

Database implementation:

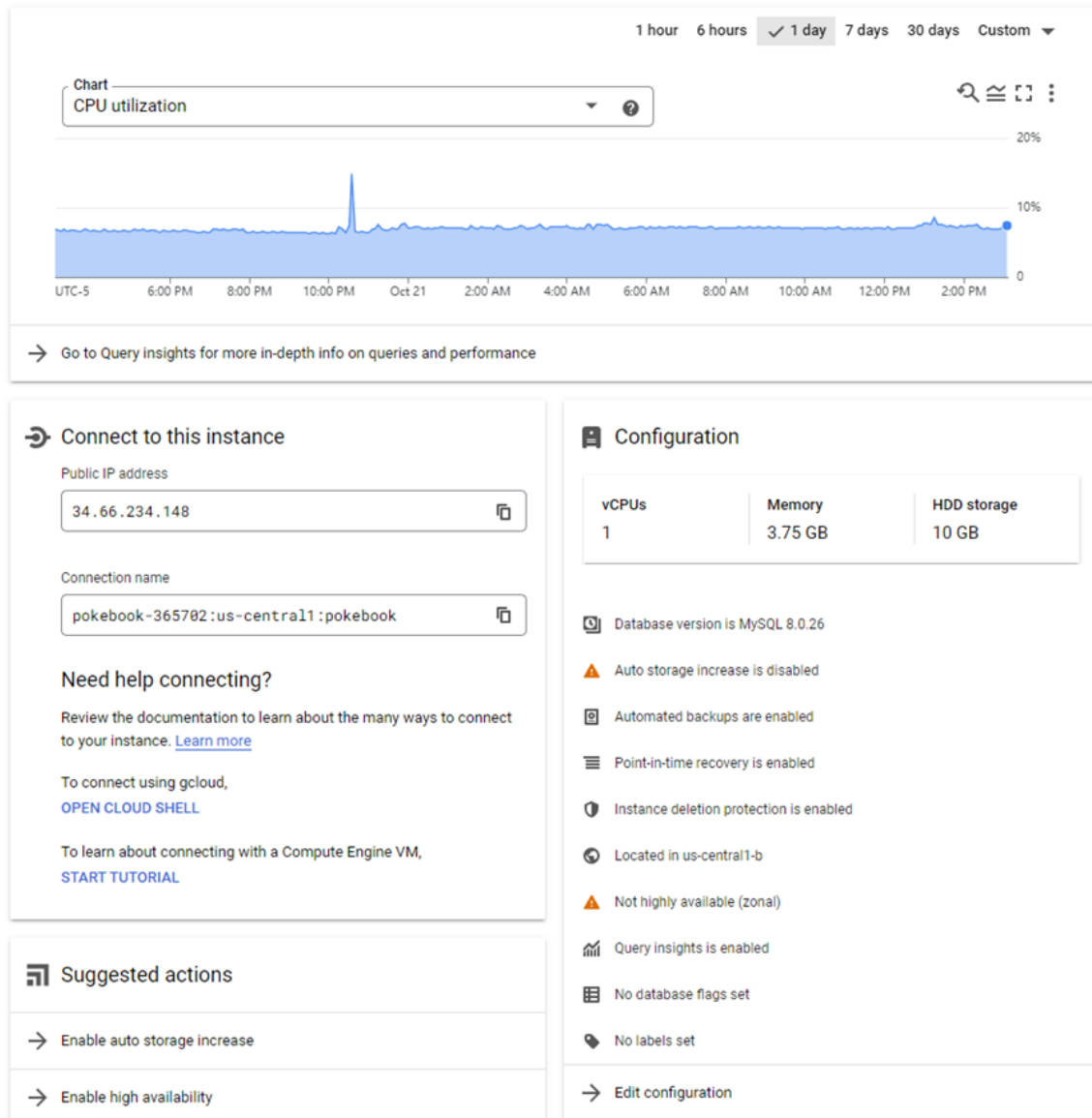
1. Screenshot of the connection

GCP

All instances > pokebook

✓ **pokebook**

MySQL 8.0



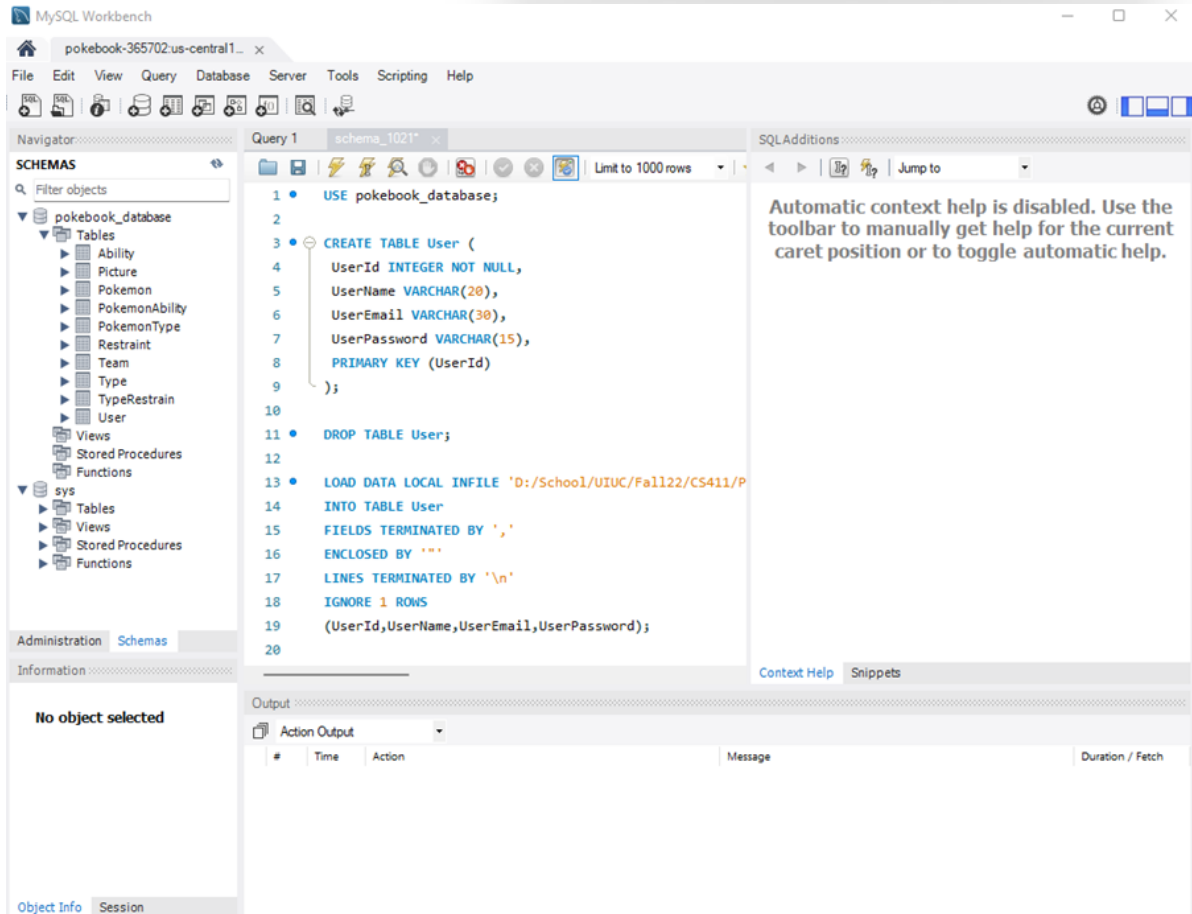
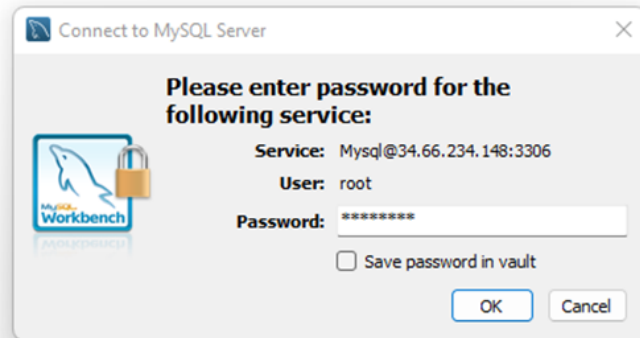
MySQL connection:

