

-----Mandatory Information to
fill-----

Group ID:

Group ID: Group 278

Group Members Name with Student ID:

1. Rahul Prashar - 2024AB05058 - 100%
2. Rahul Agarwal - 2024AA05676 - 100%
3. Rahul Sinha - 2024AA05036 - 100%
4. Raghavendra Sathakarni A S - 2024AB05118 - 100%

Scenario

A pharmaceutical company is conducting clinical trials to evaluate the effectiveness of three antiretroviral drug combinations for treating HIV-positive patients. Due to the ethical and cost constraints of clinical trials, it is critical to identify the most effective treatment regimen using the least number of patients. Each treatment (or "arm") can lead to different outcomes depending on patient responses. The effectiveness of each treatment is evaluated using a reward function derived from the improvement in patients' immune system markers and survival status.

Problem Definition

You are provided with a clinical dataset where each record corresponds to a patient, including the treatment they received and the resulting health outcomes. Your task is to simulate a clinical trial environment using various MAB strategies to sequentially recommend treatments and observe outcomes. The objective is to maximize the overall success rate across trials by identifying and favouring the most effective treatment.

Dataset

You will be provided a dataset containing the following fields:

- **Age (age)**: Patient's age in years at baseline.
- **Weight (wtkg)**: Continuous feature representing weight in kilograms at baseline.
- **Gender (gender)**: Binary indicator of gender (0 = Female, 1 = Male).
- **CD4 Counts (cd40, cd420)**: Integer values representing CD4 counts at baseline and 20+/-5 weeks.

- **Treatment Indicator (trt):** Categorical feature indicating the type of treatment received (0 = ZDV only, 1 = ZDV + ddl, 2 = ZDV + Zai, 3 = ddl only).
- **Censoring Indicator (label):** Binary indicator (1 = failure, 0 = censoring) denoting patient status.

Link for accessing dataset:

https://drive.google.com/file/d/1LYflrJ4VEEGeyOsSt_qoLk7FaAv5Jfx-/view?usp=sharing

Environment Setup

Arms (Actions): The treatment types (trt)

- Arm 0: ZDV only
- Arm 1: ZDV + ddl
- Arm 2: ZDV + Zai
- Arm 3: ddl only

Reward Function:

Reward r is defined as:

```
r = 1, if (label == 0) and (cd420 > cd40)
```

```
r = 0, otherwise
```

This reward represents a successful treatment outcome as an increase in CD4 count and survival.

Assumptions:

Number of Iterations: Run the simulation for at least 1000 trials (iterations), with the option to extend the number of trials depending on the convergence behavior or observed reward trends. In each iteration, simulate one patient trial using one of the bandit policies.

Requirements and Deliverables:

Implement the Multi-Arm Bandit Problem for the given above scenario for all the below mentioned policy methods.

Initialize constants

```
In [35]: # Constants
NUM_ITERATIONS = 1000 # Number of patient-trial simulations per policy
```

Load Dataset (0.5M)

```
In [36]: # Imports
import pandas as pd # For data manipulation and CSV loading
import numpy as np  # For numerical operations and array handling
import random       # For random arm selection
import math          # For mathematical functions
import matplotlib.pyplot as plt # For plotting results

# Code for Dataset loading and print dataset statistics
data = pd.read_csv('Clinical_Trial.csv')
print(f"Loaded dataset with {data.shape[0]} records and {data.shape[1]} columns")
print(data.head())
```

Loaded dataset with 2139 records and 7 columns.

	age	wtkg	gender	cd40	cd420	trt	label
0	48	89.8128	0	422	477	2	0
1	61	49.4424	0	162	218	3	1
2	45	88.4520	1	326	274	3	0
3	47	85.2768	1	287	394	3	0
4	43	66.6792	1	504	353	0	0

Designing Clinical Trial Environment (0.5M)

