiny if and only if its Speed, Defense, and Special IVs are 10 and its Attack IV is either 2, 3, 6, 7, 10, 11, 14, or 15. Assuming that IVs are randomly generated, the probability of getting a shiny Pokémon is $\frac{1}{16} \cdot \frac{1}{16} \cdot \frac{1}{16} \cdot \frac{1}{2} = \frac{1}{8192}$.

Games from Gen III and beyond use the personality value. To determine whether or not a Pokémon is shiny, we need to know about an operation on various numbers known as a *bitwise xor*. The word "xor" stands for "exclusive or." For one-bit numbers A and B, A xor B is equal to 1 if and only if $A = 1$ or $B = 1$, but not both.

A	B	A xor B
0	0	0
0	1	1
1	0	1
1	1	0

To extend this to binary numbers arbitrary length, you simply xor the first bits of each number, then the second bits, then the third bits, and so on.

A Pokémon's shininess depends on two other numbers besides its personality value: its trainer ID T and its secret ID S, two 16-bit numbers that identify your player character. You can easily check what your trainer ID is; this number appears on your trainer card. Your secret ID, however, is hidden, and you can only find out what it is by actually looking at the correct memory address, which is not as easy to do.

To calculate whether or not a Pokémon is shiny, let A be the first two bytes of its personality value and B the last two bytes. Then, compute $k = (A \text{ xor } B) \text{ xor } (S \text{ xor } T)$. If $k < 8$, the Pokémon is shiny. Since all these numbers are randomly generated, k may also be considered a random 16-bit number. This suggests that the probability of getting a shiny Pokémon is $\frac{8}{2^{16}} = \frac{1}{8192}$.

Let's work out an example with the personality value we chose above. Then $A = 11110101\ 01110011$ and $B = 10111111\ 00110011$. Now suppose our trainer ID T is 55897, which corresponds to the binary number $11011010\ 01011001$, and our secret ID S is 36890, which corresponds to the binary number $10010000\ 00011010$. If we perform the calculations, we get A xor $B = 01001010\ 01000000$ and S xor $T = 01001010\ 01000011$. Therefore $k = (A \text{ xor } B) \text{ xor } (S \text{ xor } T) = (00000000\ 00000011)_2 = 3$. Since 3 is less than 8, this Pokémon is shiny.

Let's talk about some of the math behind searching for shiny Pokémon. If we ignore things like chaining, and we assume that every wild encounter is independent, then the probability that it will take you exactly n encounters to find your first shiny is $\left(\frac{8191}{8192}\right)^{n-1} \cdot \frac{1}{8192}$. It follows that the expected number of tries you'll need is 8192. (Intuitively, this should sort of make sense.) However, the standard deviation turns out to be approximately 8191.5. In other words, the number of tries it will take is very fickle, and it will fluctuate wildly between different players.

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[16]Like this: `http://www.youtube.com/watch?v=MT4fqJG-DMc&t=28s`

To look at this from another perspective, the probability that you won't encounter any shinies in n encounters is $\left(\frac{8191}{8192}\right)^n$, which is approximately $e^{-n/8192}$. This means that the probability that you won't find a shiny after 8192 tries is around 37%. The probability that you won't find a shiny after 20,000 tries is around 8.7%. It's a little unlucky, but it's not unheard of.

5.5 Spinda's Spots

One neat feature that Spinda have is that they have four randomly placed spots on their face: one on each ear and two on the face. The locations of these spots are determined by a Spinda's personality value. To determine these locations, take each of the four bytes in the personality value and treat them as (x, y) coordinates, with the upper four bits representing the x offset and the lower four bits representing the y offset. For example, the byte `11110101` corresponds to the point $(15, 3)$.

5.6 Unown's Letter

(Note: Only Gen III games use the personality value to determine Unown's letter.)

Unown can take 28 different forms: one for each letter of the alphabet, along with an exclamation point and a question mark. To calculate which form Unown takes, take the last two bits of each byte of the personality value and concatenate them. For example:

$$111101\underline{01}\ 011100\underline{11}\ 101111\underline{11}\ 001100\underline{11} \rightarrow \underline{01}\,\underline{11}\,\underline{11}\,\underline{11}$$

You then take the remainder when this value is divided by 28. Whatever you get will tell you which form you get. The numbers 0 through 25 represent the letters A through Z, 26 represents the question mark, and 27 the exclamation point. In the above example, we have $(\texttt{01111111})_2 = 127$, which leaves a remainder of 15 when divided by 28. Therefore an Unown with this personality value would be the letter P.

