Lab 5 : Du Notebook au Déploiement Conteneurisé d'un Modèle de Machine Learning

Étape 1 : Vérifier l'installation de Docker

Instructions :

- **Ouvrez un terminal (PowerShell ou bash).**
- **Vérifiez la version de Docker :**

```
docker --version
```

- **Vérifiez que le démon Docker fonctionne :**

```
docker ps
```

```
PS C:\Users\anoua> docker --version
Docker version 29.1.3, build f52814d
PS C:\Users\anoua> docker ps
CONTAINER ID   IMAGE     COMMAND   CREATED   STATUS    PORTS     NAMES
PS C:\Users\anoua>
```

Étape 2 : Lancer un serveur Nginx dans un conteneur

Instructions :

Lancez un conteneur Nginx en arrière-plan :

- **Lancez un conteneur Nginx en arrière-plan :**

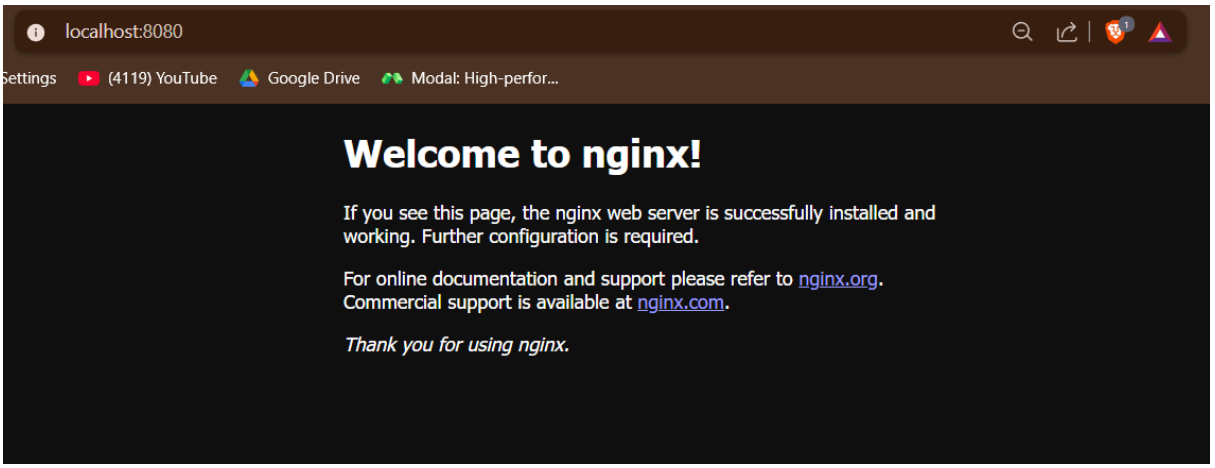
```
docker run -d -p 8080:80 --name demo-nginx nginx
```

```
PS C:\Users\anoua> docker run -d -p 8080:80 --name demo-nginx nginx
Unable to find image 'nginx:latest' locally
latest: Pulling from library/nginx
02d7611c4eae: Pull complete
dcea87ab9c4a: Pull complete
35df28ad1026: Pull complete
99ae2d6d05ef: Pull complete
a2b008488679: Pull complete
d03ca78f31fe: Pull complete
d6799cf0ce70: Pull complete
Digest: sha256:ca871a86d45a3ec6864dc45f014b11fe626145569ef0e74deaffc95a3b15b430
Status: Downloaded newer image for nginx:latest
badcd23f1708315f956d11cb54ea64da76bd5659437ca18a312ad4cf6523fabb
PS C:\Users\anoua>
```

Ouvrez un navigateur et accédez à :

- **Ouvrez un navigateur et accédez à :**

```
http://localhost:8080
```



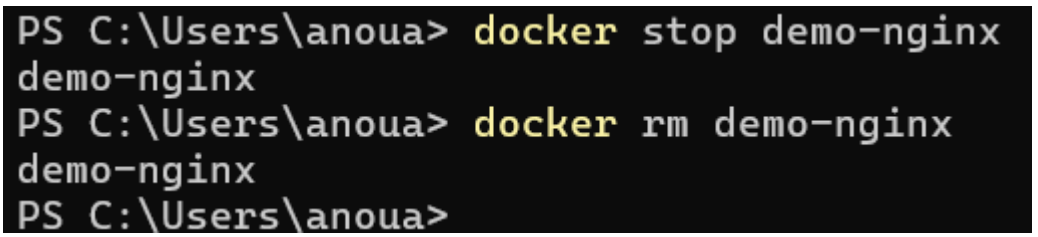
- **Vérifiez que la page par défaut de Nginx s'affiche.**
- **Listez les conteneurs en cours d'exécution :**

```
docker ps
```

```
PS C:\Users\anoua> docker ps
CONTAINER ID   IMAGE     COMMAND                  CREATED              STATUS          PORTS
          NAMES
badcd23f1708   nginx     "/docker-entrypoint.…"   About a minute ago   Up 47 seconds   0.0.0.0:8080->80/tcp, [::]:8080->
80/tcp   demo-nginx
PS C:\Users\anoua>
```

- **Arrêtez puis supprimez le conteneur :**

```
docker stop demo-nginx
docker rm demo-nginx
```

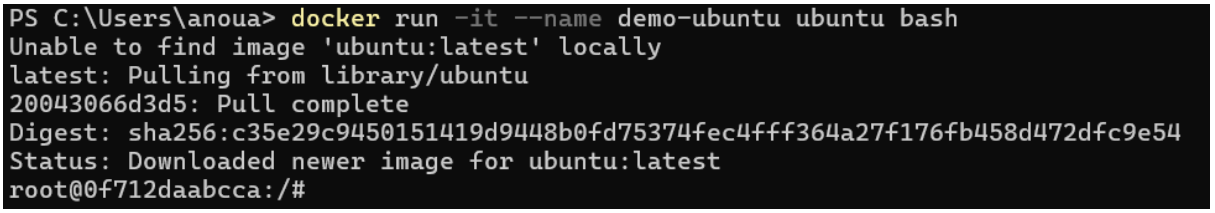


Étape 3 : Ouvrir un shell Linux isolé dans un conteneur

Instructions :

- **Lancez un conteneur Linux interactif (exemple avec `ubuntu`) :**

```
docker run -it --name demo-ubuntu ubuntu bash
```



- **Dans le shell à l'intérieur du conteneur, exécutez quelques commandes :**

```
ls
cat /etc/os-release
pwd
```

```
root@0f712daabcca:/# ls
bin  boot  dev  etc  home  lib  lib64  media  mnt  opt  proc  root  run  sbin  srv  sys  tmp  usr  var
root@0f712daabcca:/# cat /etc/os-release
PRETTY_NAME="Ubuntu 24.04.3 LTS"
NAME="Ubuntu"
VERSION_ID="24.04"
VERSION="24.04.3 LTS (Noble Numbat)"
VERSION_CODENAME=noble
ID=ubuntu
ID_LIKE=debian
HOME_URL="https://www.ubuntu.com/"
SUPPORT_URL="https://help.ubuntu.com/"
BUG_REPORT_URL="https://bugs.launchpad.net/ubuntu/"
PRIVACY_POLICY_URL="https://www.ubuntu.com/legal/terms-and-policies/privacy-policy"
UBUNTU_CODENAME=noble
LOGO=ubuntu-logo
root@0f712daabcca:/# pwd
/
root@0f712daabcca:/#
```