Bandit environment with treatment arms and compute the binary reward using CD4 count improvement and patient survival

```
In [37]: # Code for environment setup along with reward function
class ClinicalTrialEnvironment:
    def __init__(self, data):
        self.data = data.copy() # Store a copy of
        self.arms = sorted(self.data['trt'].unique()) # List of unique

    def compute_reward(self, arm):
        # Filter dataset for patients who received the chosen arm
        subset = self.data[self.data['trt'] == arm]

        # Randomly sample one patient record from this arm
        record = subset.sample(n=1).iloc[0]

        # Determine success: label==0 (not failure) AND cd420 > cd40 (CD4 count improvement)
        reward = int((record['label'] == 0) and (record['cd420'] > record['cd40']))

        # Return the reward
        return reward
```

Random policy for treatment selection (0.5M)

- Implementing the Random policy for treatment selection.
- Running the simulation for 1000 iterations and printing the treatment selected and reward at each iteration

```
In [38]: # Run the environment with an agent that is guided by a random policy
class RandomPolicy:
    """
    Policy that selects each treatment arm uniformly at random.
```

```

    """
def select_random_arm(self, arms):
    """
    Choose an arm randomly from the available arms.
    Args:
        arms (list): List of arm indices.
    Returns:
        int: Selected arm index.
    """
    return random.choice(arms) # Uniform random selection

# Initialize environment and random policy
clinical_trial_env = ClinicalTrialEnvironment(data)
random_policy = RandomPolicy()
random_rewards = [] # To store rewards for plotting later

# Run NUM_ITERATIONS of random selections
for i in range(NUM_ITERATIONS):
    selected_arm = random_policy.select_random_arm(clinical_trial_env.arm
    reward = clinical_trial_env.compute_reward(selected_arm)
    random_rewards.append(reward)
    print(f"Iteration {i+1}: Treatment Selected {selected_arm}, Reward {r
```

