

# RUTGERS

Rutgers Business School  
Newark and New Brunswick

ebb&flo

## 2022 Summer Final Presentation

August 15<sup>th</sup>, 2022

Caroline Bortolon  
Tianna Fougeray  
Shahid Khan  
Qiuzi Li  
Neel Patel

## Agenda

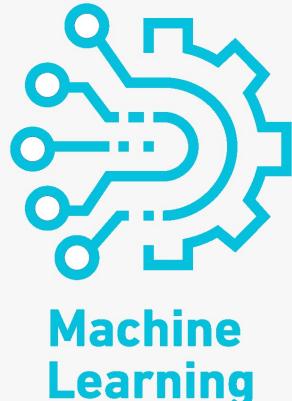
- ✓ Project Requirements & Deliverables
- ✓ Project Plan with Timeline and Milestones
- ✓ Process Map
- ✓ Research Methodology
- ✓ Data Analysis/Insights
- ✓ Machine Learning Methods
- ✓ Questionnaire Content and Data Analysis
- ✓ Risks and problems identified
- ✓ Recommendations
- ✓ Learnings
- ✓ References



## Project Requirements & Deliverables

### Objective:

- Develop an AI machine learning model to be used in testing for endometriosis care focusing on explainability, transparency, security (robustness), privacy, and fairness.
- Identify the most significant medical events in the patient journey that lead to the diagnosis of endometriosis.
- Small-batch testing to conclude if a patient has endometriosis or not
- Provide basic structure of what the diagnosis process can look like for a larger website/app that client will utilize
- Build the foundation of a data pipeline strategy to find/extract and store internal data in an organized manner for endometriosis AI clinical diagnostics



Machine  
Learning

### Tasks:

- Research data sources for endometriosis
- Identify inputs and outputs from the data
- Test Machine Learning Models and recommend the best
- Discover possible outcomes for the diagnostic assessment
- Analyze questionnaire and patient data given
- Beta Testing and building the model as the structure for a larger purpose



PROJECT  
PLAN

### Deliverables:

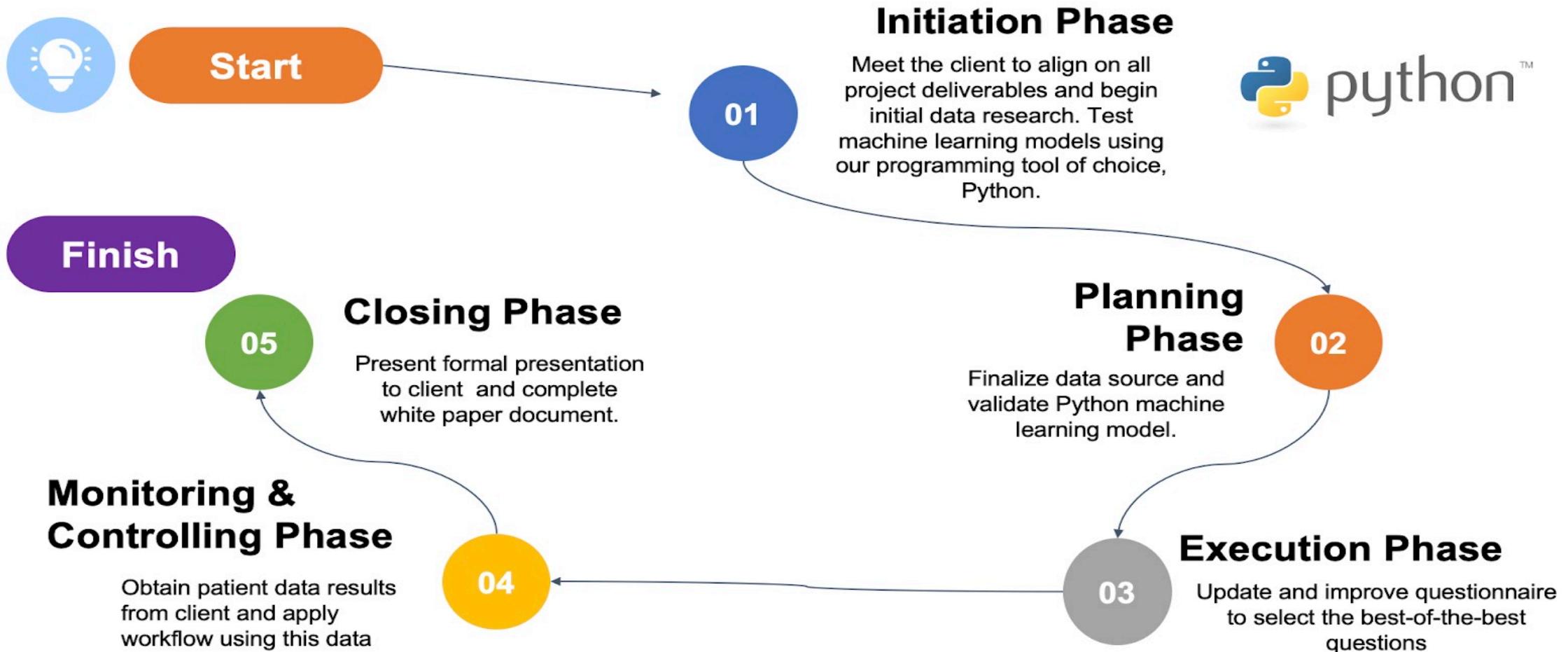
- Establish a strategy to create, extract, and manage data for ebb&flo
- Develop an AI diagnostic process for endometriosis to improve disease awareness, management and delivery of diagnostics, ongoing support and precision medicine
- Risk assessment for implementation



# Project Plan with Timeline and Milestones

Date	Performance to Date
06/08/2022	First client meeting held with Kelly. Define objectives and scope of the project. Assess each team member's background experience and skill sets for project tasks.
06/13/2022	Research data sources and analyze all client-provided resources with team members. Identify input and output from the data. Prepare to review chosen data source and initial machine learning model ideas with Kelly on next meeting, 6/20. Schedule weekly meeting with the client on Mondays @ 7 PM.
06/20/2022	Present machine learning models and research findings to Kelly and hear feedback regarding other outside data sources. Research more data on endometriosis to potentially tie into project. Test more machine learning models and prepare to share with Kelly on 6/27.
06/27/2022	Present all six machine learning models and share rank of prediction accuracy. Validate the machine learning model that we will use for the project with Kelly based on the highest accuracy as well as the models that we will not move forward with. Following meeting, Kelly will share a questionnaire so our team can begin beta testing for the algorithm.
07/04/2022	Following our 6/20 meeting, Kelly will share a questionnaire so our team can begin beta testing for the algorithm. Our team begins to complete further research to determine questions and language we want to use in the questionnaire.
07/11/2022	Meet with Kelly to review questionnaire and begin to improve upon it. Prepare for midterm review with Professor Agresta to present project deliverables and findings so far this semester and what we will accomplish to complete all client tasks and exceed expectations.
07/18/2022	Present questionnaire progress so far to the client
07/25/2022	Revised questionnaires to be 3 minutes in length and finalized with the client
8/1/22 - 08/14/2022	Began to beta test our model with patient data from the surveys and prepared final presentation white paper and presentation
08/15/2022	Final presentation

# Process Map



## Research Methodology

- Research data sets exploring sites like data.world, data.gov, Propublica Data Store, GitHub
- Several analytical methods were leveraged for the analysis from the rules-based qualification criteria to Machine Learning algorithms to derive probability of endometriosis onset
- Explore similar companies like ebb&flo: FEMaLe, Ziwig, endometrix, care/of, Allara
- Explored the best programming language to be used for model testing and decided on Python



## Data Analysis/Insights

- Project Goal: *Apply machine learning to facilitate the identification of endometriosis.*
- Data source: <https://github.com/Dolev/Endometriosis>
- Data consists of 61 columns and 885 rows
  - 474 cases with “Endometriosis” and 412 cases without “Endometriosis”
    - Original dataset has 58 features including “Heavy/Extreme menstrual bleeding”, “Menstrual pain”, “Cramping”, etc.
    - Machine learning:
      - Data input: Features/Symptoms related to Endometriosis
      - Data output: Diagnostics of Endometriosis Yes/No
        - Label = 1 has Endometriosis
        - Label = 0 No Endometriosis
    - Algorithms: Linear Discriminant Analysis (LDA), Naive Bayes, K-Nearest Neighbors (KNN), Logistic-regression (LR), etc.