- **Installez un paquet (exemple) :**

```
apt-get update
apt-get install -y curl
```

```
root@0f712daabcca:/# apt-get update
Get:1 http://security.ubuntu.com/ubuntu noble-security InRelease [126 kB]
Get:2 http://archive.ubuntu.com/ubuntu noble InRelease [256 kB]
Get:3 http://security.ubuntu.com/ubuntu noble-security/restricted amd64 Packages [2898 kB]
Get:4 http://archive.ubuntu.com/ubuntu noble-updates InRelease [126 kB]
Get:5 http://archive.ubuntu.com/ubuntu noble-backports InRelease [126 kB]
Get:6 http://archive.ubuntu.com/ubuntu noble/multiverse amd64 Packages [331 kB]
Get:7 http://archive.ubuntu.com/ubuntu noble/universe amd64 Packages [19.3 MB]
Get:8 http://security.ubuntu.com/ubuntu noble-security/multiverse amd64 Packages [33.1 kB]
Get:9 http://security.ubuntu.com/ubuntu noble-security/universe amd64 Packages [1183 kB]
Get:10 http://security.ubuntu.com/ubuntu noble-security/main amd64 Packages [1752 kB]
Get:11 http://archive.ubuntu.com/ubuntu noble/main amd64 Packages [1808 kB]
Get:12 http://archive.ubuntu.com/ubuntu noble/restricted amd64 Packages [117 kB]
Get:13 http://archive.ubuntu.com/ubuntu noble-updates/restricted amd64 Packages [3059 kB]
Get:14 http://archive.ubuntu.com/ubuntu noble-updates/universe amd64 Packages [1950 kB]
Get:15 http://archive.ubuntu.com/ubuntu noble-updates/main amd64 Packages [2130 kB]
Get:16 http://archive.ubuntu.com/ubuntu noble-updates/multiverse amd64 Packages [35.9 kB]
Get:17 http://archive.ubuntu.com/ubuntu noble-backports/universe amd64 Packages [34.6 kB]
Get:18 http://archive.ubuntu.com/ubuntu noble-backports/main amd64 Packages [49.5 kB]
Fetched 35.3 MB in 45s (792 kB/s)
Reading package lists... Done
root@0f712daabcca:/# apt-get install -y curl
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  ca-certificates krb5-locales libbrotli1 libcurl4t64 libgssapi-krb5-2 libk5crypto3 libkeyutils1 libkrb5-3
  libkrb5support0 libldap-common libldap2 libnghttp2-14 libpsl5t64 librtmp1 libsasl2-2 libsasl2-modules
```

- **Quittez le shell :**

```
exit
```

```
root@0f712daabcca:/# exit
exit
PS C:\Users\anoua>
```

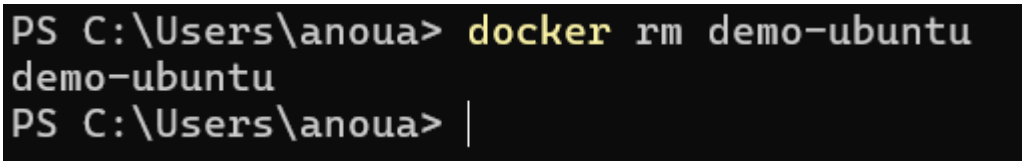
- **Vérifiez que le conteneur existe toujours mais est arrêté :**

```
docker ps -a
```

```
PS C:\Users\anoua> docker ps -a
CONTAINER ID   IMAGE     COMMAND   CREATED         STATUS                     PORTS     NAMES
0f712daabcca   ubuntu    "bash"    4 minutes ago   Exited (0) 29 seconds ago            demo-ubuntu
PS C:\Users\anoua>
```

- **Supprimez ce conteneur :**

```
docker rm demo-ubuntu
```



Étape 4 : Comprendre la structure d'une commande docker run

Instructions :

Notez la structure générale :

```
docker run [options] image [commande] [arguments]
```

Lancez de nouveau Nginx avec des options clairement visibles :

```
PS C:\Users\anoua> docker run -d --name demo-nginx  -p 8080:80 nginx
c8afc13927a2c3274bff3eca68517669275df26425c19ec46887309cac3ebf06
PS C:\Users\anoua>
```

- **Identifiez le rôle de chaque élément :**
- `d` **: détaché (arrière-plan)**
  - `-name demo-nginx` **: nom du conteneur**
  - `p 8080:80` **: port hôte 8080 → port conteneur 80**
  - `nginx` **: image utilisée**

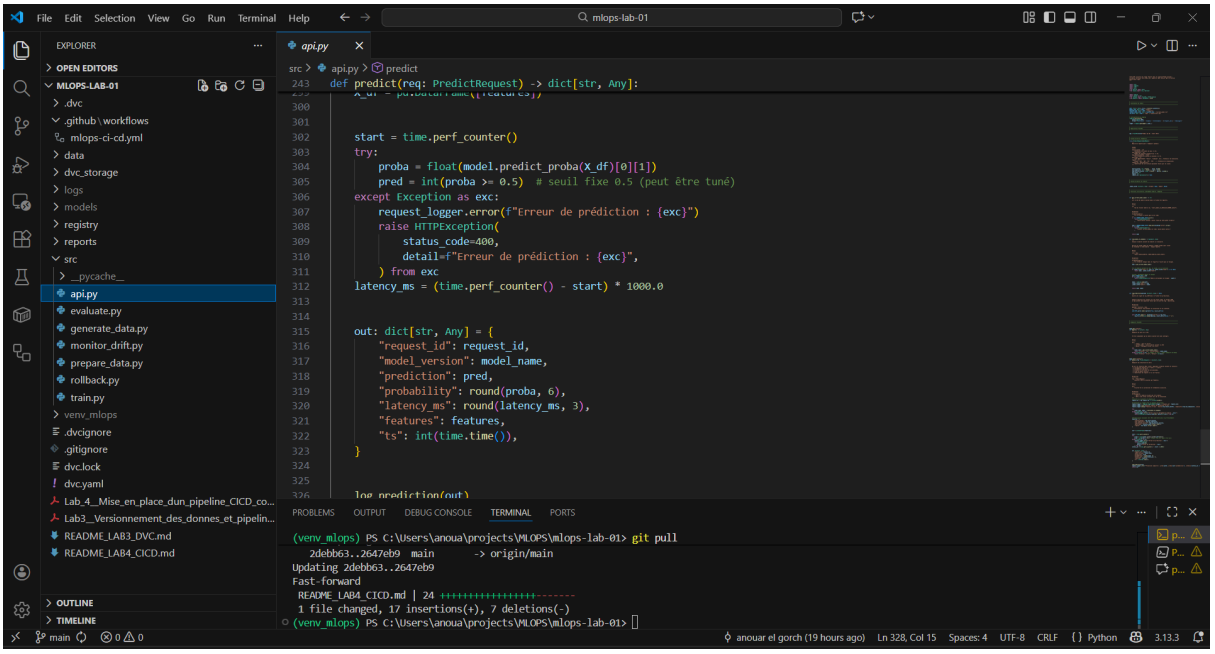
- **Arrêtez et supprimez encore une fois le conteneur :**

```
PS C:\Users\anoua> docker stop demo-nginx
demo-nginx
PS C:\Users\anoua> docker rm demo-nginx
demo-nginx
PS C:\Users\anoua>
```