MySQL Connections

pokebo...:us-central1:pokebook

root

34.66.234.148:3306



2. DDL Command:

```
USE pokebook_database;
```

```
CREATE TABLE User (
  UserId INTEGER NOT NULL,
  UserName VARCHAR(20),
  UserEmail VARCHAR(30),
  UserPassword VARCHAR(15),
  PRIMARY KEY (UserId)
);
```

```
CREATE TABLE Pokemon (
  PokemonId INTEGER NOT NULL,
  PokemonName VARCHAR(20),
  Generation INTEGER,
```

```

Height FLOAT,
Weight FLOAT,
Total INTEGER,
Hp INTEGER,
Attack INTEGER,
Defense INTEGER,
SpecialAttack INTEGER,
SpecialDefense INTEGER,
Speed INTEGER,
PRIMARY KEY (PokemonId)
);

CREATE TABLE Team (
  UserId INTEGER,
  PokemonId INTEGER,
  PRIMARY KEY (UserId, PokemonId)
);

CREATE TABLE Picture (
  PictureId INTEGER NOT NULL,
  PictureType VARCHAR(10),
  PictureLocation VARCHAR(200),
  PokemonId INTEGER,
  PRIMARY KEY (PictureId)
);

CREATE TABLE Ability (
  AbilityId INTEGER NOT NULL,
  AbilityName VARCHAR(20),
  Description VARCHAR(50),
  PRIMARY KEY (AbilityId)
);

CREATE TABLE PokemonAbility (
  PokemonId INTEGER,
  AbilityId INTEGER,
  PRIMARY KEY (PokemonId, AbilityId)
);

CREATE TABLE Type (
  TypeId INTEGER NOT NULL,
  TypeName VARCHAR(15),
  PRIMARY KEY (TypeId)
);

CREATE TABLE PokemonType (
  PokemonId INTEGER NOT NULL,
  FirstTypeId INTEGER,
  SecondTypeId INTEGER,

  PRIMARY KEY (PokemonId)
);

CREATE TABLE Restraint (

```

```
    RestraintId INTEGER NOT NULL,
    TheType INTEGER,
    RestrainingType INTEGER,
    PRIMARY KEY (RestraintId)
);

CREATE TABLE TypeRestrain (
    typeId INTEGER,
    RestraintId INTEGER,
    PRIMARY KEY (TypeId,RestraintId)
);

ALTER TABLE Team ADD CONSTRAINT Team_PokemonId FOREIGN KEY(PokemonId)
REFERENCES Pokemon(PokemonId);

ALTER TABLE Team ADD CONSTRAINT Team_UserId FOREIGN KEY (UserId)
REFERENCES User(UserId);

ALTER TABLE Picture ADD CONSTRAINT Picture_PokemonId FOREIGN KEY(PokemonId)
REFERENCES Pokemon(PokemonId);

ALTER TABLE PokemonAbility ADD CONSTRAINT PokemonAbility_PokemonId FOREIGN
KEY(PokemonId)
REFERENCES Pokemon(PokemonId);

ALTER TABLE PokemonAbility ADD CONSTRAINT PokemonAbility_AbilityId FOREIGN
KEY(AbilityId)
REFERENCES Ability(AbilityId);

ALTER TABLE PokemonType ADD CONSTRAINT PokemonType_PokemonId FOREIGN
KEY(PokemonId)
REFERENCES Pokemon(PokemonId);

ALTER TABLE PokemonType ADD CONSTRAINT PokemonType_FirstTypeId FOREIGN
KEY(FirstTypeId)
REFERENCES Type(TypeId);

ALTER TABLE PokemonType ADD CONSTRAINT PokemonType_SecondTypeId FOREIGN
KEY(SecondTypeId)
REFERENCES Type(TypeId);

ALTER TABLE Restraint ADD CONSTRAINT Restraint_TheType FOREIGN KEY(TheType)
REFERENCES Type(TypeId);

ALTER TABLE Restraint ADD CONSTRAINT Restraint_RestrainingType FOREIGN
KEY(RestrainingType)
REFERENCES Type(TypeId);

ALTER TABLE TypeRestrain ADD CONSTRAINT TypeRestrain_TypeId FOREIGN KEY(TypeId)
REFERENCES Type(TypeId);

ALTER TABLE TypeRestrain ADD CONSTRAINT TypeRestrain_RestraintId FOREIGN
KEY(RestraintId)
REFERENCES Restraint(RestraintId);
```

```

LOAD DATA LOCAL INFILE
'D:/School/UIUC/Fall22/CS411/Project/Stage3/User_data_1.1.csv'
INTO TABLE User
FIELDS TERMINATED BY ','
ENCLOSED BY '"'
LINES TERMINATED BY '\n'
IGNORE 1 ROWS
(UserId,UserName,UserEmail,UserPassword);

LOAD DATA LOCAL INFILE
'D:/School/UIUC/Fall22/CS411/Project/Stage3/Pokemon_data_1.1.csv'
INTO TABLE Pokemon
FIELDS TERMINATED BY ','
ENCLOSED BY '"'
LINES TERMINATED BY '\n'
IGNORE 1 ROWS
(PokemonId,PokemonName,Generation,Height,Weight,Total,Hp,Attack,Defense,SpecialA
ttack,SpecialDefense,Speed);

LOAD DATA LOCAL INFILE
'D:/School/UIUC/Fall22/CS411/Project/Stage3/Abilities_data_1.1.csv'
INTO TABLE Ability
FIELDS TERMINATED BY ','
ENCLOSED BY '"'
LINES TERMINATED BY '\n'
IGNORE 1 ROWS
(AbilityId,AbilityName,Description);

LOAD DATA LOCAL INFILE
'D:/School/UIUC/Fall22/CS411/Project/Stage3/Type_data_1.1.csv'
INTO TABLE Type
FIELDS TERMINATED BY ','
ENCLOSED BY '"'
LINES TERMINATED BY '\n'
IGNORE 1 ROWS
(TypeId,TypeName);

LOAD DATA LOCAL INFILE
'D:/School/UIUC/Fall22/CS411/Project/Stage3/Pokemon_Abilities_data_1.1.csv'
INTO TABLE PokemonAbility
FIELDS TERMINATED BY ','
ENCLOSED BY '"'
LINES TERMINATED BY '\n'
IGNORE 1 ROWS
(PokemonId,AbilityId);

LOAD DATA LOCAL INFILE
'D:/School/UIUC/Fall22/CS411/Project/Stage3/PokemonType_data_1.1.csv'
INTO TABLE PokemonType
FIELDS TERMINATED BY ','
ENCLOSED BY '"'
LINES TERMINATED BY '\n'
IGNORE 1 ROWS
(PokemonId,FirstTypeId,SecondTypeId);