## A Look at Our Data in Excel

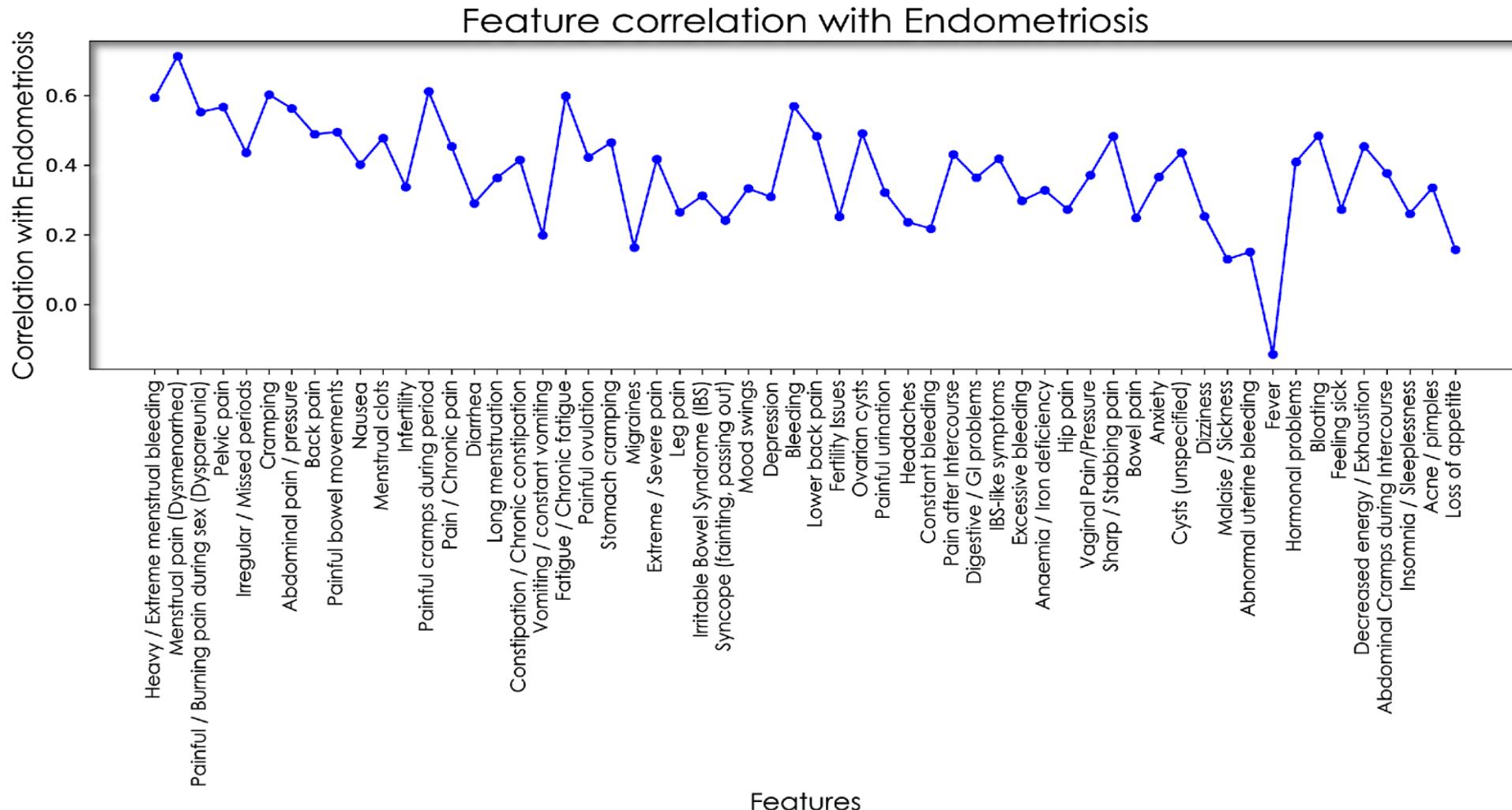
BI	BH	BG	BF	BE	BD	BC	BB	BA	AZ	AY	AX	AW	AV	AU	AT	AS	AR	AQ	AP	AO	AN	AM
label	row	Loss of appet.	Acne / pimples	Insomnia / Abdominal	Decrease	Feeling sick	Bloating	Hormonal	Fever	Abnormal	Malaise / tiredness	Dizziness	Cysts (un	Anxiety	Bowel pain	Sharp / Stabbing	Vaginal Pains	Hip pain	Anaemia / Excessive	IBS-like		
1	0	0	0	0	1	1	1	1	0	0	0	0	1	0	1	0	0	1	1	1	0	
1	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
1	2	0	0	1	0	1	1	1	0	0	0	0	0	0	0	1	0	1	1	1	0	
1	3	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	
1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	
1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	6	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	
1	7	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	1	
1	8	0	1	1	0	1	1	0	0	0	0	0	0	1	0	1	0	1	0	1	0	
1	9	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	
1	10	1	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	
1	11	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
1	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	
1	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	
1	14	0	1	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	
1	15	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
1	16	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	1	0	0	
1	17	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	
1	18	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	20	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
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1	22	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
1	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	
1	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	25	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	
1	26	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
1	27	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
1	28	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
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1	35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	
1	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	