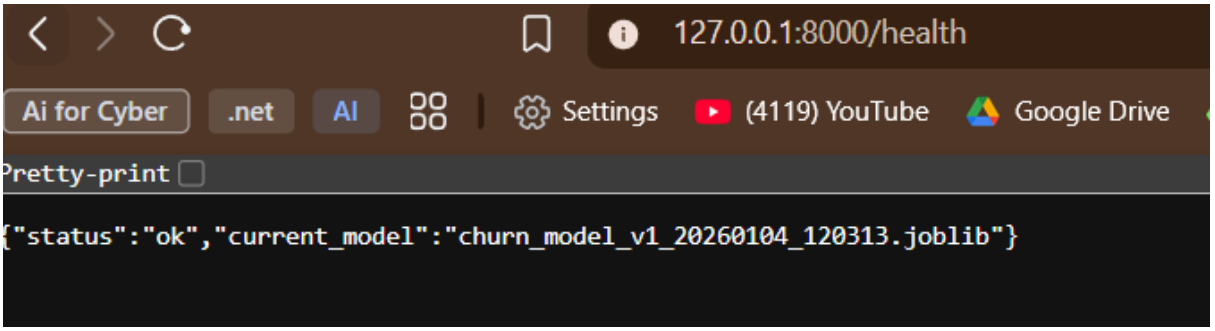
Étape 5 : Conteneuriser l'API churn du projet mlops-lab-01

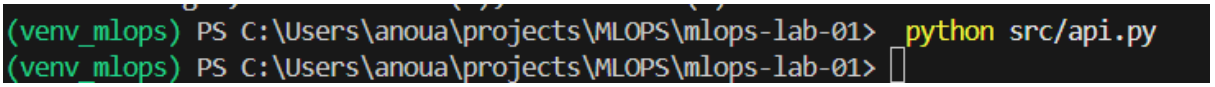
- **Vérifiez que l'arborescence contient au minimum :**

```
mlops-lab-01/
├── data/
├── logs/
├── models/
├── registry/
└── src/
```



- **Vérifiez que l'API fonctionne encore en local (optionnel mais recommandé) :**





Étape 6 : Créer un fichier requirements.txt pour l'image Docker

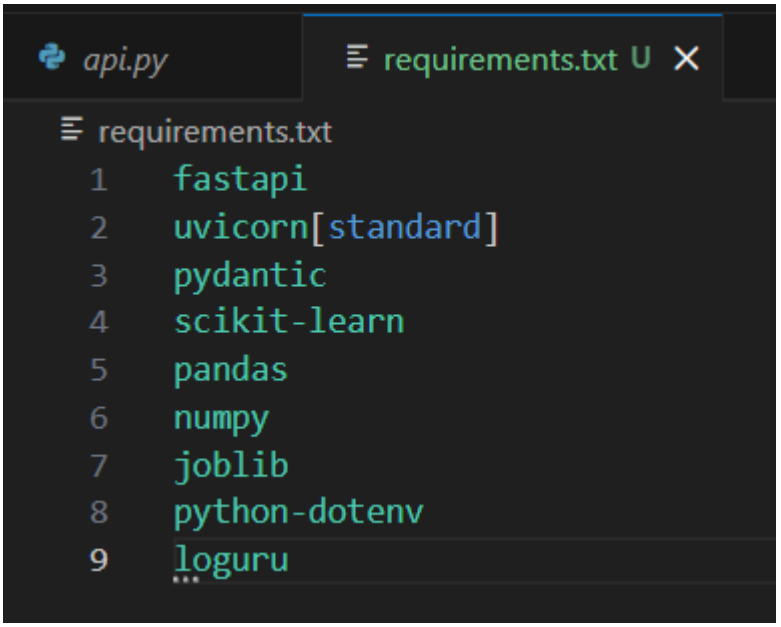
Instructions :

1. Dans le dossier `mlops-lab-01`, créez un fichier `requirements.txt`.

2. Ajoutez le contenu suivant (version minimale) :

```
fastapi
uvicorn[standard]
pydantic
scikit-learn
pandas
numpy
joblib
```

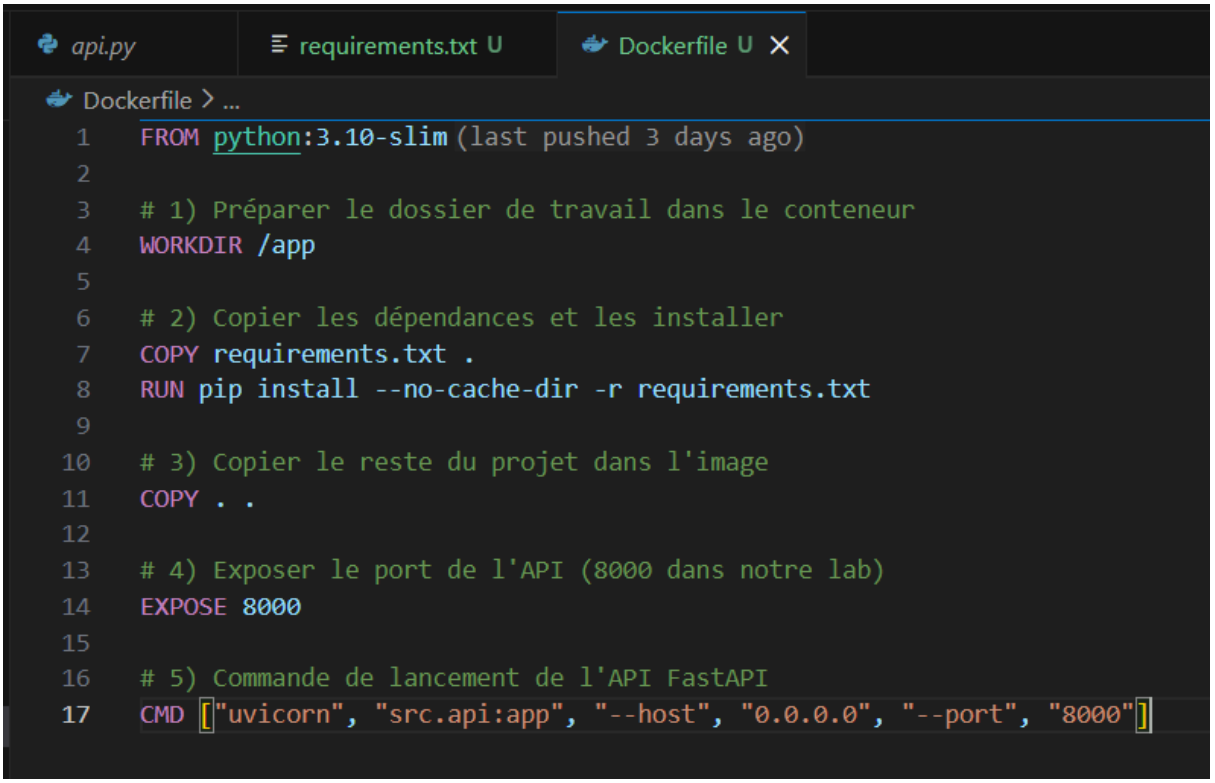
1. Enregistrez le fichier.*Remarque : si tu as des libs supplémentaires dans ton lab (par ex. `python-dotenv`, `loguru`...), ajoute-les ici.*