```

```

LOAD DATA LOCAL INFILE
'D:/School/UIUC/Fall22/CS411/Project/Stage3/Picture_data_1.2.csv'
INTO TABLE Picture
FIELDS TERMINATED BY ','
ENCLOSED BY '"'
LINES TERMINATED BY '\n'
IGNORE 1 ROWS
(PictureId,PictureType,PictureLocation,PokemonId);

```

3. Count Query :

Pokemon Table

203 • **SELECT COUNT(*) FROM Pokemon;**

Result Grid	Filter Rows:	Export:	Wrap Cell Content:
COUNT(*)			
1075			

Result 5 x Read Only

User Table

203 • **SELECT COUNT(*) FROM User;**

Result Grid	Filter Rows:	Export:	Wrap Cell Content:
COUNT(*)			
1000			

Result 6 x Read Only

Picture Table

203 • **SELECT COUNT(*) FROM Picture;**

Result Grid	Filter Rows:	Export:	Wrap Cell Content:
COUNT(*)			
1075			

Result 7 x Read Only

Advanced Queries:

First Query

Description:

The first query wants Pokémons whose attack and defense value are greater than average attack and average defense for each type. The query returns *TypeName*, *PokemonName*, *Attack*, *AvgAttack*, *Defense*, *AvgDefense*.

```
SELECT t1.TypeName, p1.PokemonName, p1.Attack,
       (SELECT AVG(p2.Attack)
        FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
       where t1.TypeId = t2.TypeId
       GROUP BY t2.TypeId) as AvgAttack,
       p1.Defense,
       (SELECT AVG(p2.Defense)
        FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
       where t1.TypeId = t2.TypeId
       GROUP BY t2.TypeId) as AvgDefense
FROM (Pokemon p1 LEFT JOIN PokemonType pt1 on p1.PokemonId = pt1.PokemonId) JOIN
Type t1 ON (pt1.FirstTypeId = t1.TypeId)
WHERE p1.Attack > (SELECT AVG(p2.Attack)
                  FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
                  where t1.TypeId = t2.TypeId
                  GROUP BY t2.TypeId)
AND
p1.Defense > (SELECT AVG(p2.Defense)
              FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
              where t1.TypeId = t2.TypeId
              GROUP BY t2.TypeId)
GROUP BY t1.TypeId, t1.TypeName, p1.PokemonName, p1.Attack, p1.Defense
ORDER BY t1.TypeName, p1.PokemonName
Limit 15;
```

Screenshot:

Result Grid						
Filter Rows:		Export:		Wrap Cell Content:		Fetch rows:
TypeName	PokemonName	Attack	AvgAttack	Defense	AvgDefense	
Bug	arctovish	125	70.8333	140	71.4405	
Bug	clawitzer	150	70.8333	140	71.4405	
Bug	cramorant	82	70.8333	95	71.4405	
Bug	drifblim	80	70.8333	102	71.4405	
Bug	forretress	90	70.8333	140	71.4405	
Bug	helioptile	185	70.8333	115	71.4405	
Bug	heracross	125	70.8333	75	71.4405	
Bug	inkay	155	70.8333	120	71.4405	
Bug	lampent	135	70.8333	105	71.4405	
Bug	pangoro	120	70.8333	95	71.4405	
Bug	parasect	95	70.8333	80	71.4405	
Bug	pinsir	125	70.8333	100	71.4405	
Bug	quilladin	109	70.8333	112	71.4405	
Bug	rotom	76	70.8333	86	71.4405	
Bug	rotom-mow	139	70.8333	139	71.4405	

Second Query

Description:

The second query wants information of Pokémons whose type is fire, water, or grass, and generation is greater or equal to 4. The query returns *PokemonName*, *FirstTypeName*, *SecondTypeName*, *Hp*, *Attack*, *Defense*, *SpecialAttack*, *SpecialDefense*, *Speed*, *Generation*.

```
(SELECT p2.PokemonName, t1.TypeName AS FirstTypeName, t2.TypeName AS
SecondTypeName, p2.Hp, p2.Attack, p2.Defense, p2.SpecialAttack,
p2.SpecialDefense, p2.Speed, p2.Generation
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId = pt2.PokemonId) JOIN
Type t1 ON (pt2.FirstTypeId = t1.TypeId) JOIN Type t2 ON (pt2.SecondTypeId =
t2.TypeId)
WHERE (t1.TypeName like '%Fire%' OR t2.TypeName like '%Fire%') AND p2.Generation
>= 4
ORDER BY p2.PokemonId ASC)
```

UNION

```
(SELECT p2.PokemonName, t1.TypeName AS FirstTypeName, t2.TypeName AS
SecondTypeName, p2.Hp, p2.Attack, p2.Defense, p2.SpecialAttack,
p2.SpecialDefense, p2.Speed, p2.Generation
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId = pt2.PokemonId) JOIN
Type t1 ON (pt2.FirstTypeId = t1.TypeId) JOIN Type t2 ON (pt2.SecondTypeId =
t2.TypeId)
WHERE (t1.TypeName like '%Water%' OR t2.TypeName like '%Water%') AND
p2.Generation >= 4
ORDER BY p2.PokemonId ASC)
```

UNION


```
(SELECT p2.PokemonName, t1.TypeName AS FirstTypeName, t2.TypeName AS
SecondTypeName, p2.Hp, p2.Attack, p2.Defense, p2.SpecialAttack,
p2.SpecialDefense, p2.Speed, p2.Generation
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId = pt2.PokemonId) JOIN
Type t1 ON (pt2.FirstTypeId = t1.TypeId) JOIN Type t2 ON (pt2.SecondTypeId =
t2.TypeId)
WHERE (t1.TypeName like '%Grass%' OR t2.TypeName like '%Grass%') AND
p2.Generation >= 4
ORDER BY p2.PokemonId ASC)
LIMIT 15;
```

Screenshot:

PokemonName	FirstTypeName	SecondTypeName	Hp	Attack	Defense	SpecialAttack	SpecialDefense	Speed	Generation
stary	Fire	NULL	44	58	44	58	44	61	4
staravia	Fire	Fighting	64	78	52	78	52	81	4
staraptor	Fire	Fighting	76	104	71	104	71	108	4
dusknoir	Fire	NULL	75	95	67	125	95	83	4
manaphy	Electric	Fire	50	65	107	105	107	86	4
emboar	Fire	Steel	91	90	106	130	106	77	4
pansage	Psychic	Fire	100	100	100	100	100	100	5
panpour	Fire	NULL	65	63	45	45	45	45	5
simipour	Fire	Fighting	90	93	55	70	55	55	5
munna	Fire	Fighting	110	123	65	100	65	65	5
excadrill	Fire	NULL	50	53	48	53	48	64	5
audino	Fire	NULL	75	98	63	98	63	101	5
minccino	Fire	NULL	70	90	45	15	45	50	5
cinccino	Fire	NULL	105	140	55	30	55	95	5
gothita	Fire	Psychic	105	30	105	140	105	55	5

(*: SecondTypeId could be null because not every Pokemon has two types.)