# A Look at Our Data in Excel

# A Look at Our Data in Excel

R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A	
Constipation	Long menstrual cycle	Diarrhea	Pain / Cramps	Chronic pain	Painful cramps	Infertility	Menstrual pain	Nausea	Painful bowel movements	Back pain	Abdominal pain	Cramping	Irregular periods	Pelvic pain	Painful / Burning pain	Menstrual pain (Dysmenorrhea)	Heavy / Extreme menstrual bleeding	
0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	Heavy / Extreme menstrual bleeding;Nausea;Painful / Burning pain
0	0	1	1	1	0	0	1	1	0	1	0	1	1	1	0	1	0	Fatigue / Chronic fatigue;Nausea;Bloating;Back pain;Painful / Burning pain
1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	1	1	1	1	0	0	0	0	1	1	0	1	0	0	1	1	0	Fatigue / Chronic fatigue;Painful / Burning pain during sex
0	0	0	1	1	0	0	0	0	1	1	0	1	0	0	1	0	1	Heavy / Extreme menstrual bleeding;Painful / Burning pain
0	1	1	0	0	0	0	1	0	1	0	0	1	0	0	1	0	1	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	1	1	0	0	0	1	0	1	0	0	0	0	1	0	0	1	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	0	Nausea;Back pain;Pain / Chronic pain;Menstrual pain (Dysmenorrhea)
0	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	Fatigue / Chronic fatigue;Painful / Burning pain during sex
0	0	1	1	0	0	0	0	0	1	1	1	0	1	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	Heavy / Extreme menstrual bleeding;Painful / Burning pain
0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	Pelvic pain;Diarrhea;Painful bowel movements;Hip pain
0	0	1	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0	Cramping;Abdominal pain / pressure;Painful cramps during sex
0	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	1	0	Fatigue / Chronic fatigue;Pain / Chronic pain;Menstrual pain
0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	1	1	Heavy / Extreme menstrual bleeding;Painful / Burning pain
0	1	0	1	1	0	0	1	0	1	1	1	1	0	1	1	0	1	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0	Fatigue / Chronic fatigue;Nausea;Painful / Burning pain during sex
0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	0	1	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	Heavy / Chronic fatigue;Painful / Burning pain during sex
0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	1	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	Heavy / Extreme menstrual bleeding;Fatigue / Chronic fatigue
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	Bloating;Back pain;Pain / Chronic pain;Cramping;Pelvic pain
0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1	Heavy / Extreme menstrual bleeding;Painful / Burning pain
0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1	Fatigue / Chronic fatigue;Painful / Burning pain during sex

## Feature Correlations – Raw data



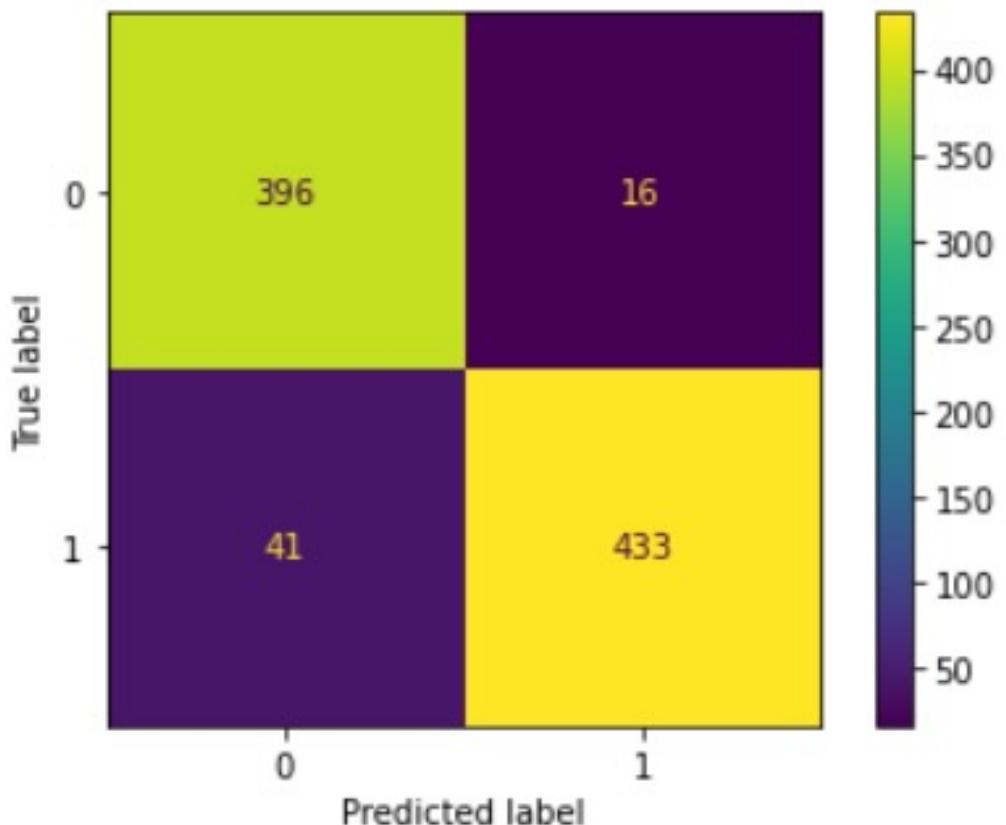
# Machine Learning Descriptions

Model Name	Description
Linear Discriminant Analysis	A classifier with a linear decision boundary, generated by fitting class conditional densities to the data and using Bayes' rule. The model fits a Gaussian density to each class, if all classes share the same covariance matrix. Using the transform method, the fitted model can also reduce the dimensionality of the input by projecting it to the most discriminative directions.
Naïve Bayes	Naive Bayes methods are a set of supervised learning algorithms based on applying Bayes' theorem with the "naive" assumption of conditional independence between every pair of features given the value of the class variable.
K-Nearest Neighbors	KNN (K-Nearest Neighbor) is a simple supervised classification algorithm we can use to assign a class to new data point. It can be used for regression as well, KNN does not make any assumptions on the data distribution, hence it is non-parametric. It keeps all the training data to make future predictions by computing the similarity between an input sample and each training instance.
Logistic-regression	Logistic regression is a statistical analysis method to predict a binary outcome, such as yes or no, based on prior observations of a data set. A logistic regression model predicts a dependent data variable by analyzing the relationship between one or more existing independent variables.
Decision Tree	A type of Supervised Machine Learning, where the data is continuously split according to a certain parameter. The tree can be explained by two entities, namely decision nodes and leaves.
Support Vector Classification	A supervised machine learning algorithm that can be employed for both classification and regression purposes. Support Vector Classification method is based on the idea of finding a hyperplane that best divides a dataset into several different classes.