Étape 7 : Créer un Dockerfile pour l'API churn

Instructions :

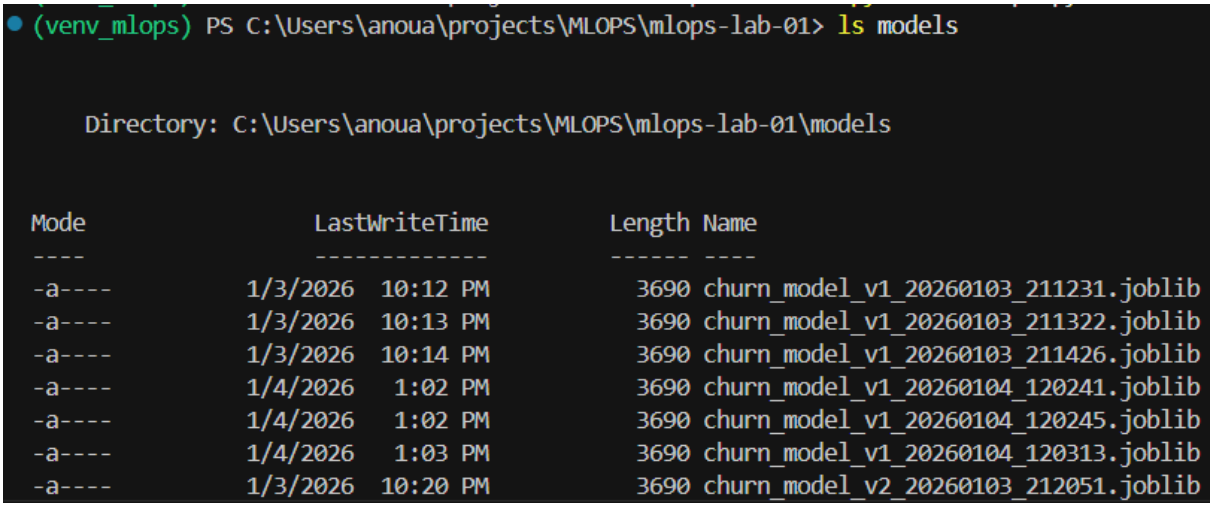
1. 1. **Dans le dossier** `mlopslab-01`**, créez un fichier nommé :**
2. 1. **Collez le contenu suivant :**
3. 1. **Sauvegardez le fichier.**



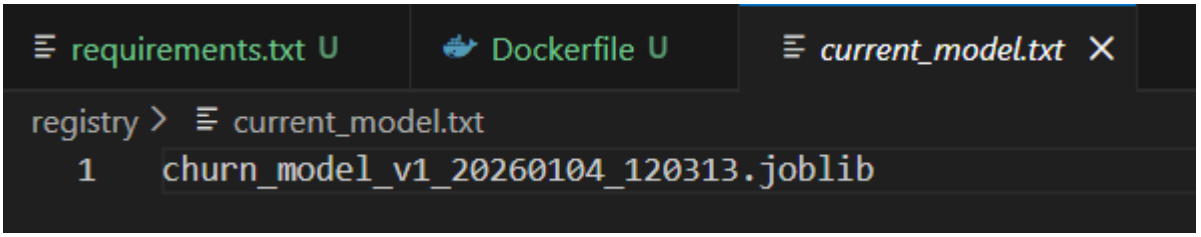
Étape 8 :Préparer un modèle actif avant de construire l'image

Instructions :

1. Assurez-vous qu'un modèle entraîné existe déjà dans `models/` **:**



2. Assurez-vous que `registry/current_model.txt` contient bien le nom d'un modèle (une ligne du type) :



3. **Vérifiez à nouveau le contenu de :**

```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> type registry/current_model.txt
churn_model_v1_20260104_120313.joblib
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

Étape 9 : Construire l'image Docker du projet churn

Instructions :

1. Dans le dossier `mlops-lab-01`, construisez l'image :

```
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker build -t churn-api:latest .
[+] Building 472.1s (10/10) FINISHED                                                    docker:desktop-linux
 => [internal] load build definition from Dockerfile                                                0.0s
 => => transferring dockerfile: 501B                                                                0.0s
 => [internal] load metadata for docker.io/library/python:3.10-slim                                 2.6s
 => [internal] load .dockerignore                                                                   0.0s
 => => transferring context: 2B                                                                     0.0s
 => [internal] load build context                                                                 123.1s
 => => transferring context: 497.75MB                                                             123.0s
 => [1/5] FROM docker.io/library/python:3.10-slim@sha256:7b68a5fa7cf0d20b4cedb1dc9a134fdd394fe27edbc4c2519756c91d21df2313  62.7s
 => => resolve docker.io/library/python:3.10-slim@sha256:7b68a5fa7cf0d20b4cedb1dc9a134fdd394fe27edbc4c2519756c91d21df2313   0.0s
 => => sha256:8715e552fa1374bdde269437d9a1c607c817289c2ebbceb9ed9ab1aa9ca86763 1.29MB / 1.29MB       1.9s
 => => sha256:9c27bc7ba63d1ac690daefc68302197d3ab9a91fc5c0e19f447cd57eda92d87c 13.82MB / 13.82MB    59.5s
 => => sha256:7da4424a113245eb185ea22f2512eceb36f80ca1d0547c64b117f28495d3c3e5 250B / 250B          1.0s
 => => sha256:7b68a5fa7cf0d20b4cedb1dc9a134fdd394fe27edbc4c2519756c91d21df2313 10.37kB / 10.37kB    0.0s
 => => sha256:05be60a538e21a03887c1b1ecbc37e18a204d7abd2ff9d18ec9e95a868d83364 1.75kB / 1.75kB      0.0s
 => => sha256:ce19342c5d49287e941ab558824eb6b0a4244066b18b5a1a9024b6c0f2f818a8 5.48kB / 5.48kB      0.0s
 => => extracting sha256:8715e552fa1374bdde269437d9a1c607c817289c2ebbceb9ed9ab1aa9ca86763           0.5s
 => => extracting sha256:9c27bc7ba63d1ac690daefc68302197d3ab9a91fc5c0e19f447cd57eda92d87c           2.8s
 => => extracting sha256:7da4424a113245eb185ea22f2512eceb36f80ca1d0547c64b117f28495d3c3e5           0.0s
 => [2/5] WORKDIR /app                                                                              0.5s
 => [3/5] COPY requirements.txt .                                                                   0.6s
 => [4/5] RUN pip install --no-cache-dir -r requirements.txt                                      328.0s
 => [5/5] COPY . .                                                                                 11.8s
 => exporting to image                                                                              5.7s
 => => exporting layers                                                                             5.7s
 => => writing image sha256:9308ce70b31960c62ed562088fbad2cc8d03f166d8dbb851e622682e97761527        0.0s
 => => naming to docker.io/library/churn-api:latest                                                 0.0s

 View build details: docker-desktop://dashboard/build/desktop-linux/desktop-linux/b9hzq2zw1l4vzj4axop02wzy3
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

1. Attendez la fin de la construction, vérifiez la présence de l'image :
Vous devez voir une ligne avec `churn-api` dans la colonne `REPOSITORY`.