Indexing Analysis:

First Query

```
SELECT t1.TypeName, p1.PokemonName, p1.Attack,
(SELECT AVG(p2.Attack)
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
where t1.TypeId = t2.TypeId
GROUP BY t2.TypeId) as AvgAttack,
p1.Defense,
(SELECT AVG(p2.Defense)
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
where t1.TypeId = t2.TypeId
GROUP BY t2.TypeId) as AvgDefense
FROM (Pokemon p1 LEFT JOIN PokemonType pt1 on p1.PokemonId = pt1.PokemonId) JOIN
Type t1 ON (pt1.FirstTypeId = t1.TypeId)
WHERE p1.Attack > (SELECT AVG(p2.Attack)
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
```

```

Where t1.TypeId = t2.TypeId
GROUP BY t2.TypeId)
AND
p1.Defense > (SELECT AVG(p2.Defense)
              FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId =
pt2.PokemonId) JOIN Type t2 ON (pt2.FirstTypeId = t2.TypeId)
              Where t1.TypeId = t2.TypeId
              GROUP BY t2.TypeId)
GROUP BY t1.TypeId, t1.TypeName, p1.PokemonName, p1.Attack, p1.Defense
ORDER BY t1.TypeName, p1.PokemonName
Limit 15;

```

First try of indexing design:

Index on Attack

```

-----+
| -> Sort: t1.TypeName, p1.PokemonName (actual time=267.198..267.242 rows=327 loops=1)
|   -> Table scan on temporary (cost=0.01..15.94 rows=1075) (actual time=0.002..0.051 rows=327 loops=1)
|     -> Temporary table with deduplication (cost=973.64..989.56 rows=1075) (actual time=266.951..267.019 rows=327 loops=1)
|       -> Nested loop inner join (cost=866.12 rows=1075) (actual time=0.737..188.122 rows=327 loops=1)
|         -> Nested loop inner join (cost=489.88 rows=1075) (actual time=0.064..2.376 rows=1075 loops=1)
|           -> Table scan on p1 (cost=113.62 rows=1075) (actual time=0.051..0.558 rows=1075 loops=1)
|             -> Filter: (p1.FirstTypeId is not null) (cost=0.25 rows=1) (actual time=0.001..0.002 rows=1 loops=1075)
|               -> Single-row index lookup on p1 using PRIMARY (PokemonId=p1.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|           -> Filter: ((p1.Attack > (select f4)) and (p1.Defense > (select f5))) (cost=0.25 rows=1) (actual time=0.173..0.173 rows=0 loops=1075)
|             -> Single-row index lookup on t1 using PRIMARY (TypeId=p1.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|               -> Select #4 (subquery in condition; dependent)
|                 -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.118..0.118 rows=1 loops=1075)
|                   -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.109 rows=77 loops=1075)
|                     -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.034 rows=77 loops=1075)
|                       -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|                         -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=77 loops=1075)
|                       -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=1075)
|                   -> Select #5 (subquery in condition; dependent)
|                     -> Single-row index lookup on p2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=82727)
|                 -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.113..0.113 rows=1 loops=495)
|                   -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.104 rows=76 loops=495)
|                     -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.033 rows=76 loops=495)
|                       -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=495)
|                         -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.027 rows=76 loops=495)
|                       -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=76 loops=495)
|                   -> Single-row index lookup on p2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=37702)
|       -> Select #2 (subquery in projection; dependent)
|         -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.118..0.118 rows=1 loops=327)
|           -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.106 rows=77 loops=327)
|             -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=77 loops=327)
|               -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                 -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=77 loops=327)
|               -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=327)
|           -> Select #3 (subquery in projection; dependent)
|             -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.117..0.117 rows=1 loops=327)
|               -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.107 rows=77 loops=327)
|                 -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=77 loops=327)
|                   -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                     -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=77 loops=327)
|                   -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=327)
|               -> Single-row index lookup on p2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|
|
-----+
| -> Sort: t1.TypeName, p1.PokemonName (actual time=274.835..274.879 rows=327 loops=1)
|   -> Table scan on temporary (cost=0.01..15.94 rows=1075) (actual time=0.002..0.053 rows=327 loops=1)
|     -> Temporary table with deduplication (cost=973.64..989.56 rows=1075) (actual time=274.386..274.456 rows=327 loops=1)
|       -> Nested loop inner join (cost=866.12 rows=1075) (actual time=0.737..195.396 rows=327 loops=1)
|         -> Nested loop inner join (cost=489.88 rows=1075) (actual time=0.062..2.654 rows=1075 loops=1)
|           -> Table scan on p1 (cost=113.62 rows=1075) (actual time=0.049..0.626 rows=1075 loops=1)
|             -> Filter: (p1.FirstTypeId is not null) (cost=0.25 rows=1) (actual time=0.002..0.002 rows=1 loops=1075)
|               -> Single-row index lookup on p1 using PRIMARY (PokemonId=p1.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|           -> Filter: ((p1.Attack > (select f4)) and (p1.Defense > (select f5))) (cost=0.25 rows=1) (actual time=0.179..0.179 rows=0 loops=1075)
|             -> Single-row index lookup on t1 using PRIMARY (TypeId=p1.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|               -> Select #4 (subquery in condition; dependent)
|                 -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.123..0.123 rows=1 loops=1075)
|                   -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.113 rows=77 loops=1075)
|                     -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.036 rows=77 loops=1075)
|                       -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|                         -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.030 rows=77 loops=1075)
|                       -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=1075)
|                   -> Select #5 (subquery in condition; dependent)
|                     -> Single-row index lookup on p2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=82727)
|                 -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.115..0.115 rows=1 loops=495)
|                   -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.106 rows=76 loops=495)
|                     -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=76 loops=495)
|                       -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=495)
|                         -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=76 loops=495)
|                       -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.020 rows=76 loops=495)
|                   -> Single-row index lookup on p2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=37702)
|       -> Select #2 (subquery in projection; dependent)
|         -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.118..0.118 rows=1 loops=327)
|           -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.012..0.108 rows=77 loops=327)
|             -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.035 rows=77 loops=327)
|               -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.002..0.002 rows=1 loops=327)
|                 -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.009..0.029 rows=77 loops=327)
|               -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.020 rows=77 loops=327)
|           -> Select #3 (subquery in projection; dependent)
|             -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.118..0.118 rows=1 loops=327)
|               -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.108 rows=77 loops=327)
|                 -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.036 rows=77 loops=327)
|                   -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                     -> Filter: ((p2.FirstTypeId = t2.TypeId) and (p2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=77 loops=327)
|                   -> Index lookup on p2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.020 rows=77 loops=327)
|               -> Single-row index lookup on p2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|
|
-----+

```

Since we wish to filter Pokemon with higher-than-average attack and defense, we have decided to create an index on Attack. However, the results are quite unsatisfactory, the running time became worse. The main reason is possibly that when we have attack as index, we are distorting the original data structure and make it more redundant.