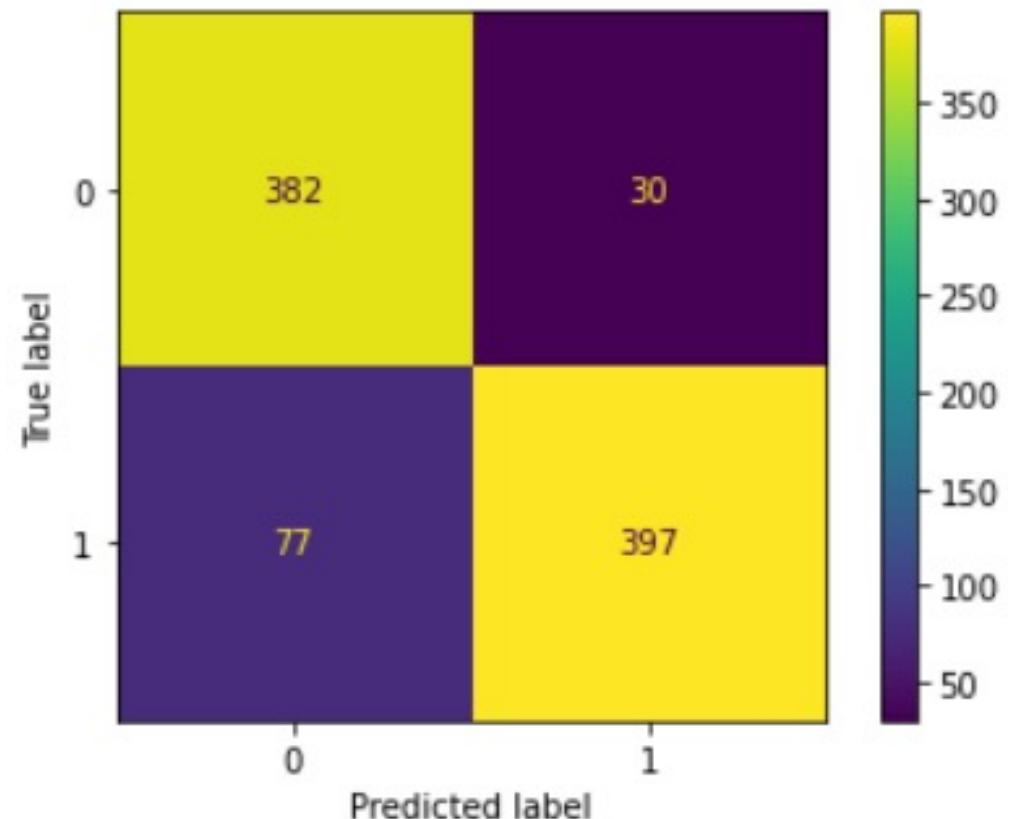
## Machine Learning – LDA & NB

Linear Discriminant Analysis



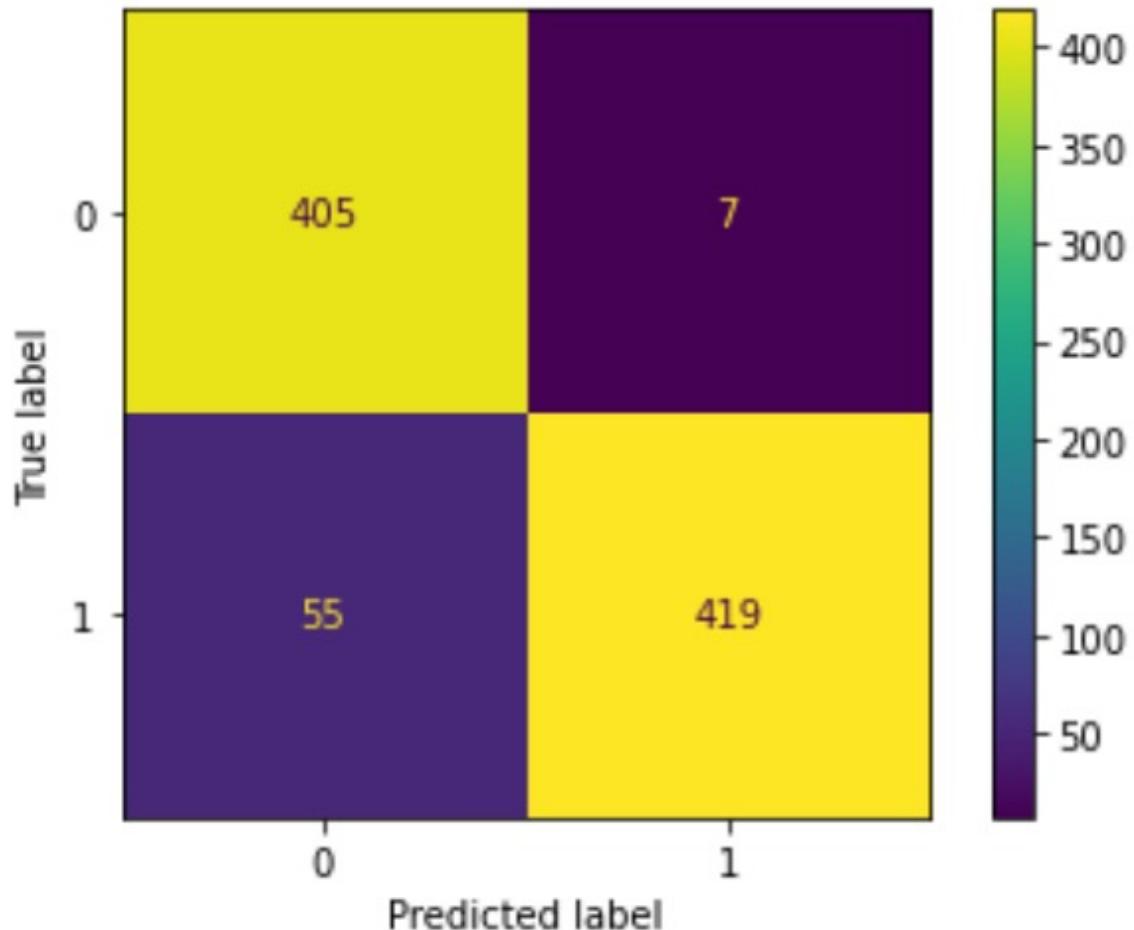
Accuracy of LDA classifier = 0.9357

Naïve Bayes