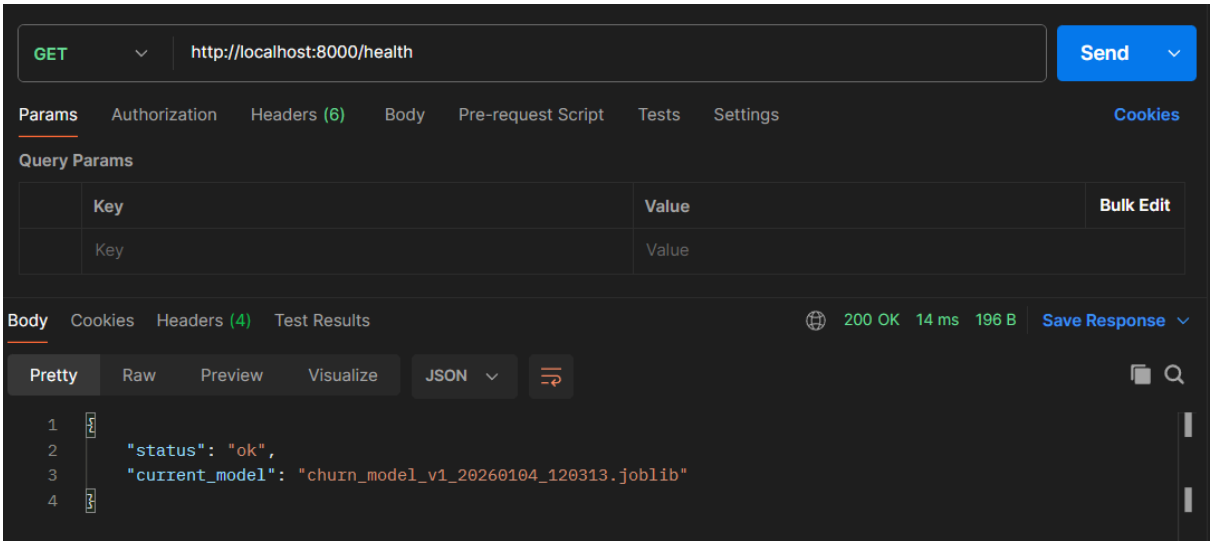
```
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker images

IMAGE                ID             DISK USAGE   CONTENT SIZE   EXTRA
churn-api:latest     9308ce70b319       968MB             0B
nginx:latest         058f4935d1cb       152MB             0B
ubuntu:latest        c3a134f2ace4      78.1MB             0B
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

Étape 10 : Lancer l'API churn dans un conteneur

Instructions :
1. Lancez un conteneur basé sur l'image et Vérifiez que le conteneur est en cours d'exécution :

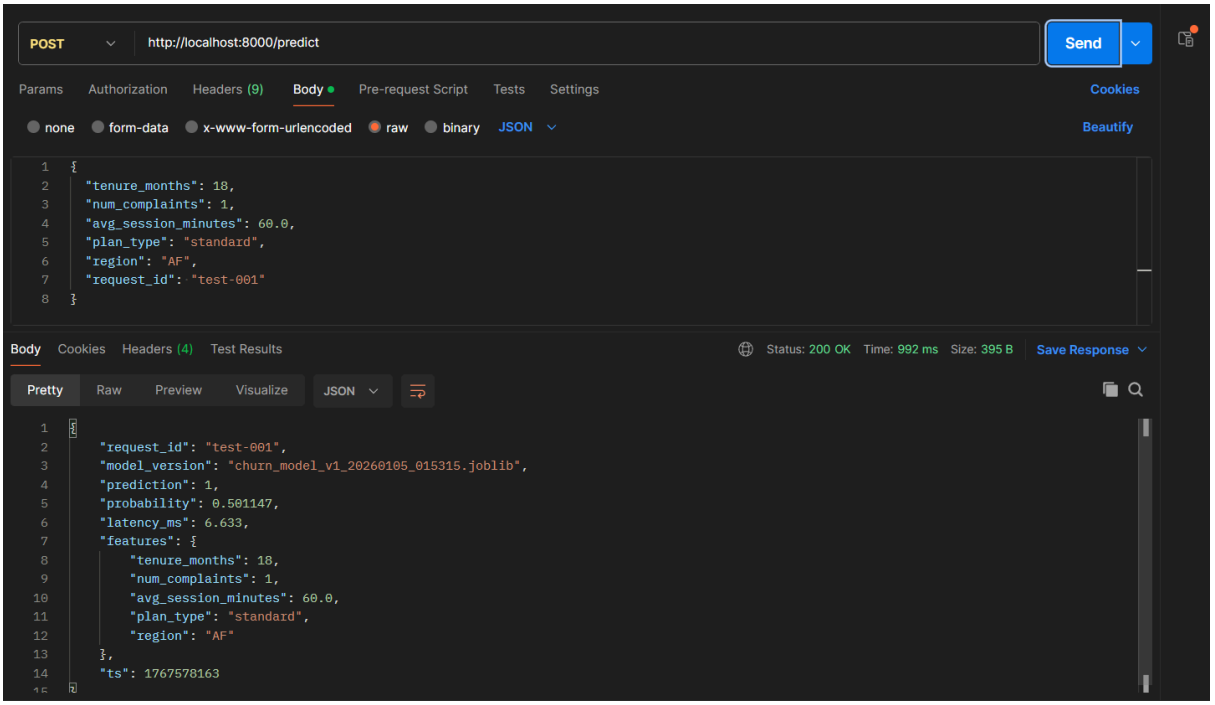
```
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker run -d --name churn-api-demo -p 8000:8000 churn-api:latest
2f5d9bf857e67eab3f56deee4aa9d4ae5e06c3fb6500555c0969146d4880ca3f
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker ps
CONTAINER ID   IMAGE            COMMAND                  CREATED          STATUS         PORTS                                                NAMES
2f5d9bf857e6   churn-api:latest   "uvicorn src.api:app…"   55 seconds ago   Up 9 seconds   0.0.0.0:8000->8000/tcp, [::]:8000->8000/tcp   churn-api-demo
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

2. Testez le endpoint `/health` avec un client HTTP (Postman, curl, ou navigateur si tu as un GET simplifié) :Exemple avec `curl` :




```
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> curl http://localhost:8000/health

Security Warning: Script Execution Risk
Invoke-WebRequest parses the content of the web page. Script code in the web page might be run when the page is parsed.
      RECOMMENDED ACTION:
      Use the -UseBasicParsing switch to avoid script code execution.

      Do you want to continue?

[Y] Yes  [A] Yes to All  [N] No  [L] No to All  [S] Suspend  [?] Help (default is "N"): y


StatusCode        : 200
StatusDescription : OK
Content           : {"status":"ok","current_model":"churn_model_v1_20260104_120313.joblib"}
RawContent        : HTTP/1.1 200 OK
                    Content-Length: 71
                    Content-Type: application/json
                    Date: Sun, 04 Jan 2026 22:46:32 GMT
                    Server: uvicorn

                    {"status":"ok","current_model":"churn_model_v1_20260104_120313.joblib"}
Forms             : {}
Headers           : {[Content-Length, 71], [Content-Type, application/json], [Date, Sun, 04 Jan 2026 22:46:32 GMT], [Server, uvicorn]}
Images            : {}
InputFields       : {}
Links             : {}
ParsedHtml        : mshtml.HTMLDocumentClass
RawContentLength  : 71
```