Running time before indexing: 267.198, 0.118, 0.117

Running time after indexing: 274.386, 0.118, 0.117

Second try of indexing design:

Index on TypeName

```
-----+-----
| -> Sort: t1.TypeName, p1.PokemonName (actual time=267.198..267.242 rows=327 loops=1)
|   -> Table scan on temporary (cost=0.01..15.94 rows=1075) (actual time=0.002..0.051 rows=327 loops=1)
|     -> Temporary table with deduplication (cost=973.64..989.56 rows=1075) (actual time=266.951..267.019 rows=327 loops=1)
|       -> Nested loop inner join (cost=866.12 rows=1075) (actual time=0.737..188.122 rows=327 loops=1)
|         -> Nested loop inner join (cost=489.88 rows=1075) (actual time=0.064..2.376 rows=1075 loops=1)
|           -> Table scan on p1 (cost=113.62 rows=1075) (actual time=0.051..0.558 rows=1075 loops=1)
|             -> Filter: (pt1.FirstTypeId is not null) (cost=0.25 rows=1) (actual time=0.001..0.009 rows=1 loops=1075)
|             -> Single-row index lookup on p1 using PRIMARY (PokemonId=pt1.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|           -> Filter: ((pt1.Attack > (select #4)) and (pt1.Defense > (select #5))) (cost=0.25 rows=1) (actual time=0.173..0.173 rows=0 loops=1075)
|           -> Single-row index lookup on t1 using PRIMARY (TypeId=pt1.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|         -> Select #4 (subquery in condition; dependent)
|           -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.118..0.118 rows=1 loops=1075)
|             -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.109 rows=77 loops=1075)
|               -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.034 rows=77 loops=1075)
|                 -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|                 -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=77 loops=1075)
|                 -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=1075)
|                 -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=82727)
|             -> Select #5 (subquery in condition; dependent)
|               -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.113..0.113 rows=1 loops=495)
|                 -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.104 rows=76 loops=495)
|                   -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.033 rows=76 loops=495)
|                     -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=495)
|                     -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.027 rows=76 loops=495)
|                     -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=76 loops=495)
|                     -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=37702)
|       -> Select #2 (subquery in projection; dependent)
|         -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.118..0.118 rows=1 loops=327)
|           -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.106 rows=77 loops=327)
|             -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=77 loops=327)
|               -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|               -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=77 loops=327)
|               -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=327)
|               -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|         -> Select #3 (subquery in projection; dependent)
|           -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.117..0.117 rows=1 loops=327)
|             -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.107 rows=76 loops=327)
|               -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=77 loops=327)
|                 -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                 -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=77 loops=327)
|                 -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=327)
|                 -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|
|-----+-----
| -> Sort: t1.TypeName, p1.PokemonName (actual time=281.344..281.387 rows=327 loops=1)
|   -> Table scan on temporary (cost=0.01..15.94 rows=1075) (actual time=0.001..0.050 rows=327 loops=1)
|     -> Temporary table with deduplication (cost=973.64..989.56 rows=1075) (actual time=281.114..281.181 rows=327 loops=1)
|       -> Nested loop inner join (cost=866.12 rows=1075) (actual time=0.708..200.402 rows=327 loops=1)
|         -> Table scan on p1 (cost=113.62 rows=1075) (actual time=0.041..0.587 rows=1075 loops=1)
|           -> Filter: (pt1.FirstTypeId is not null) (cost=0.25 rows=1) (actual time=0.009..0.009 rows=1 loops=1075)
|           -> Single-row index lookup on p1 using PRIMARY (PokemonId=pt1.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|         -> Filter: ((pt1.Attack > (select #4)) and (pt1.Defense > (select #5))) (cost=0.25 rows=1) (actual time=0.171..0.177 rows=0 loops=1075)
|         -> Single-row index lookup on t1 using PRIMARY (TypeId=pt1.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|       -> Select #4 (subquery in condition; dependent)
|         -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.120..0.120 rows=1 loops=1075)
|           -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.111 rows=77 loops=1075)
|             -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.035 rows=77 loops=1075)
|               -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|               -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=77 loops=1075)
|               -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=1075)
|               -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=82727)
|           -> Select #5 (subquery in condition; dependent)
|             -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.117..0.117 rows=1 loops=495)
|               -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.011..0.107 rows=76 loops=495)
|                 -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.035 rows=76 loops=495)
|                   -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=495)
|                   -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=76 loops=495)
|                   -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=76 loops=495)
|                   -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=37702)
|       -> Select #2 (subquery in projection; dependent)
|         -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.121..0.121 rows=1 loops=327)
|           -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.012..0.109 rows=77 loops=327)
|             -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.036 rows=77 loops=327)
|               -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.002..0.002 rows=1 loops=327)
|               -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.009..0.030 rows=77 loops=327)
|               -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.020 rows=77 loops=327)
|               -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|         -> Select #3 (subquery in projection; dependent)
|           -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.121..0.121 rows=1 loops=327)
|             -> Nested loop inner join (cost=64.82 rows=60) (actual time=0.012..0.111 rows=77 loops=327)
|               -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.038 rows=77 loops=327)
|                 -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                 -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.031 rows=77 loops=327)
|                 -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.022 rows=77 loops=327)
|                 -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|
|-----+-----
```

We are trying to optimize performance by putting types of Pokemons into category since it might cost less to traverse between data points. However, the truth turns out to be otherwise and none of the results are better. In addition to distorting original data structure, we consider there is another reason: the index type is B tree and sorting the data and there might be too much rotation and splits on the tree in order to maintain the new index.