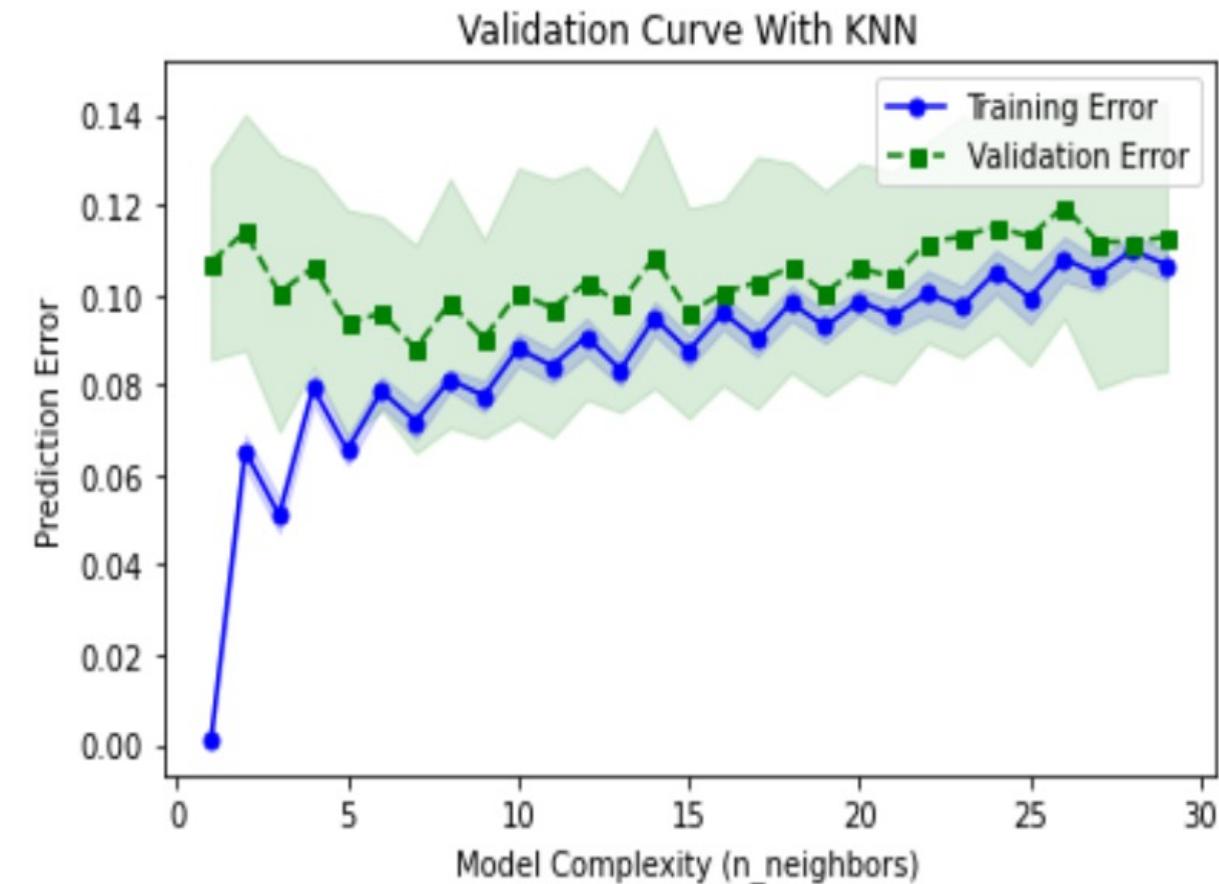


Accuracy of NB classifier = 0.8792

# Machine Learning – K Nearest Neighbors

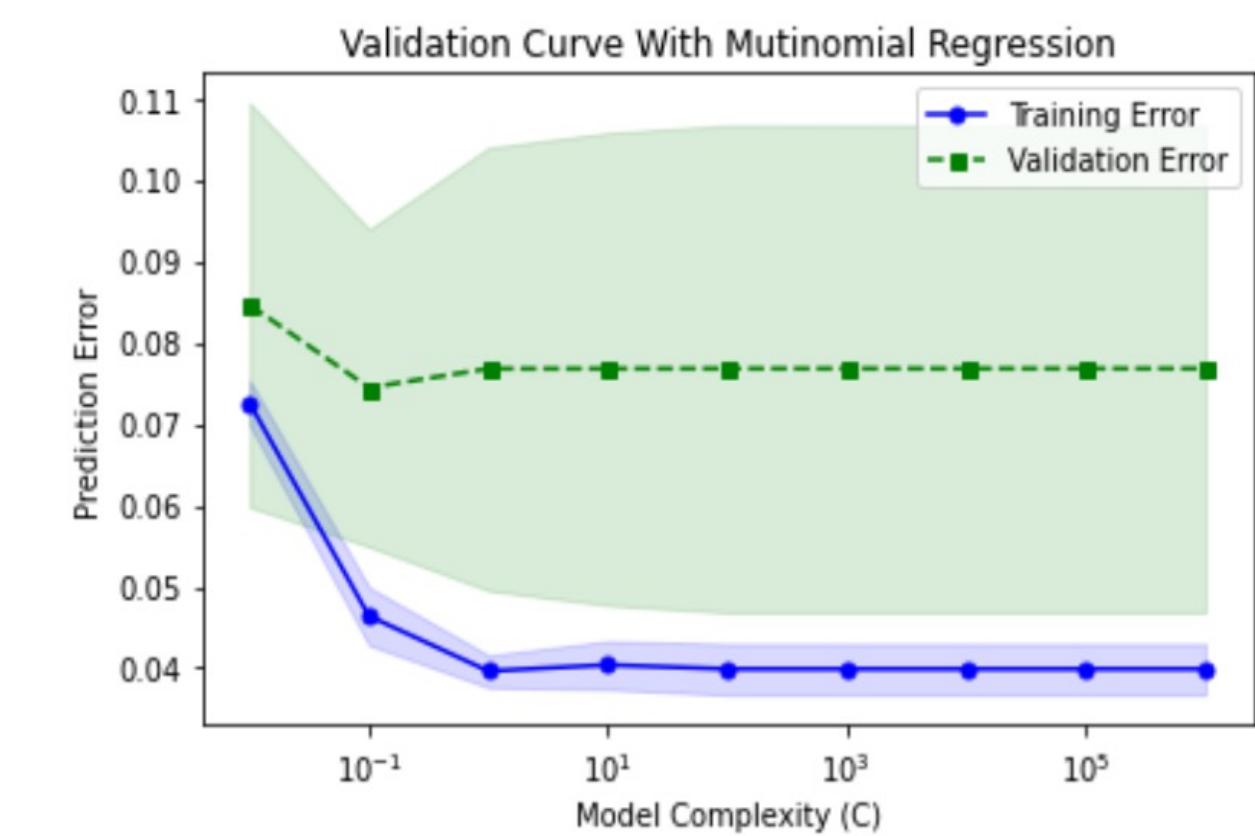
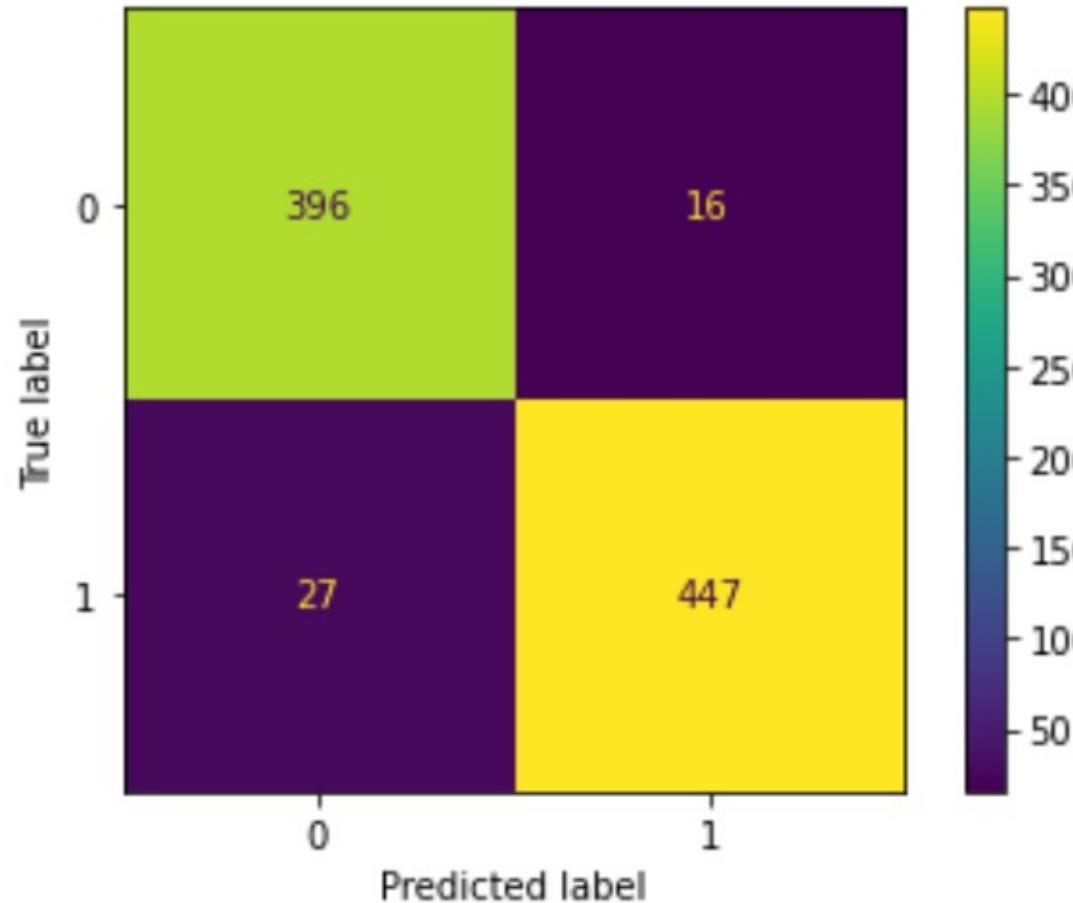