3. Testez une requête POST `/predict` en envoyant un JSON conforme au lab (tenure, complaints, etc.).



Probleme de version sicket learn 1.8 non adapter a python 3.10 donc cahnger version python dans dockerfile vers 3.11

Étape 11 : Vérifier les logs générés à l'intérieur du conteneur

Instructions :

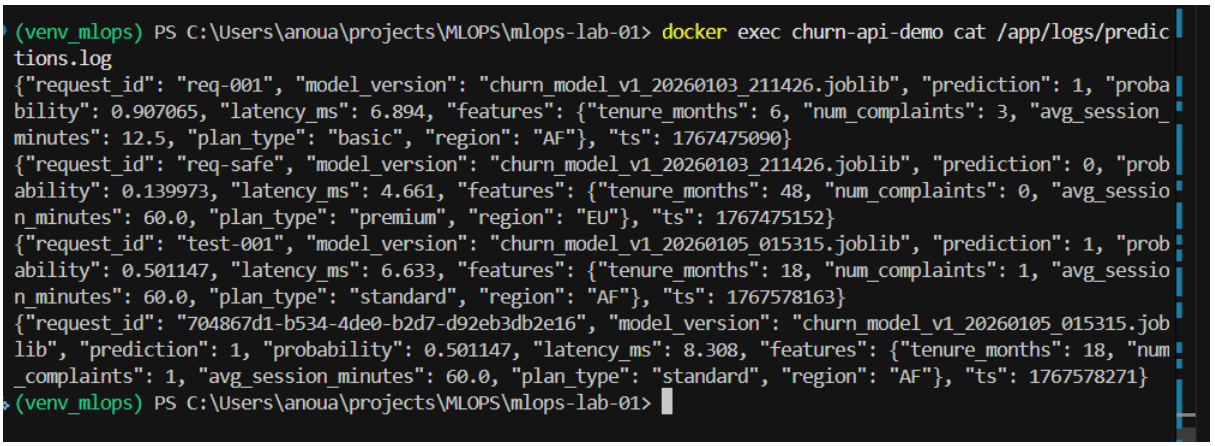
1. Listez les fichiers dans le conteneur :

```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker exec -it churn-api-demo ls
Dockerfile                                                        dvc.yaml
Lab3__Versionnement_des_donnes_et_pipelines_ML_avec_DVC.pdf       logs
Lab_4__Mise_en_place_dun_pipeline_CICD_complet_pour_un_projet_Machine_Learning.pdf  models
README_LAB3_DVC.md                                                registry
README_LAB4_CICD.md                                               reports
data                                                              requirements.txt
dvc.lock                                                          src
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

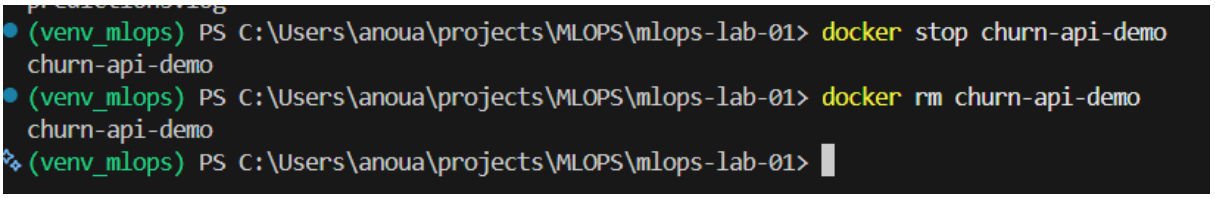
2. Vérifiez que l'application écrit des logs à l'exécution :

```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker exec -it churn-api-demo ls logs
predictions.log
```

3. Affichez quelques lignes du fichier de logs des prédictions :

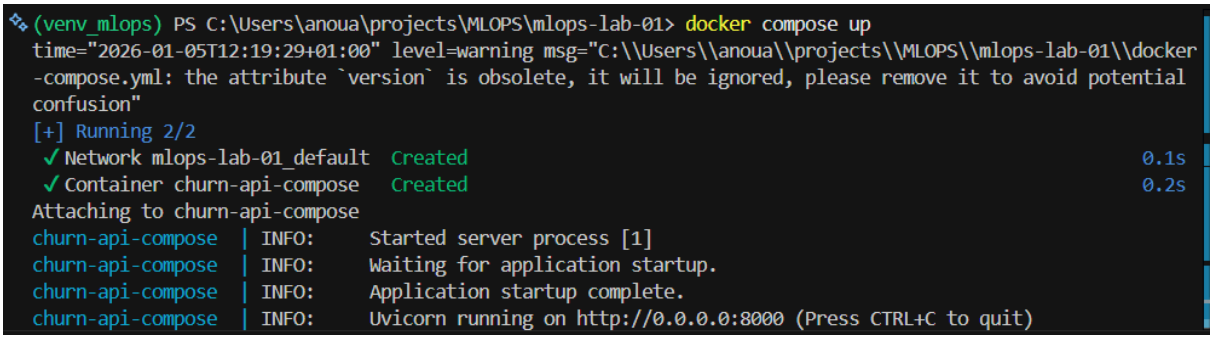


4. Arrêtez et supprimez le conteneur une fois les tests terminés :



Étape 12 : Orchestration locale avec Docker Compose

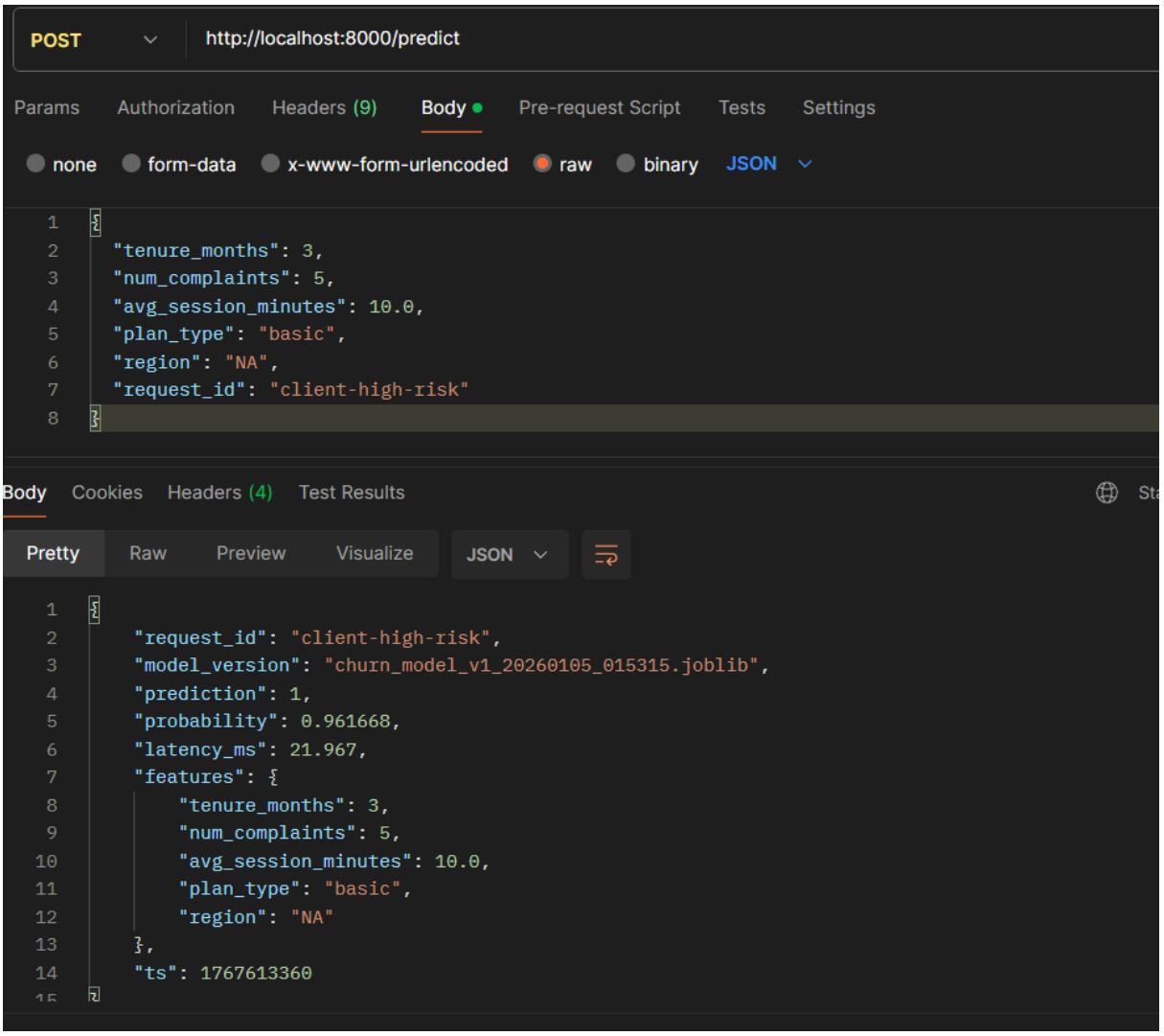
Étape 13 : Démarrer l'API via Docker Compose



Test get