Running time before indexing: 267.198, 0.118, 0.117

Running time after indexing: 281.334, 0.121, 0.121

Third try of indexing design:

Index on Generation

```
-----+-----
| -> Sort: t1.TypeName, p1.PokemonName (actual time=267.198..267.242 rows=327 loops=1)
|   -> Table scan on <temporary> (cost=0.01..15.94 rows=1075) (actual time=0.002..0.031 rows=327 loops=1)
|     -> Temporary table with deduplication (cost=973.64..989.56 rows=1075) (actual time=266.951..267.019 rows=327 loops=1)
|       -> Nested loop inner join (cost=866.12 rows=1075) (actual time=0.737..188.122 rows=327 loops=1)
|         -> Nested loop inner join (cost=489.88 rows=1075) (actual time=0.064..2.376 rows=1075 loops=1)
|           -> Table scan on p1 (cost=113.62 rows=1075) (actual time=0.051..0.558 rows=1075 loops=1)
|             -> Filter: (pt1.FirstTypeId is not null) (cost=0.25 rows=1) (actual time=0.001..0.002 rows=1 loops=1075)
|               -> Single-row index lookup on pt1 using PRIMARY (PokemonId=p1.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|           -> Filter: ((pt1.Attack > (select #4)) and (pt1.Defense > (select #5))) (cost=0.25 rows=1) (actual time=0.173..0.173 rows=0 loops=1075)
|             -> Single-row index lookup on t1 using PRIMARY (TypeId=pt1.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|             -> Select #4 (subquery in condition; dependent)
|               -> Group aggregate: avg(p2.Attack) (cost=64.82 rows=60) (actual time=0.011..0.104 rows=76 loops=1075)
|                 -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.011..0.109 rows=77 loops=1075)
|                   -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.034 rows=77 loops=1075)
|                     -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|                     -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=77 loops=1075)
|                     -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=76 loops=1075)
|                     -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=82727)
|                   -> Select #5 (subquery in condition; dependent)
|                     -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.113..0.113 rows=1 loops=495)
|                       -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.011..0.104 rows=76 loops=495)
|                         -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.033 rows=76 loops=495)
|                           -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=495)
|                           -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.027 rows=76 loops=495)
|                           -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=76 loops=495)
|                           -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=37702)
|                       -> Select #2 (subquery in projection; dependent)
|                         -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.118..0.118 rows=1 loops=327)
|                           -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.011..0.106 rows=77 loops=327)
|                             -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=77 loops=327)
|                               -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                               -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=77 loops=327)
|                               -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=327)
|                               -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|                           -> Select #3 (subquery in projection; dependent)
|                             -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.117..0.117 rows=1 loops=327)
|                               -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.011..0.107 rows=77 loops=327)
|                                 -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=77 loops=327)
|                                   -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                                   -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=77 loops=327)
|                                   -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=327)
|                                   -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|                               -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|
|-----+-----
| -> Sort: t1.TypeName, p1.PokemonName (actual time=269.036..269.080 rows=327 loops=1)
|   -> Table scan on <temporary> (cost=0.01..15.94 rows=1075) (actual time=0.002..0.050 rows=327 loops=1)
|     -> Temporary table with deduplication (cost=973.64..989.56 rows=1075) (actual time=268.806..268.877 rows=327 loops=1)
|       -> Nested loop inner join (cost=489.88 rows=1075) (actual time=0.047..2.460 rows=1075 loops=1)
|         -> Table scan on p1 (cost=113.62 rows=1075) (actual time=0.037..0.587 rows=1075 loops=1)
|           -> Filter: (pt1.FirstTypeId is not null) (cost=0.25 rows=1) (actual time=0.001..0.002 rows=1 loops=1075)
|             -> Single-row index lookup on pt1 using PRIMARY (PokemonId=p1.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|           -> Filter: ((pt1.Attack > (select #4)) and (pt1.Defense > (select #5))) (cost=0.25 rows=1) (actual time=0.175..0.175 rows=0 loops=1075)
|             -> Single-row index lookup on t1 using PRIMARY (TypeId=pt1.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|             -> Select #4 (subquery in condition; dependent)
|               -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.119..0.119 rows=1 loops=1075)
|                 -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.011..0.109 rows=77 loops=1075)
|                   -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.009..0.034 rows=77 loops=1075)
|                     -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=1075)
|                     -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=77 loops=1075)
|                     -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=76 loops=1075)
|                     -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=82727)
|                   -> Select #5 (subquery in condition; dependent)
|                     -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.116..0.116 rows=1 loops=495)
|                       -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.011..0.106 rows=76 loops=495)
|                         -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.034 rows=76 loops=495)
|                           -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=495)
|                           -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.028 rows=76 loops=495)
|                           -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=76 loops=495)
|                           -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=37702)
|                       -> Select #2 (subquery in projection; dependent)
|                         -> Group aggregate: avg(p2.Attack) (cost=70.79 rows=60) (actual time=0.117..0.117 rows=1 loops=327)
|                           -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.012..0.108 rows=77 loops=327)
|                             -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.036 rows=77 loops=327)
|                               -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.002..0.002 rows=1 loops=327)
|                               -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=77 loops=327)
|                               -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.019 rows=77 loops=327)
|                               -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|                           -> Select #3 (subquery in projection; dependent)
|                             -> Group aggregate: avg(p2.Defense) (cost=70.79 rows=60) (actual time=0.117..0.117 rows=1 loops=327)
|                               -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.011..0.108 rows=77 loops=327)
|                                 -> Nested loop inner join (cost=6.59 rows=60) (actual time=0.010..0.036 rows=77 loops=327)
|                                   -> Single-row index lookup on t2 using PRIMARY (TypeId=t1.TypeId) (cost=0.35 rows=1) (actual time=0.001..0.001 rows=1 loops=327)
|                                   -> Filter: ((pt2.FirstTypeId = t2.TypeId) and (pt2.PokemonId is not null)) (cost=6.24 rows=60) (actual time=0.008..0.029 rows=77 loops=327)
|                                   -> Index lookup on pt2 using idx_FT (FirstTypeId=t1.TypeId) (cost=6.24 rows=60) (actual time=0.008..0.020 rows=77 loops=327)
|                                   -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|                               -> Single-row index lookup on p2 using PRIMARY (PokemonId=pt2.PokemonId) (cost=0.88 rows=1) (actual time=0.001..0.001 rows=1 loops=25211)
|
|-----+-----
```

We have decided to choose generation as another index because as the Pokemon evolves, their abilities are getting better (and their type remains the same). As the data shows, there are slight improvements in terms of some of the nested loops joins. Overall, the performance is similar, and we think that our premises might not be entirely correct. Different generations of Pokemon does not mean they are getting better, it's more of an adjustment rather than evolution.

Running time before indexing: 267.198, 0.118, 0.117

Running time after indexing: 269.036, 0.117, 0.117

Second Query

```
(SELECT p2.PokemonName, t1.TypeName AS FirstTypeName, t2.TypeName AS
SecondTypeName, p2.Hp, p2.Attack, p2.Defense, p2.SpecialAttack,
p2.SpecialDefense, p2.Speed, p2.Generation
```



```

FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId = pt2.PokemonId) JOIN
Type t1 ON (pt2.FirstTypeId = t1.TypeId) JOIN Type t2 ON (pt2.SecondTypeId =
t2.TypeId)
WHERE (t1.TypeName like '%Fire%' OR t2.TypeName like '%Fire%') AND p2.Generation
>= 4
ORDER BY p2.PokemonId ASC)

UNION

(SELECT p2.PokemonName, t1.TypeName AS FirstTypeName, t2.TypeName AS
SecondTypeName, p2.Hp, p2.Attack, p2.Defense, p2.SpecialAttack,
p2.SpecialDefense, p2.Speed, p2.Generation
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId = pt2.PokemonId) JOIN
Type t1 ON (pt2.FirstTypeId = t1.TypeId) JOIN Type t2 ON (pt2.SecondTypeId =
t2.TypeId)
WHERE (t1.TypeName like '%water%' OR t2.TypeName like '%water%') AND
p2.Generation >= 4
ORDER BY p2.PokemonId ASC)

UNION

(SELECT p2.PokemonName, t1.TypeName AS FirstTypeName, t2.TypeName AS
SecondTypeName, p2.Hp, p2.Attack, p2.Defense, p2.SpecialAttack,
p2.SpecialDefense, p2.Speed, p2.Generation
FROM (Pokemon p2 LEFT JOIN PokemonType pt2 on p2.PokemonId = pt2.PokemonId) JOIN
Type t1 ON (pt2.FirstTypeId = t1.TypeId) JOIN Type t2 ON (pt2.SecondTypeId =
t2.TypeId)
WHERE (t1.TypeName like '%Grass%' OR t2.TypeName like '%Grass%') AND
p2.Generation >= 4
ORDER BY p2.PokemonId ASC)
LIMIT 15;