Accuracy of KNN classifier = 0.93



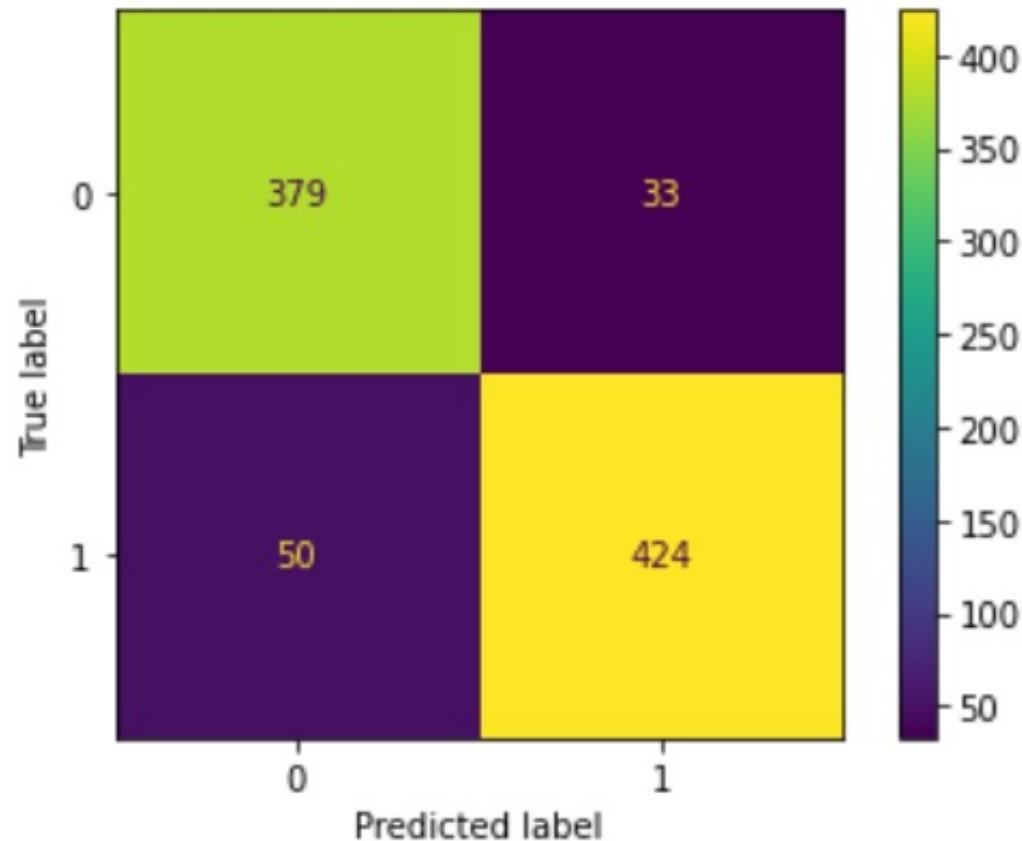
The optimal n\_neighbors = 7

# Machine Learning – Logistical regression

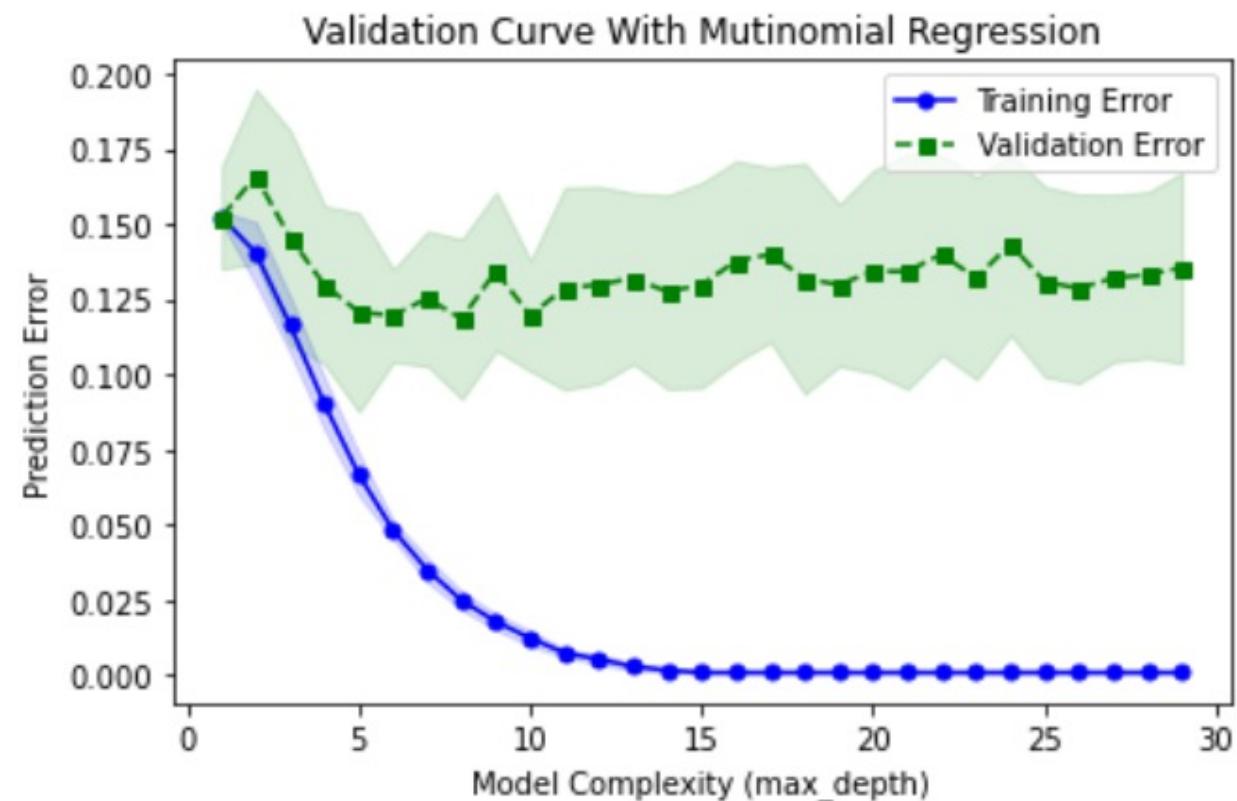


The optimal regulation strength parameter  $C = 0.1$

# Machine Learning – Decision Tree

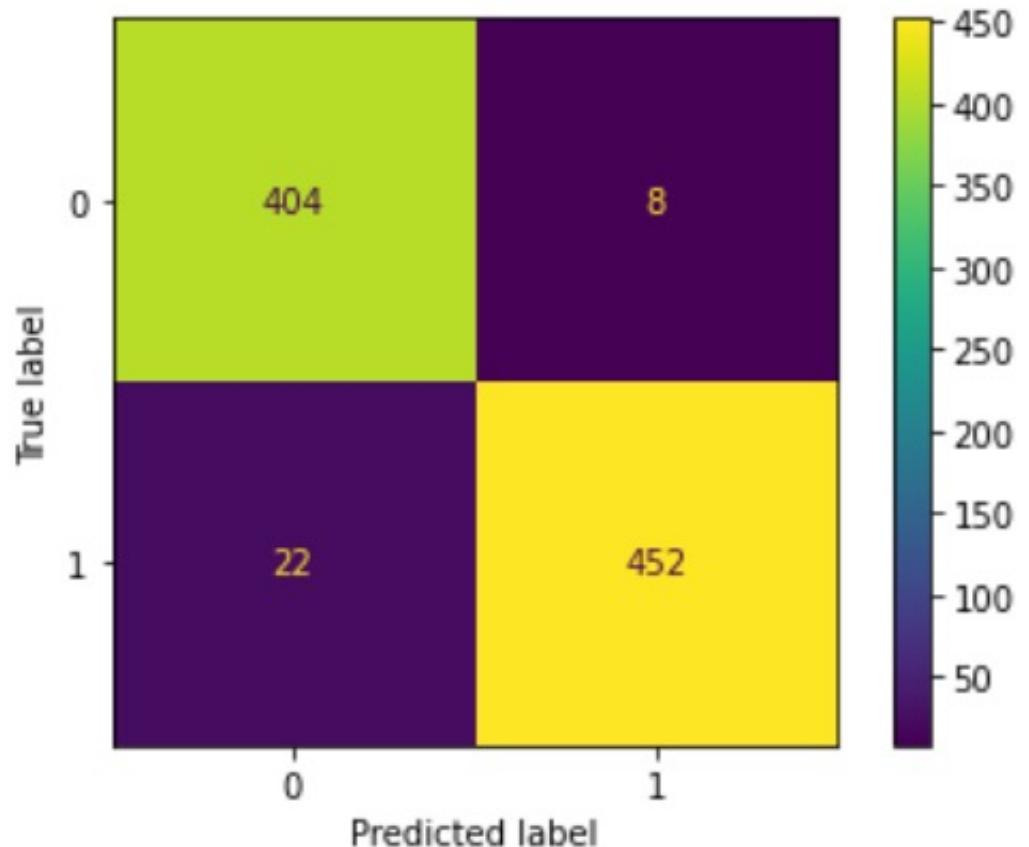


Accuracy of DT classifier = 0.9063

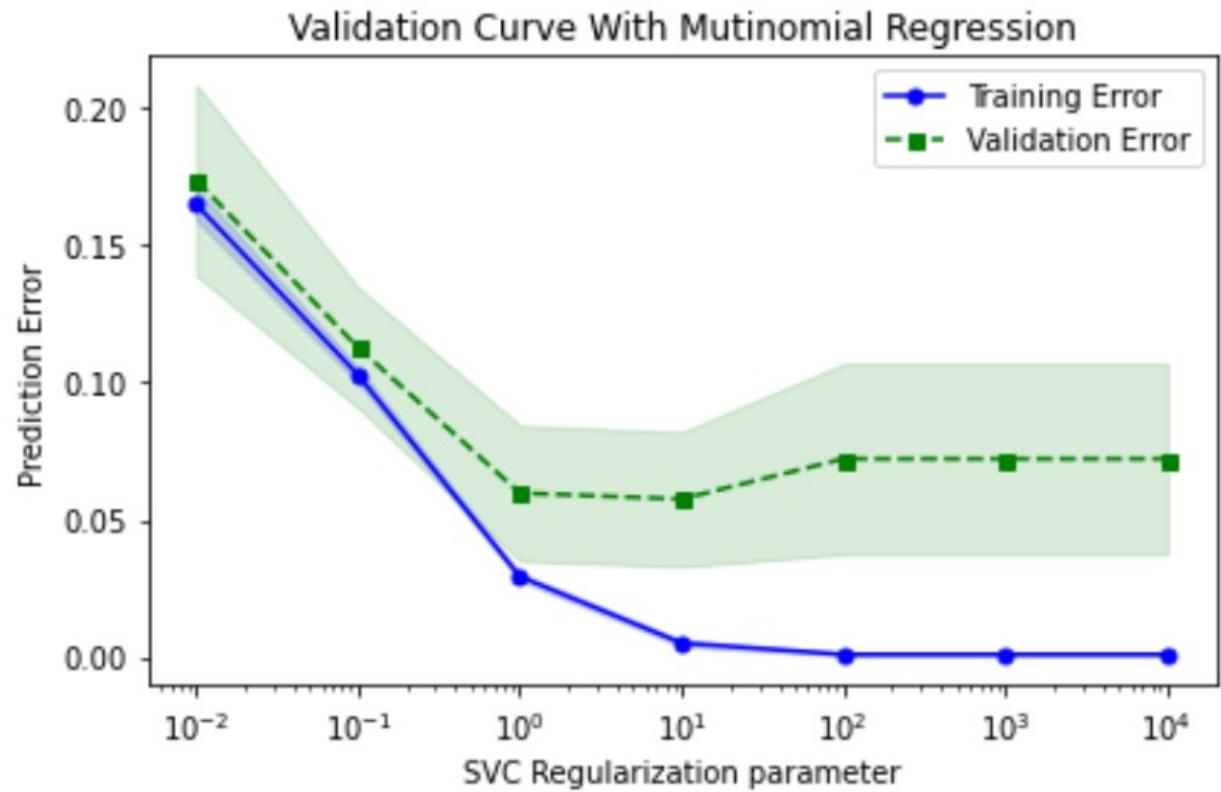


The optimal max depth parameter = 8

# Machine Learning – Support Vector Classification



Accuracy of DT classifier = 0.9661



The optimal C parameter = 10