Iteration 1: Treatment Selected 0, Reward 0
Iteration 2: Treatment Selected 0, Reward 1
Iteration 3: Treatment Selected 2, Reward 0
Iteration 4: Treatment Selected 1, Reward 0
Iteration 5: Treatment Selected 0, Reward 0
Iteration 6: Treatment Selected 1, Reward 1
Iteration 7: Treatment Selected 1, Reward 1
Iteration 8: Treatment Selected 0, Reward 1
Iteration 9: Treatment Selected 3, Reward 1
Iteration 10: Treatment Selected 1, Reward 1
Iteration 11: Treatment Selected 3, Reward 1
Iteration 12: Treatment Selected 2, Reward 0
Iteration 13: Treatment Selected 3, Reward 0
Iteration 14: Treatment Selected 1, Reward 1
Iteration 15: Treatment Selected 0, Reward 1
Iteration 16: Treatment Selected 0, Reward 0
Iteration 17: Treatment Selected 3, Reward 1
Iteration 18: Treatment Selected 1, Reward 1
Iteration 19: Treatment Selected 1, Reward 1
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Iteration 21: Treatment Selected 3, Reward 1
Iteration 22: Treatment Selected 0, Reward 1
Iteration 23: Treatment Selected 2, Reward 0
Iteration 24: Treatment Selected 1, Reward 0
Iteration 25: Treatment Selected 3, Reward 0
Iteration 26: Treatment Selected 3, Reward 1
Iteration 27: Treatment Selected 1, Reward 1
Iteration 28: Treatment Selected 0, Reward 1
Iteration 29: Treatment Selected 3, Reward 1
Iteration 30: Treatment Selected 2, Reward 1
Iteration 31: Treatment Selected 1, Reward 0
Iteration 32: Treatment Selected 0, Reward 0
Iteration 33: Treatment Selected 1, Reward 0
Iteration 34: Treatment Selected 2, Reward 1
Iteration 35: Treatment Selected 2, Reward 1
Iteration 36: Treatment Selected 2, Reward 0
Iteration 37: Treatment Selected 2, Reward 1
Iteration 38: Treatment Selected 3, Reward 0
Iteration 39: Treatment Selected 2, Reward 1
Iteration 40: Treatment Selected 1, Reward 0
Iteration 41: Treatment Selected 2, Reward 0
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Iteration 43: Treatment Selected 1, Reward 1
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Iteration 503: Treatment Selected 1, Reward 1
Iteration 504: Treatment Selected 3, Reward 0
Iteration 505: Treatment Selected 1, Reward 0
Iteration 506: Treatment Selected 3, Reward 0
Iteration 507: Treatment Selected 2, Reward 0
Iteration 508: Treatment Selected 1, Reward 0
Iteration 509: Treatment Selected 0, Reward 0
Iteration 510: Treatment Selected 1, Reward 1
Iteration 511: Treatment Selected 0, Reward 0
Iteration 512: Treatment Selected 2, Reward 0
Iteration 513: Treatment Selected 1, Reward 1
Iteration 514: Treatment Selected 2, Reward 0
Iteration 515: Treatment Selected 3, Reward 0
Iteration 516: Treatment Selected 2, Reward 0
Iteration 517: Treatment Selected 1, Reward 1
Iteration 518: Treatment Selected 2, Reward 1
Iteration 519: Treatment Selected 0, Reward 0
Iteration 520: Treatment Selected 3, Reward 1
Iteration 521: Treatment Selected 2, Reward 1
Iteration 522: Treatment Selected 2, Reward 0
Iteration 523: Treatment Selected 2, Reward 0
Iteration 524: Treatment Selected 1, Reward 1
Iteration 525: Treatment Selected 1, Reward 1
Iteration 526: Treatment Selected 3, Reward 1
Iteration 527: Treatment Selected 1, Reward 0
Iteration 528: Treatment Selected 3, Reward 1
Iteration 529: Treatment Selected 2, Reward 0
Iteration 530: Treatment Selected 2, Reward 0
Iteration 531: Treatment Selected 2, Reward 1
Iteration 532: Treatment Selected 1, Reward 0
Iteration 533: Treatment Selected 1, Reward 0
Iteration 534: Treatment Selected 0, Reward 0
Iteration 535: Treatment Selected 0, Reward 0
Iteration 536: Treatment Selected 3, Reward 0
Iteration 537: Treatment Selected 3, Reward 1
Iteration 538: Treatment Selected 2, Reward 1
Iteration 539: Treatment Selected 1, Reward 0
Iteration 540: Treatment Selected 2, Reward 0

Iteration 541: Treatment Selected 1, Reward 1
Iteration 542: Treatment Selected 2, Reward 1
Iteration 543: Treatment Selected 2, Reward 1
Iteration 544: Treatment Selected 0, Reward 0
Iteration 545: Treatment Selected 2, Reward 0
Iteration 546: Treatment Selected 2, Reward 0
Iteration 547: Treatment Selected 2, Reward 0
Iteration 548: Treatment Selected 1, Reward 0
Iteration 549: Treatment Selected 3, Reward 0
Iteration 550: Treatment Selected 3, Reward 0
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Iteration 552: Treatment Selected 0, Reward 0
Iteration 553: Treatment Selected 2, Reward 1
Iteration 554: Treatment Selected 1, Reward 0
Iteration 555: Treatment Selected 3, Reward 1
Iteration 556: Treatment Selected 0, Reward 1
Iteration 557: Treatment Selected 3, Reward 1
Iteration 558: Treatment Selected 2, Reward 0
Iteration 559: Treatment Selected 0, Reward 1
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Iteration 562: Treatment Selected 3, Reward 0
Iteration 563: Treatment Selected 0, Reward 0
Iteration 564: Treatment Selected 2, Reward 1
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Iteration 567: Treatment Selected 2, Reward 1
Iteration 568: Treatment Selected 1, Reward 0
Iteration 569: Treatment Selected 1, Reward 1
Iteration 570: Treatment Selected 3, Reward 1
Iteration 571: Treatment Selected 1, Reward 0
Iteration 572: Treatment Selected 2, Reward 0
Iteration 573: Treatment Selected 0, Reward 0
Iteration 574: Treatment Selected 2, Reward 1
Iteration 575: Treatment Selected 3, Reward 0
Iteration 576: Treatment Selected 1, Reward 1
Iteration 577: Treatment Selected 2, Reward 0
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Iteration 584: Treatment Selected 2, Reward 1
Iteration 585: Treatment Selected 1, Reward 0
Iteration 586: Treatment Selected 2, Reward 1
Iteration 587: Treatment Selected 2, Reward 0
Iteration 588: Treatment Selected 2, Reward 1
Iteration 589: Treatment Selected 3, Reward 1
Iteration 590: Treatment Selected 2, Reward 0
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Iteration 598: Treatment Selected 3, Reward 0
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Iteration 600: Treatment Selected 3, Reward 0