Gen II games use a somewhat similar approach, but instead use the middle two bits of the Attack, Defense, Speed, and Special IVs. Furthermore, the result is divided by 10 and the remainder is dropped to yield a number between 0 and 25, which correspond to the letters A through Z.

Gens IV and V have a separate byte unrelated to the personality value that determines Unown's letter.

5.7 Wurmple's Evolution

The personality value also determines which evolutionary line a Wurmple will take. To figure this out, take the number formed by the last two bytes (in other words, B from when determining shininess) and look at its remainder when divided by 10. If this number is 4 or less, Wurmple will take the Silcoon→Beautifly line. Otherwise it will take the Cascoon→Dustox line. For example, with the personality value we're using, $B = (\texttt{10111111}\ \texttt{00110011})_2 = 48947$. This leaves a remainder of 7, so a Wurmple with this personality value will eventually evolve into a Dustox.

6 Pokémon Breeding

Many features that a trainer might want to control to have a Pokémon optimized for battling are determined randomly. Therefore, whenever you're wandering around in tall grass, you're at the mercy of the game's random number generator. However, Pokémon breeding gives you some control over what features a new Pokémon will have. In this section we'll discuss which features get passed down and how you can control them.

6.1 Eligibility

First we need to talk about when two Pokémon can actually create an egg. Each Pokémon belongs to one or two of 16 egg groups. Of these eggs groups, 13 of them we may consider "normal." The other three are the Genderless group, which contains Pokémon that do not have genders (obviously), the Ditto group, which just contains Ditto, and the Undiscovered group, which mostly contains legendary Pokémon and baby Pokémon.

In order for two Pokémon to be eligible for breeding, in most cases, they must be of opposite genders and share at least one egg group. This is the case for all Pokémon in one of the 13 "normal" egg groups. This clearly doesn't apply

to Pokémon who have no gender, such as Magnemite. However, genderless Pokémon are still allowed to breed, but they can only breed with Ditto. Ditto can breed with any Pokémon except for those in the Undiscovered group, who cannot breed at all.

6.2 Getting an Egg

When you drop off two compatible Pokémon at Day Care, they can generate an egg. Every 256 steps you take, the game decides whether or not the two Pokémon generate an egg. The probability of generating an egg at any time depends on how many of these statements are true:

- The two Pokémon are of the same species.

- The two Pokémon have different ID numbers.

If none of these statements are true, then there is a 20% chance of generating an egg every 256 steps. If one statement is true, there is a 50% chance. If both are true, there is a 70% chance. If you don't get an egg after the first 256 steps, just keep trying!

6.3 What Will Hatch?

The Pokémon that hatches from the resulting egg will be level 5 in Gen II and Gen III games, and it will be level 1 in Gen IV and Gen V games. Other characteristics of the hatched Pokémon depend on its parents' attributes. We will now discuss some of these attributes that get passed down.

6.3.1 Species

The species of the Pokémon that hatches from the egg will be, for the most part, the first-stage evolutionary form of the female parent. For example, breeding a male Luxio with a female Bibarel will result in a Bidoof. Some exceptions to this are when you breed with Dittos, for which the non-Ditto parent will determine the species. For example, breeding a Nidoran♂ with a Ditto will yield a baby Nidoran (either male or female). Another exception is using incense, a held item that allows for backwards compatibility with baby Pokémon that were introduced in later games. For example, breeding two Snorlax together would obviously generate a Snorlax in Gen III, but Snorlax was given a baby form, Munchlax, in Gen IV. You can get a Munchlax to hatch by giving one of the parents a Full Incense to hold.

6.3.2 Moves

Newly hatched Pokémon inherit moves from both of their parents, although the father contributes more. Hatched Pokémon are assigned moves in the following order:

1. Moves that the baby would start out with

2. Moves both parents know that the baby would learn by leveling up

3. TM, HM, and tutor[17] moves the father knows and that the baby can learn by machine

4. Egg moves the baby can learn that the father knows

Lists of these moves can be found on websites like Bulbapedia.

It is possible that these conditions will generate more than four moves. If this is the case, the baby will just learn the last four moves we generated.

6.3.3 Stats

When a baby hatches from an egg, its EVs start out at 0. However, it receives some of its IVs from its parents. Which parents pass which IVs depends on the game.

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[17]Only in Crystal.