```

First try of indexing design:

Index on **Generation**

```

-----
| -> Table scan on <union temporary> (cost=0.01..15.93 rows=1075) (actual time=0.002..0.024 rows=136 loops=1)
|   -> Union materialize with deduplication (cost=1577.02..1592.93 rows=1075) (actual time=8.922..8.951 rows=136 loops=1)
|     -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.306..3.021 rows=41 loops=1)
|       -> Nested loop inner join (cost=364.43 rows=358) (actual time=0.280..2.301 rows=683 loops=1)
|         -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.272..1.167 rows=683 loops=1)
|           -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.258..0.667 rows=683 loops=1)
|             -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.060..0.578 rows=1075 loops=1)
|               -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: ((t1.TypeName like '%Fire%') or (t2.TypeName like '%Fire%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                 -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: ((t1.TypeName like '%Fire%') or (t2.TypeName like '%Fire%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                 -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.285..0.674 rows=683 loops=1)
|             -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.059..0.586 rows=1075 loops=1)
|               -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: ((t1.TypeName like '%water%') or (t2.TypeName like '%water%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                 -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: ((t1.TypeName like '%water%') or (t2.TypeName like '%water%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                 -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.345..1.163 rows=683 loops=1)
|             -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.041..0.537 rows=1075 loops=1)
|               -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: ((t1.TypeName like '%Grass%') or (t2.TypeName like '%Grass%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                 -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Filter: ((t1.TypeName like '%Grass%') or (t2.TypeName like '%Grass%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                 -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
-----

```

raw

```

1 -> Table scan on <union temporary> (cost=0.01..28.10 rows=2049) (actual time=0.001..0.029 rows=136 loops=1)
   -> Union materialize with deduplication (cost=2697.24..2729.32 rows=4) (actual time=0.481..0.527 rows=136 loops=1)
       -> Nested loop inner join (cost=830.77 rows=683) (actual time=0.282..2.045 rows=683 loops=1)
           -> Nested loop inner join (cost=591.72 rows=683) (actual time=0.256..2.144 rows=683 loops=1)
               -> Nested loop inner join (cost=352.67 rows=683) (actual time=0.247..1.592 rows=683 loops=1)
                   -> Filter: (p2.Generation >= 4) (cost=113.62 rows=683) (actual time=0.233..0.639 rows=683 loops=1)
                       -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.057..0.557 rows=1075 loops=1)
                           -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                               -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                   -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                       -> Filter: ((t1.TypeName like '%Fire%') or (t2.TypeName like '%Fire%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                           -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                               -> Nested loop inner join (cost=830.77 rows=683) (actual time=0.247..2.711 rows=44 loops=1)
                                                   -> Nested loop inner join (cost=591.72 rows=683) (actual time=0.219..2.002 rows=683 loops=1)
                                                       -> Nested loop inner join (cost=352.67 rows=683) (actual time=0.216..1.449 rows=683 loops=1)
                                                           -> Filter: (p2.Generation >= 4) (cost=113.62 rows=683) (actual time=0.212..0.614 rows=683 loops=1)
                                                               -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.042..0.527 rows=1075 loops=1)
                                                                   -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                       -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                           -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                               -> Filter: ((t1.TypeName like '%Water%') or (t2.TypeName like '%Water%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                                                                   -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                       -> Nested loop inner join (cost=830.77 rows=683) (actual time=0.234..2.744 rows=52 loops=1)
                                                                                           -> Nested loop inner join (cost=591.72 rows=683) (actual time=0.225..2.017 rows=683 loops=1)
                                                                                               -> Nested loop inner join (cost=352.67 rows=683) (actual time=0.221..1.462 rows=683 loops=1)
                                                                                                   -> Filter: (p2.Generation >= 4) (cost=113.62 rows=683) (actual time=0.216..0.622 rows=683 loops=1)
                                                                                                       -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.042..0.527 rows=1075 loops=1)
                                                                                                           -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                               -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                                   -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                                       -> Filter: ((t1.TypeName like '%Grass%') or (t2.TypeName like '%Grass%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                                                                                                           -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)

```

In this experiment we have used generation as an index, since one important filters in the query is whether generation >= 4. As seen from the pictures shown above, in terms of filtering, the efficiency has greatly been improved compared to the original method. This can be explained by the less redundant pattern in searching (since nodes are categorized by generation and generations < 4 are separated)

Running time before indexing: 0.258, 0.285, 0.332

Running time after indexing: 0.233, 0.212, 0.216

Second try of indexing design:

Index on **FirstTypeId**

```

1 -> Table scan on <union temporary> (cost=0.01..15.93 rows=1075) (actual time=0.002..0.024 rows=136 loops=1)
   -> Union materialize with deduplication (cost=1577.02..1592.93 rows=1075) (actual time=8.922..8.951 rows=136 loops=1)
       -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.306..2.021 rows=683 loops=1)
           -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.272..1.167 rows=683 loops=1)
               -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.258..0.667 rows=683 loops=1)
                   -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.060..0.578 rows=1075 loops=1)
                       -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                           -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                               -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                   -> Filter: ((t1.TypeName like '%Fire%') or (t2.TypeName like '%Fire%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                       -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                           -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.331..2.746 rows=44 loops=1)
                                               -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.292..1.501 rows=683 loops=1)
                                                   -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.285..0.674 rows=683 loops=1)
                                                       -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.059..0.586 rows=1075 loops=1)
                                                           -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                               -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                   -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                       -> Filter: ((t1.TypeName like '%Water%') or (t2.TypeName like '%Water%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                                                           -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                               -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.365..2.971 rows=52 loops=1)
                                                                                   -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.311..1.519 rows=683 loops=1)
                                                                                       -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.345..1.639 rows=683 loops=1)
                                                                                           -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.043..0.637 rows=1075 loops=1)
                                                                                               -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                   -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                       -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                           -> Filter: ((t1.TypeName like '%Grass%') or (t2.TypeName like '%Grass%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                                                                                               -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)