## Rank of All Six Machine Learning Approaches

- Based on the above analysis, we can rank the prediction accuracy for all six different machine learning approaches Rank LDA, Naïve Bayes, KNN, Logistic-regression, Decision Tree, and SVC
- Conclusion Support Vector Classification achieves the best predictability while Decision Tree is the worst

	method	Accuracy
4	Decision Tree	0.865615
1	NB	0.872459
2	KNN	0.911964
0	LDA	0.919918
3	Logistic-regression	0.925549
5	SVC	0.942390

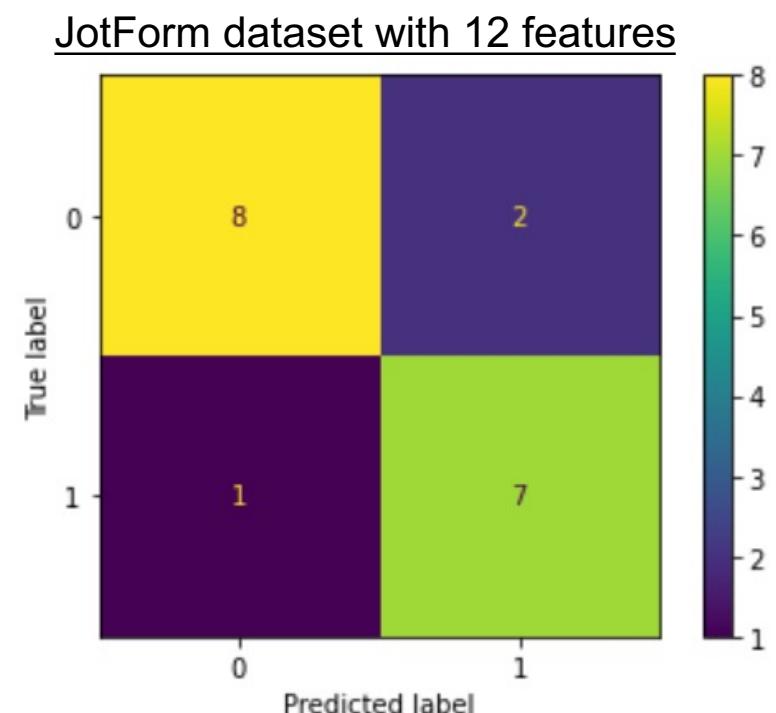
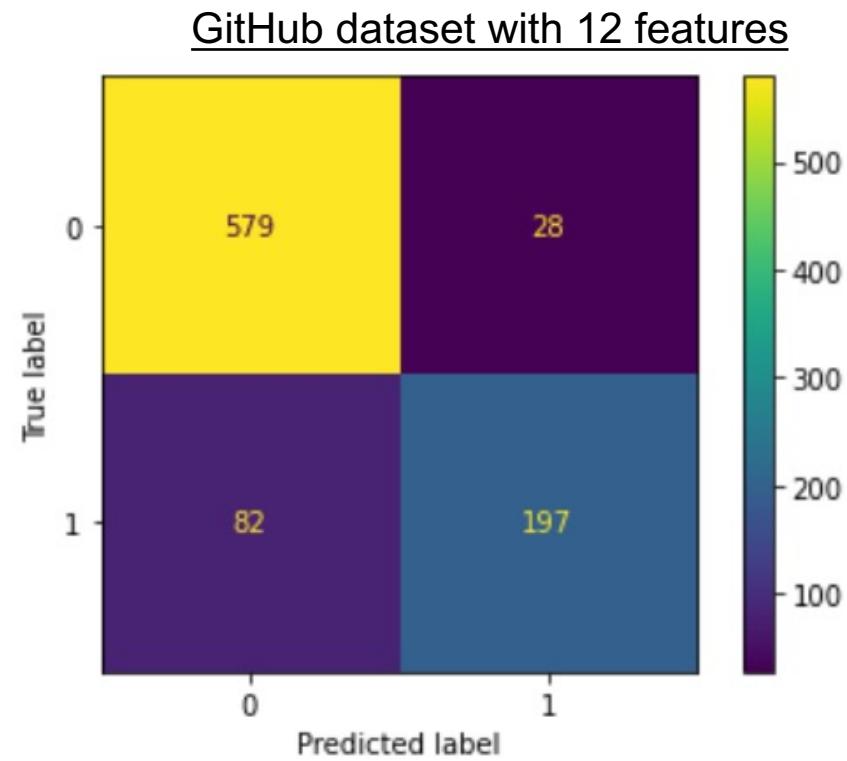
## Endometriosis Questionnaire Content