Gold, Silver, Crystal. If one parent was a Ditto, IVs are passed from the Ditto. Otherwise IVs are passed from the parent of the opposite gender. The Defense IV is passed down. The Special IV is also passed down, but there is a 50% chance that the Special EV of the baby will differ by exactly 8. For example, if the parent's Special IV is 13, then the baby's Special IV will either be 13 or 5. The Attack and Speed IVs are chosen randomly. The HP IV is chosen as follows: add 8 for an odd Attack IV, add 4 for an odd Defense IV, add 2 for an odd Speed IV, and add 1 for an odd Special IV. For example, if your Attack, Defense, Speed, and Special IVs are 9, 12, 5, and 6, respectively, then your HP IV is 10.

From this it follows that you can breed for shininess. We'll talk about this later.

Ruby, Sapphire, FireRed, LeafGreen. The baby inherits exactly three of the six IVs from its parents. Which parents pass down which stats, however, is entirely random.

Emerald, Diamond, Pearl. The process is similar to the above process, but the stats are chosen independently. Therefore it is possible that a stat will be chosen more than once. In this case, the later choices overwrite the earlier choices. For example, if the three choices are (Speed-Mother, Defense-Father, Speed-Father), then the baby will inherit its Speed IV from the father. Any remaining IVs are chosen at random.

HeartGold, SoulSilver, Black, White, Black 2, White 2. The process is similar to RS and FRLG, but with an added mechanic. If any parent is holding an EV-enhancing item, like the Power Weight, the corresponding IV will always be passed down from that parent. In this case, only two other IVs will be inherited, even if both parents are holding EV-enhancing items, in which case the baby inherits four IVs instead of three.

6.3.4 Natures

Everstones allow for the passing of Natures.[18] In Gen III, if there is a Ditto present, and the Ditto is holding an Everstone, it has a 50% chance of passing down its Nature to the baby. If there is no Ditto, then the female parent is responsible for passing down the Nature.

This was changed starting in HeartGold and SoulSilver; either parent may pass down its Nature as long as it is holding an Everstone. This was further changed in Black 2 and White 2; now holding an Everstone will guarantee passing down the Nature.

6.3.5 Abilities

Normally you can't pass down abilities. However, some Pokémon have a hidden ability, which differs from the normal one or two they can have when found in the wild. For example, a Pachirisu normally has either the Run Away or the Pickup ability; however, it also has Volt Absorb as a hidden ability. These hidden abilities do not occur in Pokémon randomly in the wild; rather, they can only be obtained through special events. If the female parent has a hidden ability, she has a 60% chance of passing it down to the baby.

6.3.6 Shininess

In Gen II games, since shininess is determined by IVs, it is possible to breed for shininess. If one of the parents is shiny, then it has an improved chance of passing down the correct IVs to generate shiny offspring. It always passes down the correct Defense IV, and it will pass down the correct Special IV with probability $\frac{1}{2}$. Since the Attack and Speed IVs are entirely random, they have probabilities $\frac{1}{2}$ and $\frac{1}{16}$ respectively of being correct. This yields a total probability of $\frac{1}{64}$, but only if the offspring is of the opposite gender of the shiny parent. Therefore one may argue that the probabiltiy is only $\frac{1}{64}$ when both parents are shiny; if only one is shiny, the probability is approximately $\frac{1}{128}$. Nevertheless, it's still approximately a hundredfold improvement.

Unfortunately, there is no similar trick in later games that improves your odds this much because shininess is no longer determined by IVs. In fact, Gen III games still put the probability of a shiny baby at 1 in 8192. However, Generation IV introduced the Masuda method, named after Game Freak director Junichi Masuda, which increases the

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[18]Believe it or not, Everstones actually have a useful purpose! I know, it surprised me too.

chances of getting a shiny baby to 5 in 8192 if you breed two Pokémon created in games of different languages.[19] An easy way to do this, of course, is to trade internationally with the aid of Nintendo Wi-Fi Connection.

Generation V does the same thing, only it checks six personality values instead of five, increasing the Masuda method's odds to 6 in 8192.

7   Battling

Now that you've bred your team to have the Natures and Abilities you want along with perfect IVs, let me say that you have way too much time on your hands.[20] Not only that, but you can also have a really great battle team! Of course, this is not enough. It's also important to know how to battle most effectively. So let's talk about Pokémon battles!

7.1   Moves

Every move has three properties that determine how it behaves in battle: its base power, its base accuracy, and its priority. Moves with a higher base power are generally more powerful. Moves with a higher base accuracy are more likely to hit successfully. Moves with a higher priority tend to go before moves with a lower priority.