```

```

1 -> Table scan on <union temporary> (cost=0.01..15.93 rows=1075) (actual time=0.001..0.023 rows=136 loops=1)
   -> Union materialize with deduplication (cost=1577.02..1592.93 rows=1075) (actual time=13.558..13.588 rows=136 loops=1)
       -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.686..2.981 rows=683 loops=1)
           -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.542..6.405 rows=683 loops=1)
               -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.407..1.052 rows=683 loops=1)
                   -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.119..0.935 rows=1075 loops=1)
                       -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.007..0.008 rows=1 loops=683)
                           -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.007..0.007 rows=1 loops=683)
                               -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                   -> Filter: ((t1.TypeName like '%Fire%') or (t2.TypeName like '%Fire%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                       -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                           -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.268..2.737 rows=44 loops=1)
                                               -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.236..2.053 rows=683 loops=1)
                                                   -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.224..0.647 rows=683 loops=1)
                                                       -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.050..0.562 rows=1075 loops=1)
                                                           -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                               -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                   -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                       -> Filter: ((t1.TypeName like '%Water%') or (t2.TypeName like '%Water%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                                                           -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                               -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.237..2.636 rows=52 loops=1)
                                                                                   -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.222..2.053 rows=683 loops=1)
                                                                                       -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.221..1.393 rows=683 loops=1)
                                                                                           -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.040..0.533 rows=1075 loops=1)
                                                                                               -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                   -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                       -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
                                                                                                           -> Filter: ((t1.TypeName like '%Grass%') or (t2.TypeName like '%Grass%')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
                                                                                                               -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)

```

In this experiment we have used FirstTypeId as an index, in order to cluster similar types together. When it comes to the filtering results on our index, there is not too much difference since the actual time are too small to tell apart (both with values of 0.001). However, the nested loop join efficiencies are quite intriguing. Two of them became faster but one became significantly slower. We are not sure about the causation but we are quite certain that this issue is correlated with the distribution of "Fire" Pokemon in our database.

Running time before indexing: 8.92, 0.331, 0.365

Running time after indexing: 13.56, 0.236, 0.237

Third try of indexing design:

Index on **PokemonName**

```
-----
| -> Table scan on <union temporary> (cost=0.01..28.10 rows=2049) (actual time=0.001..0.029 rows=136 loops=1)
|   -> Union materialize with deduplication (cost=2697.24..2725.32 rows=2049) (actual time=8.489..8.524 rows=136 loops=1)
|     -> Nested loop inner join (cost=830.77 rows=683) (actual time=0.282..2.845 rows=41 loops=1)
|       -> Nested loop inner join (cost=591.72 rows=683) (actual time=0.256..2.144 rows=683 loops=1)
|         -> Nested loop inner join (cost=352.67 rows=683) (actual time=0.247..1.592 rows=683 loops=1)
|           -> Filter: (p2.Generation >= 4) (cost=113.62 rows=683) (actual time=0.233..0.639 rows=683 loops=1)
|             -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.057..0.557 rows=1075 loops=1)
|               -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Filter: ((t1.TypeName like 'Fire') or (t2.TypeName like 'Fire')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|               -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Nested loop inner join (cost=830.77 rows=683) (actual time=0.247..2.711 rows=44 loops=1)
|                   -> Nested loop inner join (cost=591.72 rows=683) (actual time=0.225..2.207 rows=683 loops=1)
|                     -> Nested loop inner join (cost=352.67 rows=683) (actual time=0.216..1.449 rows=683 loops=1)
|                       -> Filter: (p2.Generation >= 4) (cost=113.62 rows=683) (actual time=0.212..0.614 rows=683 loops=1)
|                         -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.042..0.527 rows=1075 loops=1)
|                           -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                             -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                               -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                 -> Filter: ((t1.TypeName like 'Water') or (t2.TypeName like 'Water')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                               -> Nested loop inner join (cost=830.77 rows=683) (actual time=0.234..2.711 rows=52 loops=1)
|                                 -> Nested loop inner join (cost=591.72 rows=683) (actual time=0.225..2.017 rows=683 loops=1)
|                                   -> Nested loop inner join (cost=352.67 rows=683) (actual time=0.221..1.462 rows=683 loops=1)
|                                     -> Filter: (p2.Generation >= 4) (cost=113.62 rows=683) (actual time=0.216..0.622 rows=683 loops=1)
|                                       -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.042..0.543 rows=1075 loops=1)
|                                         -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                           -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                             -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                               -> Filter: ((t1.TypeName like 'Grass') or (t2.TypeName like 'Grass')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                                             -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
```

```
-----
| -> Table scan on <union temporary> (cost=0.01..15.93 rows=1075) (actual time=0.002..0.024 rows=136 loops=1)
|   -> Union materialize with deduplication (cost=1577.02..1592.93 rows=1075) (actual time=8.793..8.823 rows=136 loops=1)
|     -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.424..3.145 rows=41 loops=1)
|       -> Nested loop inner join (cost=364.43 rows=358) (actual time=0.374..2.314 rows=683 loops=1)
|         -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.340..1.722 rows=683 loops=1)
|           -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.324..0.745 rows=683 loops=1)
|             -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.068..0.645 rows=1075 loops=1)
|               -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|               -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Filter: ((t1.TypeName like 'Fire') or (t2.TypeName like 'Fire')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|               -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                 -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.276..2.795 rows=44 loops=1)
|                   -> Nested loop inner join (cost=364.43 rows=358) (actual time=0.242..2.208 rows=683 loops=1)
|                     -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.239..1.521 rows=683 loops=1)
|                       -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.227..0.643 rows=683 loops=1)
|                         -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.048..0.557 rows=1075 loops=1)
|                           -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                             -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                               -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                 -> Filter: ((t1.TypeName like 'Water') or (t2.TypeName like 'Water')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                               -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                 -> Nested loop inner join (cost=489.84 rows=358) (actual time=0.252..2.662 rows=52 loops=1)
|                                   -> Nested loop inner join (cost=364.43 rows=358) (actual time=0.237..2.142 rows=683 loops=1)
|                                     -> Nested loop inner join (cost=239.03 rows=358) (actual time=0.237..1.427 rows=683 loops=1)
|                                       -> Filter: (p2.Generation >= 4) (cost=113.62 rows=358) (actual time=0.232..0.640 rows=683 loops=1)
|                                         -> Table scan on p2 (cost=113.62 rows=1075) (actual time=0.044..0.556 rows=1075 loops=1)
|                                           -> Filter: ((pt2.FirstTypeId is not null) and (pt2.SecondTypeId is not null)) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                             -> Single-row index lookup on pt2 using PRIMARY (PokemonId=p2.PokemonId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                               -> Single-row index lookup on t1 using PRIMARY (TypeId=pt2.FirstTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
|                                                 -> Filter: ((t1.TypeName like 'Grass') or (t2.TypeName like 'Grass')) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=683)
|                                                 -> Single-row index lookup on t2 using PRIMARY (TypeId=pt2.SecondTypeId) (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1 loops=683)
```

Since Pokemons are like animals, their naming conventions are also categorical. We are trying to explore whether the names of Pokemon can be of value to optimizing our query. It turns out that the results are worse than the original result. So, it can be concluded that naming conventions do not have effects on the searching of certain types or generations of Pokemon. However, we believe that with more advanced "identifying methods" such as prefixes, the estimated result would be better than the present one, in which we are only using alphabetical order as index.

Running time before indexing: 9.489, 0.247, 0.234

Running time after indexing: 8.793, 0.276, 0.252