Iteration 601: Treatment Selected 1, Reward 1
Iteration 602: Treatment Selected 0, Reward 0
Iteration 603: Treatment Selected 1, Reward 1
Iteration 604: Treatment Selected 3, Reward 1
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Iteration 606: Treatment Selected 3, Reward 0
Iteration 607: Treatment Selected 1, Reward 1
Iteration 608: Treatment Selected 1, Reward 1
Iteration 609: Treatment Selected 2, Reward 0
Iteration 610: Treatment Selected 3, Reward 0
Iteration 611: Treatment Selected 1, Reward 0
Iteration 612: Treatment Selected 3, Reward 0
Iteration 613: Treatment Selected 0, Reward 0
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Iteration 618: Treatment Selected 2, Reward 1
Iteration 619: Treatment Selected 3, Reward 0
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Iteration 621: Treatment Selected 2, Reward 0
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Iteration 628: Treatment Selected 1, Reward 0
Iteration 629: Treatment Selected 3, Reward 1
Iteration 630: Treatment Selected 2, Reward 1
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Iteration 632: Treatment Selected 2, Reward 0
Iteration 633: Treatment Selected 1, Reward 1
Iteration 634: Treatment Selected 1, Reward 0
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Iteration 636: Treatment Selected 2, Reward 0
Iteration 637: Treatment Selected 2, Reward 0
Iteration 638: Treatment Selected 3, Reward 0
Iteration 639: Treatment Selected 2, Reward 1
Iteration 640: Treatment Selected 1, Reward 1
Iteration 641: Treatment Selected 2, Reward 1
Iteration 642: Treatment Selected 0, Reward 1
Iteration 643: Treatment Selected 3, Reward 1
Iteration 644: Treatment Selected 2, Reward 0
Iteration 645: Treatment Selected 1, Reward 1
Iteration 646: Treatment Selected 2, Reward 1
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Iteration 648: Treatment Selected 1, Reward 1
Iteration 649: Treatment Selected 3, Reward 0
Iteration 650: Treatment Selected 3, Reward 1
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Iteration 652: Treatment Selected 0, Reward 0
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Iteration 654: Treatment Selected 1, Reward 1
Iteration 655: Treatment Selected 0, Reward 1
Iteration 656: Treatment Selected 3, Reward 0
Iteration 657: Treatment Selected 0, Reward 1
Iteration 658: Treatment Selected 3, Reward 0
Iteration 659: Treatment Selected 0, Reward 0
Iteration 660: Treatment Selected 1, Reward 0