7.2   The Battle Structure

When in a battle, you can either choose to fight, use an item, switch to a different Pokémon, or flee from battle. Any of the latter three options always have priority. However, if both sides choose to fight, the following happens: If the two moves have different priorities, then the move with the higher priority goes first. This allows moves like Quick Attack to go first or moves like Counter to go last. If the two moves have the same priority, then the Pokémon with the higher speed stat goes first.

7.3   The Damage Formula

Here is the amount of damage most moves will do:

$$\text{damage} = \left(\frac{2 \cdot \text{level} + 10}{250} \cdot \frac{\text{attack}}{\text{defense}} \cdot \text{base} + 2 \right) \cdot \text{modifier} \cdot R$$

Here, the level refers to the level of the attacking Pokémon, base refers to the base power of the move, and R is a random number between 0.85 and 1.

Attack and defense refer to the Attack and Defense stats of the attacker and defender respectively for physical moves, and the Special Attack and Special Defense stats for special moves.[21]

We will talk about modifiers later.

7.4   Stat Modification

Some moves, like Growl or Agility, cause a Pokémon's stats to change temporarily in battle. These stat changes work on a level system:

Level	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6
Multiplier	0.25	0.29	0.33	0.40	0.50	0.67	1.00	1.50	2.00	2.50	3.00	3.50	4.00

Every stat starts at level 0 at the beginning of a battle. A move like Growl, which results in a phrase like, "Turtwig's Attack fell," drops the opponent's Attack by one level. A move like Agility, which results in a phrase like, "Skarmory's Speed sharply rose," raises the user's Speed by two levels. Levels cannot drop below −6 or go above +6.

Accuracy and evasiveness have a slightly different table:

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[19] The game does this by generating five personality values, checking each one for shininess. The probability is not exactly 5 in 8192; it is more like $1 - (8191/8192)^5$. However, they are approximately equal.

[20] But who am I to talk? I'm putting together a 20-page LaTeX document on the game mechanics of Pokémon, for Arceus' sake!

[21] In Generations I through III, moves were classified as physical or special based on their type. Starting in Generation IV, moves are classified on a move-by-move basis. This makes some classifications more logical. For example, Bite, a Dark-type move, makes more sense to be a physical attack, even though Dark was classified as a special type.

Level	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6
Multiplier	0.33	0.38	0.43	0.50	0.60	0.75	1.00	1.33	1.67	2.00	2.33	2.67	3.00

To determine whether or not a move hits, multiply the base accuracy of a move by the attacker's accuracy multiplier and divide by the user's evasiveness multiplier. The resulting number is the probability than a move will hit. (If this value is greater than 1, it's guaranteed to hit.)

7.5 Modifiers

Modifiers are what can really make or break a battle. There are many different types of modifiers, some more well-known than others.

7.5.1 Type Advantages

There are 17 different elemental types, each with their own strengths and weaknesses. A copy of the type advantages table can be found at the end of this handout as an appendix.

Moves can either be super effective, not very effective, or not effective at all against a particular type of Pokémon. These multiply the modifier by 2, ½, and 0, respectively. In the case of dual-type Pokémon, these modifiers multiply together. For example, a Water-type move is doubly super effective against a dual Fire/Rock type, and therefore does 4 times as much damage.

7.5.2 Same-Type Attack Bonus

The same-type attack bonus, or STAB, is a bonus given to Pokémon who use moves that are of the same type as the user. For example, a Chikorita, a Grass type, benefits from the STAB if it uses Giga Drain, a Grass-type move. Such moves multiply the amount of damage done by 1.5.[22]

There are two common misconceptions about the STAB. Firstly, some believe that Normal types don't benefit from the STAB for using Normal-type moves. This is not true; all types benefit from the STAB. Secondly, some believe that for dual types the STAB is reduced to $1.25\times$. This is also not true; dual types still get a $1.5\times$ bonus for either of their types.

We can prove that the first myth is false by using game footage from Episode 4 of ZephyrSonic's Let's Play of Pokémon Stadium.[23] At 3:37, a level 50 Persian inflicts 90 damage against a level 50 Wigglytuff using Double-Edge, a Normal type move. If Normal types like Persian do not benefit from the STAB, what is the most damage we could have inflicted?

Earlier in the video you can see that Persian's Attack stat is 99. Furthermore, Wigglytuff's base Defense stat is 45, so if it has no EVs or IVs, its Defense stat is 50. Finally, Double-Edge has a base power of 100 in Gen I. Setting $R = 1$ and multiplier $= 1$ yields:

$$\text{maximum damage} = \left(\frac{2 \cdot 50 + 10}{250} \cdot \frac{99}{50} \cdot 100 + 2 \right) \cdot 1 \cdot 1 = 89.12$$

Keep in mind that since the game rounds all divisions down to the nearest integer, we are being generous with our estimate. But even with this generous upper bound, we still inflicted more damage! Therefore there must have been a STAB. Myth busted.