```
PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> curl http://localhost:8000/health
StatusCode        : 200
StatusDescription : OK
Content           : {"status":"ok","current_model":"churn_model_v1_20260105_015315.joblib"}
RawContent        : HTTP/1.1 200 OK
                    Content-Length: 71
                    Content-Type: application/json
                    Date: Mon, 05 Jan 2026 11:19:41 GMT
                    Server: uvicorn

                    {"status":"ok","current_model":"churn_model_v1_20260105_015315.joblib"}
Forms             : {}
Headers           : {[Content-Length, 71], [Content-Type, application/json], [Date, Mon, 05 Jan 2026
                    11:19:41 GMT], [Server, uvicorn]}
Images            : {}
InputFields       : {}
Links             : {}
ParsedHtml        : mshtml.HTMLDocumentClass
RawContentLength  : 71
```

test post



stoping

```
churn-api-compose  | INFO:     172.18.0.1:56392 - "GET /health HTTP/1.1" 200 OK
churn-api-compose  | 2026-01-05 11:42:38,851 - src.api - INFO - [client-high-risk] - Nouvelle requête de pr
édiction reçue
churn-api-compose  | 2026-01-05 11:42:40,940 - src.api - INFO - [client-high-risk] - Prédiction complétée :
 pred=1, proba=0.961668, latency=21.967ms
churn-api-compose  | INFO:     172.18.0.1:54292 - "POST /predict HTTP/1.1" 200 OK
Gracefully Stopping... press Ctrl+C again to force
 Container churn-api-compose  Stopping
```

Étape 14 : lancer les services en arrière-plan et observer les logs

Instructions :

Lancez les services en mode détaché