Iteration 661: Treatment Selected 1, Reward 1
Iteration 662: Treatment Selected 2, Reward 0
Iteration 663: Treatment Selected 3, Reward 0
Iteration 664: Treatment Selected 0, Reward 0
Iteration 665: Treatment Selected 1, Reward 1
Iteration 666: Treatment Selected 3, Reward 1
Iteration 667: Treatment Selected 1, Reward 0
Iteration 668: Treatment Selected 1, Reward 1
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Iteration 675: Treatment Selected 3, Reward 0
Iteration 676: Treatment Selected 0, Reward 0
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Iteration 678: Treatment Selected 2, Reward 1
Iteration 679: Treatment Selected 0, Reward 0
Iteration 680: Treatment Selected 2, Reward 1
Iteration 681: Treatment Selected 0, Reward 0
Iteration 682: Treatment Selected 3, Reward 0
Iteration 683: Treatment Selected 3, Reward 1
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Iteration 693: Treatment Selected 1, Reward 1
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Iteration 699: Treatment Selected 1, Reward 0
Iteration 700: Treatment Selected 3, Reward 1
Iteration 701: Treatment Selected 2, Reward 0
Iteration 702: Treatment Selected 3, Reward 0
Iteration 703: Treatment Selected 1, Reward 1
Iteration 704: Treatment Selected 3, Reward 0
Iteration 705: Treatment Selected 3, Reward 1
Iteration 706: Treatment Selected 0, Reward 0
Iteration 707: Treatment Selected 1, Reward 0
Iteration 708: Treatment Selected 1, Reward 0
Iteration 709: Treatment Selected 3, Reward 0
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Iteration 718: Treatment Selected 2, Reward 0
Iteration 719: Treatment Selected 2, Reward 1
Iteration 720: Treatment Selected 2, Reward 0

Iteration 721: Treatment Selected 2, Reward 1
Iteration 722: Treatment Selected 2, Reward 1
Iteration 723: Treatment Selected 3, Reward 1
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Iteration 729: Treatment Selected 2, Reward 1
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Iteration 742: Treatment Selected 3, Reward 0
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Iteration 746: Treatment Selected 2, Reward 0
Iteration 747: Treatment Selected 1, Reward 0
Iteration 748: Treatment Selected 1, Reward 0
Iteration 749: Treatment Selected 3, Reward 0
Iteration 750: Treatment Selected 1, Reward 0
Iteration 751: Treatment Selected 3, Reward 0
Iteration 752: Treatment Selected 3, Reward 0
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Iteration 754: Treatment Selected 3, Reward 1
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Iteration 759: Treatment Selected 2, Reward 0
Iteration 760: Treatment Selected 1, Reward 1
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Iteration 762: Treatment Selected 0, Reward 0
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Iteration 766: Treatment Selected 2, Reward 0
Iteration 767: Treatment Selected 2, Reward 1
Iteration 768: Treatment Selected 3, Reward 1
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Iteration 780: Treatment Selected 2, Reward 1

Iteration 781: Treatment Selected 3, Reward 0
Iteration 782: Treatment Selected 1, Reward 0
Iteration 783: Treatment Selected 1, Reward 0
Iteration 784: Treatment Selected 3, Reward 0
Iteration 785: Treatment Selected 2, Reward 1
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Iteration 800: Treatment Selected 0, Reward 1
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Iteration 803: Treatment Selected 1, Reward 1
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Iteration 816: Treatment Selected 3, Reward 0
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Iteration 818: Treatment Selected 1, Reward 1
Iteration 819: Treatment Selected 2, Reward 0
Iteration 820: Treatment Selected 2, Reward 0
Iteration 821: Treatment Selected 1, Reward 1
Iteration 822: Treatment Selected 3, Reward 0
Iteration 823: Treatment Selected 0, Reward 1
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Iteration 836: Treatment Selected 3, Reward 1
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Iteration 838: Treatment Selected 2, Reward 1
Iteration 839: Treatment Selected 3, Reward 0
Iteration 840: Treatment Selected 3, Reward 1