I have not been able to find an explicit example that I can link to that disproves the reduced STAB myth, though. It does get tricky because of all the assumptions we are making. However, you could easily set up an experiment and get better information if you know your own stats and your opponent's stats, either by doing Free Battle in Pokémon Stadium or by battling with a friend.

7.5.3 Critical Hits

Critical Hits come at random and they have the ability to turn the tides of any battle. Overall, a Critical Hit multiplies the amount of damage done by 2 and ignores and stat modifiers that are disadvantageous to the attacker.[24]

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[22]If the user has the Adaptability ability, the multiplier is increased from 1.5 to 2.

[23]http://www.youtube.com/watch?v=dmaCArfXJP8

[24]If the user has the Sniper ability, the Critical Hit multiplier is 3. In Generation I, all stat modifiers are ignored, even if they would end up being beneficial to the attacker.

In Generation I, the probability of a Pokémon landing a Critical Hit with a normal move is equal to its base speed stat divided by 512. For moves with a high Critical Hit ratio[25] like Slash, Karate Chop, or Razor Leaf, the probability is equal to the base speed stat divided by 64. If the base speed of the Pokémon is greater than or equal to 64, the probability is rounded down to $\frac{255}{256}$, around 99.6%.

In Generations II and beyond, there is another level system for the probability of Critical Hits:

Level	Probability
1	6.25%
2	12.5%
3	25%
4	33.3%
5	50%

All Pokémon start at Critical Hit level 1. Moves such as Focus Energy and items like Dire Hit increase the level permanently, and moves with high Critical Hit ratios temporarily increase the level.

7.5.4 Other Modifiers

There are many other possible modifiers to the damage formula.[26] They include:

- Weather. During rain, the power of Water-type moves is multiplied by 1.5, and the power of Fire-type moves is halved. In harsh sunlight the reverse is true. Weather can also modify other aspects about moves. For example, in rain, the moves Thunder and Hurricane, both of which have base accuracies of 70%, are always guaranteed to hit. Weather can also trigger certain Abilities, like Rain Dish.

- Abilities. They can modify the Critical Hit ratio, the stats of a Pokémon under certain conditions, and other things. For example, Blaze boosts the power of Fire-type moves by 50% if the user has less than $\frac{1}{3}$ HP.

- Held items. Some held items can change a Pokémon's stats. For example, BlackGlasses boosts the power of Dark-type moves by 20%.[27]

- Status ailments. For example, a burn cuts a Pokémon's Attack in half,[28] and paralysis cuts a Pokémon's Speed by a factor of 4.

- Double battles. Some moves, like Surf and Explosion, hit multiple Pokémon. These moves are reduced to 75% of their normal power in double battles and triple battles.

8 Applications

Using this information, it's easier to train and battle more wisely. Consider the following case studies:

8.1 Training Pokémon Evenly?

Many people like to train their Pokémon evenly, but this may not always be necessary. Pokémon with naturally higher base stats may not need as much training as others. Take Arcanine, for example:

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[25]There are 19 moves with a high Critical Hit ratio. Two additional moves, Frost Breath and Storm Throw, always land a Critical Hit unless the defending Pokémon has the Battle Armor or Shell Armor ability, or is under the effect of a Lucky Chant.

[26]See http://www.smogon.com/dp/articles/damage_formula for a comprehensive summary of the Gen IV damage formula and all of its modifiers.

[27]10% in Generations II and III.

[28]If the Pokémon has the Guts ability, its Attack is raised by 50% instead.

	Arcanine's stats	Average stats (fully evolved)
HP	90	80
Attack	110	90
Defense	80	83
Special Attack	100	83
Special Defense	80	83
Speed	95	78

Arcanine has only slightly below average Defense and Special Defense, which can easily be made up with some EV training. However, its Attack and Special Attack stats are pretty well above average. Therefore one may not need to train an Arcanine as much to do the same amount of damage as an average fully evolved Pokémon. This becomes convenient because Arcanine is in the slow experience group.

8.2   Move Selection

Suppose you have a Linoone, a Normal type, and you can either teach it Surf or Strength. Which one would you choose?