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	First Name	e-mail for results	Ethnicity	How old are you	Your gender at birth	Has anyone in your family exp:	Has any family men	What brings you here?	Are you familiar with care or tre	Are you currently experiencing endometriosis symp	Have you been diagnos	Who diagnosed you?	If hysterectomy
2	Alex		White	20	Female	No	No	I think I might have endometriosis	Yes	Yes	No		
3	May Palacios	whatsapp	Hispanic or Latino	24	Female	Yes	Yes	I have endometriosis	Yes	Yes	No	obgyn	
4	Crystal	papirmassepulp@gmail.com	Black or African American	27	Female	Yes	No	I think I might have endometriosis	No		No	self-diagnosis	
5	Samantha Gardner	text me/ whatsapp results	White	27	Female	Yes	No	I think I might have endometriosis	No	Yes	No	self-diagnosis	
6	Carley	Whittle	White	28	Female	Yes	No	I think I might have endometriosis	No	No			
7	Shani Jones	whatsapp	Black or African American	31	Female	Yes	No	I think I might have endometriosis	No	Yes	No	self?	
8	Franceta	Johnson	Black or African American	31	Female	Yes	Yes	I think I might have endometriosis	No	Yes	Yes	I found on google then brought it to my famili	
9	Michelle Dawn	text me	White	31	Female	No	No	I think I might have endometriosis	Yes	Yes	No	google	
10	Daphne	Freeman	White	32	Female	No	No	I have endometriosis	Yes	Yes	Yes	Family doctor, confirmed by gynaecologist	
11	Juana		Hispanic or Latino	33	Female	Yes	Yes	I think I might have endometriosis	No	Yes	No		
12	Alysa	Atkins	White	34	Female	No	No	I think I might have endometriosis	No	Yes	No	self-diagnosis, also considering PCOS with r	
13	Les	whatsapp	Black or African American	34	Female	No	No	I think I might have endometriosis	Yes	Yes	Yes	doctor	

- Survey data has 12 features listed below for diagnostics tests:
  - Menstrual pain (Dysmenorrhea); Pelvic pain; Irregular / Missed periods; Back Pain ; Painful bowel movements; Fatigue / Chronic fatigue; Painful Ovulation; Depression; Bleeding; Excessive bleeding Abnormal uterine bleeding; Abdominal Cramps during Intercourse

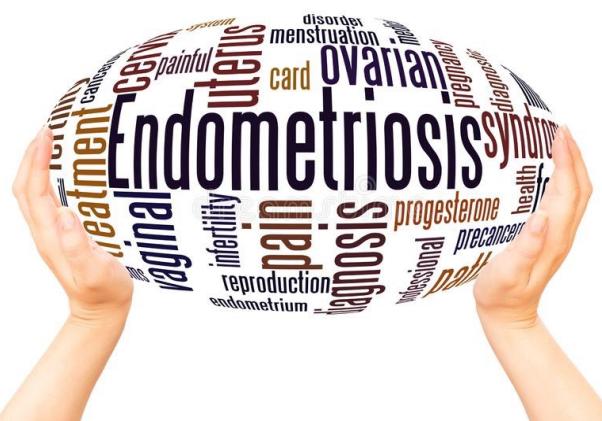
# Endometriosis Questionnaire Data Analysis

- Test SVC approach with survey data
- Survey data (12 features) has less features than the original data set (58 features) obtained from GitHub
- Retrain the SVC model and test the accuracy of prediction



## Risks and Problems Identified

- Difficult to find data for endometriosis affecting the *entire* body, and not just a female's reproductive system
- Beta testing: a larger dataset would be needed to test the robustness of the machine learning approach
- Support Vector Classification achieves the best predictability while Decision Tree is the worst. Even with SVC, there is still a 6% chance of low predictability
- Other risks related to machine learning approaches:
  - Poor data quality
  - Overfitting
  - Biased data



## Recommendations

- Natural Language Processing (NLP) should be tested and implemented in order to use machine learning techniques for analyzing the second, more personalized questionnaire including providing education recommendations
- Privacy policy needs to be cleared and explained to all patients before testing as well as data usage explanation.
- For the Webapp, we recommend for Kelly to integrate the dataset with the model, with the Python code we created running in the background
  - IT professional needs to implement WebApp to incorporate machine learning algorithms in the website background so that patients can obtain diagnostic results immediately after filling out the questionnaire.
- After everything is finished processing, you will be able to click the submit button and the outcome will be populated
  - We can use Python code to predict 'yes or no' based on the patient's survey results and then each person's response will be matched to the Excel



## Learnings

- Our team learned a great deal about not only the project topic researched but about ourselves working in a team as well
  - We learned from each team member coming from different backgrounds and careers
- A specific task that we have spent a lot of time on for the project was working on the patient questionnaires. This gave us all insight into what a patient survey can look like and the type of questions to ask since we all were not familiar with this prior to the project.
  - Interesting to learn how the wording of the questions and the time it takes to complete each question play a large role in the overall quality of the survey.
  - Our team member, Caroline, was diagnosed with endometriosis, so we can all confidently say that we learned from her experience about the condition and what it is like for patients living through it daily.
- We have also learned to always have an alternate course of action - a 'Plan B' - if a task did not go as we initially planned
  - Adjust to delays, working together virtually, communication, busy schedules



## References

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# Thank you!

*Kelly, we are very grateful to have worked with you. Your energy, ambition, passion and knowledge as a CEO was contagious and inspiring to each one of us. We hope that you can utilize the model we have created and wish you and ebb&flo the very best of success!*

- Your Project Team ☺