Iteration 841: Treatment Selected 0, Reward 1
Iteration 842: Treatment Selected 0, Reward 0
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Iteration 845: Treatment Selected 3, Reward 1
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Iteration 850: Treatment Selected 0, Reward 0
Iteration 851: Treatment Selected 3, Reward 1
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Iteration 855: Treatment Selected 3, Reward 1
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Iteration 861: Treatment Selected 3, Reward 1
Iteration 862: Treatment Selected 0, Reward 0
Iteration 863: Treatment Selected 0, Reward 0
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Iteration 865: Treatment Selected 3, Reward 0
Iteration 866: Treatment Selected 2, Reward 1
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Iteration 868: Treatment Selected 2, Reward 0
Iteration 869: Treatment Selected 2, Reward 1
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Iteration 874: Treatment Selected 1, Reward 0
Iteration 875: Treatment Selected 1, Reward 1
Iteration 876: Treatment Selected 2, Reward 0
Iteration 877: Treatment Selected 0, Reward 0
Iteration 878: Treatment Selected 3, Reward 1
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Iteration 881: Treatment Selected 0, Reward 1
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Iteration 883: Treatment Selected 2, Reward 0
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Iteration 886: Treatment Selected 2, Reward 0
Iteration 887: Treatment Selected 1, Reward 1
Iteration 888: Treatment Selected 1, Reward 1
Iteration 889: Treatment Selected 2, Reward 1
Iteration 890: Treatment Selected 1, Reward 0
Iteration 891: Treatment Selected 3, Reward 0
Iteration 892: Treatment Selected 2, Reward 1
Iteration 893: Treatment Selected 0, Reward 0
Iteration 894: Treatment Selected 2, Reward 1
Iteration 895: Treatment Selected 2, Reward 0
Iteration 896: Treatment Selected 1, Reward 0
Iteration 897: Treatment Selected 0, Reward 0
Iteration 898: Treatment Selected 2, Reward 0
Iteration 899: Treatment Selected 1, Reward 0
Iteration 900: Treatment Selected 2, Reward 0

Iteration 901: Treatment Selected 1, Reward 0
Iteration 902: Treatment Selected 2, Reward 0
Iteration 903: Treatment Selected 0, Reward 1
Iteration 904: Treatment Selected 2, Reward 1
Iteration 905: Treatment Selected 3, Reward 0
Iteration 906: Treatment Selected 1, Reward 1
Iteration 907: Treatment Selected 2, Reward 0
Iteration 908: Treatment Selected 1, Reward 0
Iteration 909: Treatment Selected 3, Reward 1
Iteration 910: Treatment Selected 0, Reward 0
Iteration 911: Treatment Selected 2, Reward 1
Iteration 912: Treatment Selected 0, Reward 0
Iteration 913: Treatment Selected 1, Reward 1
Iteration 914: Treatment Selected 2, Reward 1
Iteration 915: Treatment Selected 0, Reward 1
Iteration 916: Treatment Selected 1, Reward 1
Iteration 917: Treatment Selected 1, Reward 1
Iteration 918: Treatment Selected 3, Reward 0
Iteration 919: Treatment Selected 0, Reward 1
Iteration 920: Treatment Selected 0, Reward 0
Iteration 921: Treatment Selected 0, Reward 0
Iteration 922: Treatment Selected 0, Reward 0
Iteration 923: Treatment Selected 3, Reward 1
Iteration 924: Treatment Selected 0, Reward 0
Iteration 925: Treatment Selected 0, Reward 0
Iteration 926: Treatment Selected 1, Reward 1
Iteration 927: Treatment Selected 3, Reward 0
Iteration 928: Treatment Selected 2, Reward 0
Iteration 929: Treatment Selected 3, Reward 0
Iteration 930: Treatment Selected 3, Reward 0
Iteration 931: Treatment Selected 0, Reward 0
Iteration 932: Treatment Selected 3, Reward 1
Iteration 933: Treatment Selected 2, Reward 0
Iteration 934: Treatment Selected 2, Reward 0
Iteration 935: Treatment Selected 1, Reward 1
Iteration 936: Treatment Selected 0, Reward 0
Iteration 937: Treatment Selected 0, Reward 0
Iteration 938: Treatment Selected 3, Reward 0
Iteration 939: Treatment Selected 0, Reward 0
Iteration 940: Treatment Selected 3, Reward 0
Iteration 941: Treatment Selected 2, Reward 0
Iteration 942: Treatment Selected 2, Reward 0
Iteration 943: Treatment Selected 0, Reward 0
Iteration 944: Treatment Selected 3, Reward 1
Iteration 945: Treatment Selected 2, Reward 0
Iteration 946: Treatment Selected 0, Reward 0
Iteration 947: Treatment Selected 0, Reward 0
Iteration 948: Treatment Selected 0, Reward 0
Iteration 949: Treatment Selected 2, Reward 0
Iteration 950: Treatment Selected 0, Reward 0
Iteration 951: Treatment Selected 0, Reward 1
Iteration 952: Treatment Selected 2, Reward 1
Iteration 953: Treatment Selected 0, Reward 0
Iteration 954: Treatment Selected 1, Reward 1
Iteration 955: Treatment Selected 2, Reward 1
Iteration 956: Treatment Selected 2, Reward 0
Iteration 957: Treatment Selected 2, Reward 0
Iteration 958: Treatment Selected 3, Reward 0
Iteration 959: Treatment Selected 0, Reward 0
Iteration 960: Treatment Selected 0, Reward 1