Surf and Strength both have a base accuracy of 100%, but Surf's base power is 95 while Strength's base power is only 80. However, this does not necessarily mean that Surf is the stronger move. Linoone's Attack base stat, 70, is higher then its Special Attack base stat, 50. In addition, Linoone receives a STAB for using Strength, a Normal-type move. Therefore Strength would end up doing more damage overall.

However, teaching Linoone Surf has some notable advantages. A Water-type move helps cover the types that Normal-type moves are weak against: Rock, Ghost, and Steel. Normally, Normal-type moves are not very effective against Rock and Steel, and do not affect Ghost-type Pokémon. However, a Water-type move is super effective against Rock types and damages Ghost and Steel types normally. This makes Surf a good addition to round out Linoone's moveset. Besides, Linoone learns other Normal-type moves with comparable base powers, like Slash (base power 70, but high Critical Hit ratio).

8.3   Battling Effectively[29]

A move's total effectiveness does not necessarily correspond to type effectiveness. Consider an example where your Lucario, a Fighting/Steel type, is battling a Gliscor, a Ground/Flying type. Suppose you are between two moves: Crunch, a physical Dark-type move with base power 80 and 100% accuracy, or Close Combat, a physical Fighting-type move with base power 120 and 100% accuracy. Crunch does not receive any modifiers, so its power is 80. Close Combat, despite being not very effective against Gliscor (Flying-type Pokémon resist Fighting-type moves), receives a STAB and therefore have an effective power of $120 \times 1.5 \div 2 = 90$. Therefore Close Combat will do more damage despite being at a type disadvantage.

Of course, Lucario is weak to Ground-type moves, so the optimal choice here would probably be to switch out, especially since Close Combat will also lower your own Defense and Special Defense. But we are only looking at damage here. The point here is that it's not just modifiers that determine how you should battle; it also depends on the moves you choose. In this case you would probably be screwed either way, so you may just want to get a single hit in and pray that it's enough to make your opponent faint.

8.4   Ridiculously Huge Multipliers[30]

When done right, multipliers can add up to do massive damage. Pokémon Stadium 2 gives an example of a Pikachu able to get a 24× multiplier against a Gyarados with an Electric attack (1.5× for the STAB, 4× type effectiveness, 2× if holding a Light Ball, and 2× for a Critical Hit). However, we can go much higher.

If you have a Chansey using Rollout on a Moltres, you can get huge multipilers. Rollout doubles in power for every consecutive use, up to 16×. Also, if you use Defense Curl beforehand, Rollout's power doubles. Other multipliers

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[29]Thanks to leafbarrett of the Nuzlocke Forums for this example!

[30]Check out `http://amgleit.scripts.mit.edu/pokemon/multiplier/index.html` for an interactive demo.

include being type effectiveness (4×), assisted by Helping Hand (1.5×), Cherrim's Flower Gift ability[31] (1.5×), a Choice Band (1.5×), doing Skill Swap against a Pokémon with the Pure Power ability[32] (2×), a Critical Hit (2×). Then, raise Chansey's Attack to stage +6 (4×), and lower Moltres' Defense to stage -6 (4×). This yields a whopping $27,648\times$ multiplier, which can allow a level 1 Chansey, despite having the lowest Attack stat of all Pokémon, to OHKO a fully EV trained level 100 Moltres!

8.5   F.E.A.R.

You can also do insane amounts of damage is by choosing the right moves at the right time. F.E.A.R., which stands for **F**ocus Sash, **E**ndeavor, Quick **A**ttack, **R**attata,[33] depends on this idea. Here's how you do it:

Start by sending out a "weak" Pokémon (often Rattata) that is holding a Focus Sash and also knows the moves Endeavor and Quick Attack. Let it take a hit; the Focus Sash will prevent it from fainting and leave it with 1 HP. Then use Endeavor, which will reduce your opponent down to 1 HP as well. On your next turn, use Quick Attack and knock it out. Now that's what I call a top percentage Rattata!

Of course, this method has two main weak points. First, it can only be used once unless you call back your Pokémon and heal it. Second, it can be counteracted by a Pokémon who knows a move with higher priority, like Extremespeed. However, this strategy can easily catch an unknowing trainer off guard.

8.6   Magikarp Sweeping

But if you really want to do some major trolling, with a little luck you can pull off Magikarp sweeping. For this you will need a Magikarp holding a Focus Sash with good Attack and Speed EVs and IVs. You will also need another Pokémon that knows a move that will immobilize the opponent (Hypnosis, e.g.), moves or items that enhance Attack, Speed, and the Critical Hit ratio, and Baton Pass.