```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker compose up -d
time="2026-01-05T12:44:36+01:00" level=warning msg="C:\\Users\\anoua\\projects\\MLOPS\\mlops-lab-01\\docker
-compose.yml: the attribute `version` is obsolete, it will be ignored, please remove it to avoid potential
confusion"
[+] Running 1/1
 ✓ Container churn-api-compose  Started                                                          0.7s
```

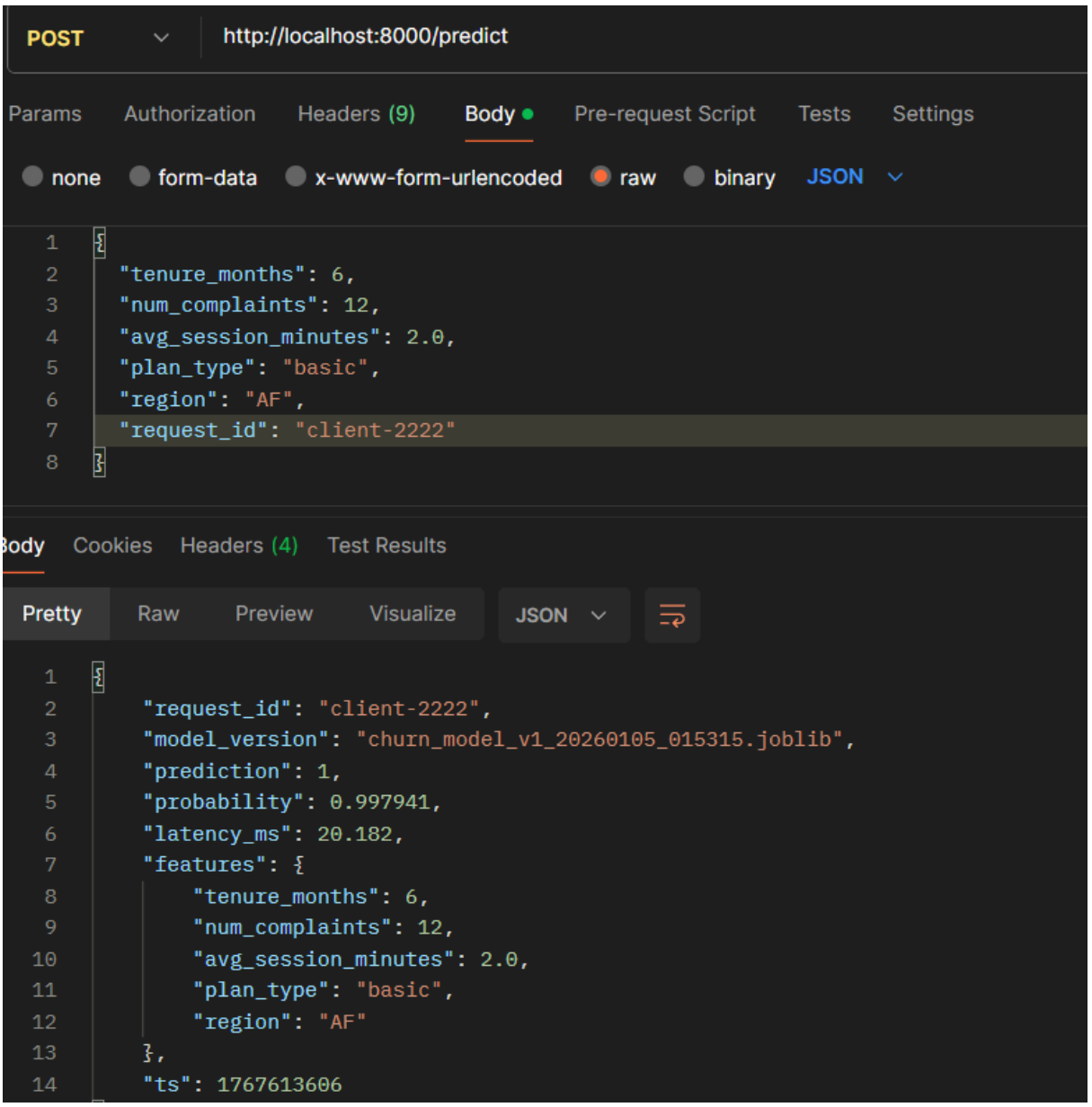
Vérifiez les conteneurs en cours d'exécution :

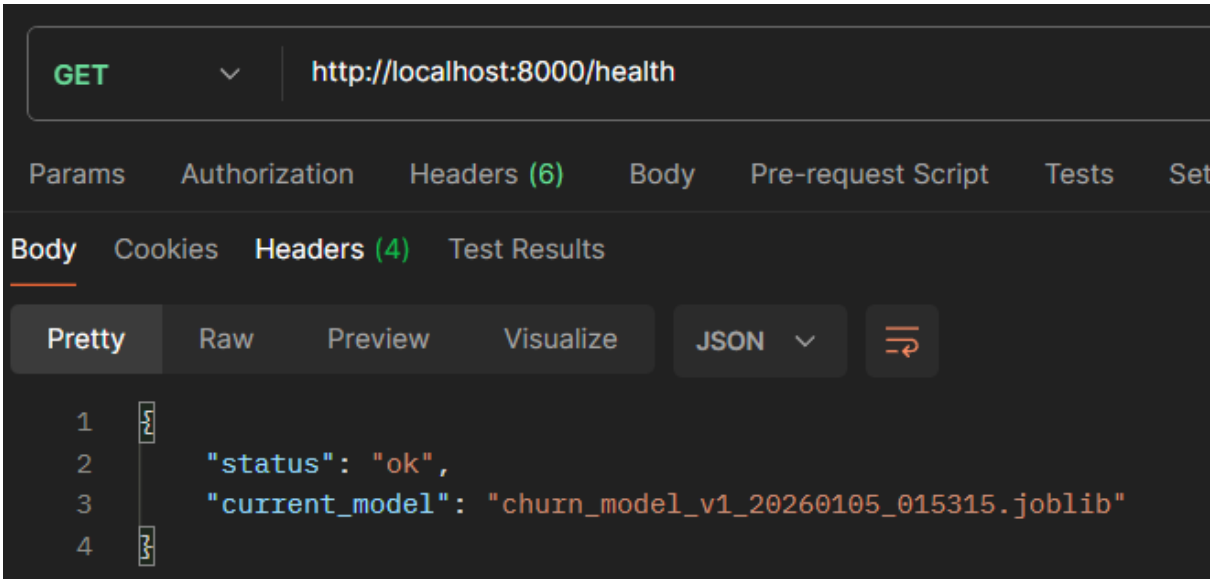
```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker ps
CONTAINER ID   IMAGE             COMMAND                  CREATED          STATUS         PORTS
                          NAMES
e9ef4c344838   churn-api:latest   "uvicorn src.api:app…"   27 minutes ago   Up 2 minutes   0.0.0.0:8000->80
00/tcp, [::]:8000->8000/tcp   churn-api-compose
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

Affichez les logs du service :

```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker compose logs -f churn-api
-compose.yml: the attribute `version` is obsolete, it will be ignored, please remove it to avoid potential
confusion"
churn-api-compose  | INFO:     Started server process [1]
churn-api-compose  | INFO:     Waiting for application startup.
churn-api-compose  | INFO:     Application startup complete.
churn-api-compose  | INFO:     Uvicorn running on http://0.0.0.0:8000 (Press CTRL+C to quit)
churn-api-compose  | INFO:     172.18.0.1:56392 - "GET /health HTTP/1.1" 200 OK
churn-api-compose  | 2026-01-05 11:42:38,851 - src.api - INFO - [client-high-risk] - Nouvelle requête de pr
édiction reçue
churn-api-compose  | 2026-01-05 11:42:40,940 - src.api - INFO - [client-high-risk] - Prédiction complétée :
 pred=1, proba=0.961668, latency=21.967ms
churn-api-compose  | INFO:     172.18.0.1:54292 - "POST /predict HTTP/1.1" 200 OK
churn-api-compose  | INFO:     Shutting down
churn-api-compose  | INFO:     Waiting for application shutdown.
churn-api-compose  | INFO:     Application shutdown complete.
churn-api-compose  | INFO:     Finished server process [1]
churn-api-compose  | INFO:     Started server process [1]
churn-api-compose  | INFO:     Waiting for application startup.
churn-api-compose  | INFO:     Application startup complete.
churn-api-compose  | INFO:     Uvicorn running on http://0.0.0.0:8000 (Press CTRL+C to quit)
```

Testez `/health` et `/predict` pendant que les logs défilent.Arrêtez les services :





Arrêtez les services :

```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> docker compose down
time="2026-01-05T12:48:35+01:00" level=warning msg="C:\\Users\\anoua\\projects\\MLOPS\\mlops-lab-01\\docker
-compose.yml: the attribute `version` is obsolete, it will be ignored, please remove it to avoid potential
confusion"
[+] Running 2/2
 ✓ Container churn-api-compose   Removed                                                    1.1s
 ✓ Network mlops-lab-01_default  Removed                                                    0.4s
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

Étape 15 : lier Docker Compose au reste du cours (Git + DVC)

Assurez-vous que :

- **le projet** `mlops-lab-01` **est versionné avec Git (lab Git),**
- **les données et modèles lourds sont suivis par DVC (lab DVC),**
- **l'API est conteneurisée via Docker (lab Docker).**

```
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> git add .
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01> git commit -m "feat: ajout conteneurisation Doc
ker de l'API churn"
[main 4ef1778] feat: ajout conteneurisation Docker de l'API churn
 7 files changed, 690 insertions(+), 151 deletions(-)
 create mode 100644 Dockerfile
 create mode 100644 docker-compose.yml
 create mode 100644 requirements.txt
(venv_mlops) PS C:\Users\anoua\projects\MLOPS\mlops-lab-01>
```

Notez dans ton cours que l’on a maintenant :

- **MLOps local : pipeline + API + monitoring**
- **Git : versionnement du code et de la structure**
- **DVC : versionnement des données / modèles (lab suivant)**
- **Docker / Compose : déploiement reproductible de l’API**