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Iteration 961: Treatment Selected 3, Reward 0
Iteration 962: Treatment Selected 3, Reward 0
Iteration 963: Treatment Selected 0, Reward 1
Iteration 964: Treatment Selected 3, Reward 1
Iteration 965: Treatment Selected 0, Reward 1
Iteration 966: Treatment Selected 2, Reward 0
Iteration 967: Treatment Selected 3, Reward 0
Iteration 968: Treatment Selected 0, Reward 0
Iteration 969: Treatment Selected 0, Reward 0
Iteration 970: Treatment Selected 3, Reward 0
Iteration 971: Treatment Selected 2, Reward 0
Iteration 972: Treatment Selected 3, Reward 1
Iteration 973: Treatment Selected 3, Reward 1
Iteration 974: Treatment Selected 3, Reward 1
Iteration 975: Treatment Selected 3, Reward 0
Iteration 976: Treatment Selected 0, Reward 0
Iteration 977: Treatment Selected 0, Reward 0
Iteration 978: Treatment Selected 2, Reward 0
Iteration 979: Treatment Selected 0, Reward 0
Iteration 980: Treatment Selected 1, Reward 1
Iteration 981: Treatment Selected 1, Reward 1
Iteration 982: Treatment Selected 2, Reward 0
Iteration 983: Treatment Selected 2, Reward 1
Iteration 984: Treatment Selected 0, Reward 1
Iteration 985: Treatment Selected 0, Reward 0
Iteration 986: Treatment Selected 2, Reward 0
Iteration 987: Treatment Selected 1, Reward 0
Iteration 988: Treatment Selected 1, Reward 0
Iteration 989: Treatment Selected 3, Reward 0
Iteration 990: Treatment Selected 3, Reward 1
Iteration 991: Treatment Selected 3, Reward 0
Iteration 992: Treatment Selected 0, Reward 0
Iteration 993: Treatment Selected 3, Reward 1
Iteration 994: Treatment Selected 1, Reward 0
Iteration 995: Treatment Selected 0, Reward 1
Iteration 996: Treatment Selected 2, Reward 0
Iteration 997: Treatment Selected 1, Reward 1
Iteration 998: Treatment Selected 3, Reward 0
Iteration 999: Treatment Selected 2, Reward 0
Iteration 1000: Treatment Selected 1, Reward 1

```

Using Greedy Policy (1M)

- Implement the Greedy policy that always selects the treatment with the highest average reward.
- Run the simulation and print each iteration's decision and reward.