Start by sending out your Magikarp. Let it take a hit; as in F.E.A.R., the Magikarp will be left with 1 HP thanks to the Focus Sash. Then switch out to your other Pokémon. While keeping your opponent immobilized, boost your Attack stat and Critical Hit ratio all the way up, boost your Speed stat a few levels. Baton Pass back to Magikarp. Then use Flail, which will have base power 200 when the user has a sliver of HP left. You'll do massive damage!

Let's work out an example. A fully trained level 100 Magikarp with a helpful nature has an Attack stat of 130. Suppose you're up against Arceus, who has a maximum Defense stat of 372 when fully trained and with a helpful nature. If you use Flail with your Attack stage at +6 and you land a Critical Hit, here's how much damage you will do:

$$\text{damage} = \left(\frac{2\cdot 100 + 10}{250}\cdot \frac{130\cdot 4}{372}\cdot 200 + 2\right)\cdot 2\cdot R \approx 473R$$

So you'll do anywhere between around 402 and 473 damage. Arceus has at most 444 HP at level 100, so with a little bit of luck, a Magikarp will OHKO Arceus. You read that right; *a Magikarp can OHKO Arceus.*

9   How Pokémon Can Make You Rich

If you're reading this, you probably don't need any more convincing that Pokémon is awesome. However, there's one more thing I want to mention that can blow your mind. If you can unlock the secret to being able to solve any arbitrary Pokémon game efficiently, you can win a million dollars. The catch is you must be able to find a path through *any* layout of obstacles and trainers for which it is possible to do so, even the hardest ones, or report that a certain layout is impossible. Furthermore, your algorithm must be efficient.

The idea of doing this is making the layout analogous to solving a famous puzzle.

9.1   3-SAT: A Simple Description

Suppose you are in a room with two red keys R_1 and R_2, two blue keys B_1 and B_2, two yellow keys Y_1 and Y_2, and two green keys G_1 and G_2. The next room contains locked doors in groups of three, and the only way to pass a group of locked doors is to use one of these keys to open one of them. See the image below for an example of the second room:

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[31]Multiplies an ally's Attack stat by 1.5 in harsh sunlight.

[32]Pure Power doubles the user's Attack stat. Skill Swap exchanges abilities with another Pokémon.

[33]Alternatively, **F**. . .ing **E**vil **A**nnoying **R**odent.
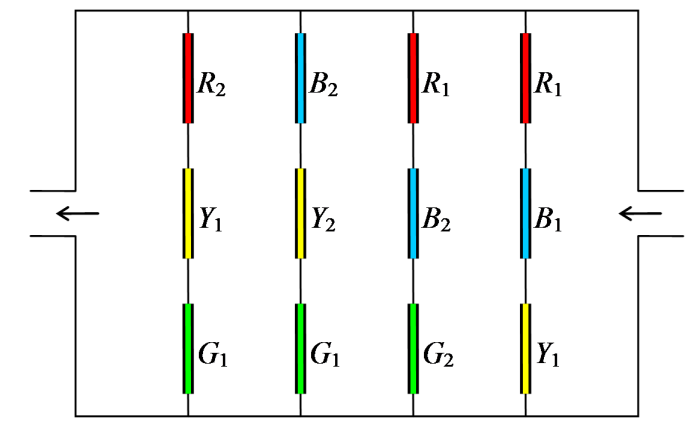
The catch is, you are only allowed to take one key of any particular color. Furthermore, once you leave the key room with your keys, you cannot go back in. You know the exact layout of the locked doors in the next room, and you may use them to make your decision. Which keys should you take if you want to escape?

This problem is a formulation of a famous problem called 3-SAT. Your set of keys must satisfy (which is where the "SAT" comes from) a set of conditions of the form "X or Y or Z." Each of these conditions has three parts, which is where the "3" comes from.

The above example is fairly simple; one possible solution is to take keys R_1, B_2, Y_2, and G_1. However, as you increase the number of pairs of keys and the number of groups of locked doors in the second room, this problem becomes very difficult very quickly. Although it is very easy to check whether or not a proposed answer is correct, mathematicians do not yet know an efficient way to find a correct answer, or even if it is possible to come up with such a way.[34] These types of problems where the solutions are easy to check are called *NP-complete*.

This leads to a question: if a problem is such that its solutions can be checked easily, is it possible to *find* the solutions easily too? This is the P vs. NP problem, and it's one of the seven Millennium Prize Problems. If you can answer this problem, the Clay Mathematics Institute will award you $1,000,000.

9.2 What Does This Have to Do with Pokémon?

Now we will pose another question: given an arbitrary map of the Pokémon overworld with obstacles and trainers, is it possible to get from a certain start point to a certain end point? We would like to be able to solve this problem for any map.

Erik Demaine, a professor in MIT's Computer Science and Artificial Intelligence Laboratory, has shown a way to construct a Pokémon overworld that is analogous to the key puzzle rooms specified before.[35] The main obstacles are the trainers, which are either trivially easy or impossible. For example, your party could consist of a low-level Ghost type. Easy trainers would consist of an Electrode that only knows Selfdestruct (which won't affect Ghost types), and hard trainers would consist of a high-level Pokémon that can easily OHKO you. He created a fork block where once you choose the first way to go, the other branch is sealed off forever. He also created a block where you can only go through one way, after which the block can never be traversed again. These two blocks are shown below, with the red trainers being trivially easy and the blue trainers being impossible to defeat.

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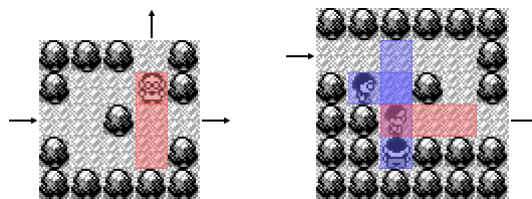
[34]Here, "efficient" means that if there are k pairs of keys and d sets of doors, then the amount of time it takes to find a solution is no more than some polynomial $P(k,d)$. The details of this are beyond the scope of this class, but if you're interested, feel free to send me an e-mail.

[35]The paper can be found at http://erikdemaine.org/papers/Nintendo/. The foundation for his system of creating these worlds is described in another paper at http://erikdemaine.org/papers/PushPush2DTR/.

Instead of unlocking doors with keys, you might choose a path that allows you to move a trainer out of the path leading to the goal.

Using the techniques Demaine discusses, it becomes very easy to create a Pokémon overworld that corresponds to a particular key puzzle. Therefore, if you can write a computer program that can efficiently solve any Pokémon game, even these hard cases, you will have come up with an efficient way to solve the key puzzle, which means you will have solved P vs. NP. In other words, if you can prove that you the absolute best Pokémon player in the world, you'll become a millionaire. (Better yet, you'll finally be able to afford that bike in Cerulean City!)

10 Conclusion

Now that you know some of the secrets behind how the world of Pokémon works, your strategies may change to reflect your new knowledge, giving yourself previously unsen advantages. You may have also gotten a new sense of respect for how complex the Pokémon World can be and how much in depth you can analyze it. Now go out there and be the best Pokémon Master you can be, like no one ever was!

A Type Effectiveness Chart: Gen I

	Normal	Fire	Water	Electric	Grass	Ice	Fighting	Poison	Ground	Flying	Psychic	Bug	Rock	Ghost	Dragon
Normal													½	0	
Fire		½	½		2	2						2	½		½
Water		2	½		½				2				2		½
Electric			2	½	½				0	2					½
Grass		½	2		½			½	2	½		½	2		½
Ice			½		2	½			2	2					2
Fighting	2					2		½		½	½	½	2	0	
Poison					2			½	½			2	½	½	
Ground		2		2	½			2		0		½	2		
Flying				½	2		2					2	½		
Psychic							2	2			½				
Bug		½			2		½	2		½	2				
Rock		2				2	½		½	2		2			
Ghost	0										0			2	
Dragon															2

Attacking type (rows); Defending type (columns)

B Type Effectiveness Chart: Gen II and Beyond

	Normal	Fire	Water	Electric	Grass	Ice	Fighting	Poison	Ground	Flying	Psychic	Bug	Rock	Ghost	Dragon	Dark	Steel
Normal													½	0			½
Fire		½	½		2	2						2	½		½		2
Water		2	½		½				2				2		½		
Electric			2	½	½				0	2					½		
Grass		½	2		½			½	2	½		½	2		½		½
Ice		½	½		2	½			2	2					2		½
Fighting	2					2		½		½	½	½	2	0		2	2
Poison					2			½	½				½	½			0
Ground		2		2	½			2		0		½	2				2
Flying				½	2		2					2	½				½
Psychic							2	2			½					0	½
Bug		½			2		½	½		½	2			½		2	½
Rock		2				2	½		½	2		2					½
Ghost	0										2			2		½	½
Dragon															2		½
Dark							½				2			2		½	½
Steel		½	½	½		2							2				½

Attacking type (rows); Defending type (columns)