```

In [39]: # Run the environment with an agent that is guided by a greedy policy
class GreedyPolicy:
    """
    Policy that always exploits: selects the arm with highest estimated m
    Bootstraps by sampling each arm once initially.
    """
    def __init__(self, n_arms):
        """
        Initialize count and value trackers for each arm.
        Args:
            n_arms (int): Number of available treatment arms.

```

```

    """
    self.counts = [0] * n_arms    # Number of times each arm has been
    self.values = [0.0] * n_arms # Cumulative reward for each arm

def select_arm_with_highest_average_reward(self, arms):
    """
    Select the arm with highest sample mean. If any arm is untried, s
    Args:
        arms (list): List of arm indices.
    Returns:
        int: Selected arm index.
    """
    # If any arms are untried, sample one randomly
    # Avoids divide-by-zero and gives each arm a chance to be evaluat
    untried_arms = [arm for arm in arms if self.counts[arm] == 0]
    if untried_arms:
        return random.choice(untried_arms)

    # Compute average rewards
    avg_rewards = [self.values[a] / self.counts[a] for a in arms]
    max_val = max(avg_rewards)

    # Break ties randomly
    candidates = [arms[i] for i, v in enumerate(avg_rewards) if v ==
    return random.choice(candidates)

def update(self, arm, reward):
    """
    Update internal estimates after pulling an arm.
    Args:
        arm (int): The arm index that was selected.
        reward (int): Observed reward (0 or 1).
    """
    self.counts[arm] += 1    # Increment pull count
    self.values[arm] += reward # Accumulate reward

# Initialize greedy policy
greedy_policy = GreedyPolicy(len(clinical_trial_env.arms))
greedy_rewards = [] # To store greedy rewards for plotting

# Run NUM_ITERATIONS of greedy policy
for i in range(NUM_ITERATIONS):
    arm = greedy_policy.select_arm_with_highest_average_reward(clinical_t
    reward = clinical_trial_env.compute_reward(arm)
    greedy_policy.update(arm, reward)
    greedy_rewards.append(reward)
    print(f"Iteration {i+1}: Arm selected {arm}, Reward {reward}")

```

Iteration 1: Arm selected 3, Reward 0
Iteration 2: Arm selected 0, Reward 0
Iteration 3: Arm selected 1, Reward 0
Iteration 4: Arm selected 2, Reward 0
Iteration 5: Arm selected 0, Reward 0
Iteration 6: Arm selected 3, Reward 0
Iteration 7: Arm selected 1, Reward 1
Iteration 8: Arm selected 1, Reward 1
Iteration 9: Arm selected 1, Reward 1
Iteration 10: Arm selected 1, Reward 0
Iteration 11: Arm selected 1, Reward 1
Iteration 12: Arm selected 1, Reward 1
Iteration 13: Arm selected 1, Reward 1
Iteration 14: Arm selected 1, Reward 1
Iteration 15: Arm selected 1, Reward 0
Iteration 16: Arm selected 1, Reward 1
Iteration 17: Arm selected 1, Reward 0
Iteration 18: Arm selected 1, Reward 1
Iteration 19: Arm selected 1, Reward 1
Iteration 20: Arm selected 1, Reward 1
Iteration 21: Arm selected 1, Reward 1
Iteration 22: Arm selected 1, Reward 1
Iteration 23: Arm selected 1, Reward 1
Iteration 24: Arm selected 1, Reward 1
Iteration 25: Arm selected 1, Reward 0
Iteration 26: Arm selected 1, Reward 1
Iteration 27: Arm selected 1, Reward 1
Iteration 28: Arm selected 1, Reward 1
Iteration 29: Arm selected 1, Reward 1
Iteration 30: Arm selected 1, Reward 0
Iteration 31: Arm selected 1, Reward 1
Iteration 32: Arm selected 1, Reward 0
Iteration 33: Arm selected 1, Reward 1
Iteration 34: Arm selected 1, Reward 1
Iteration 35: Arm selected 1, Reward 0
Iteration 36: Arm selected 1, Reward 1
Iteration 37: Arm selected 1, Reward 1
Iteration 38: Arm selected 1, Reward 0
Iteration 39: Arm selected 1, Reward 0
Iteration 40: Arm selected 1, Reward 1
Iteration 41: Arm selected 1, Reward 0
Iteration 42: Arm selected 1, Reward 0
Iteration 43: Arm selected 1, Reward 0
Iteration 44: Arm selected 1, Reward 1
Iteration 45: Arm selected 1, Reward 1
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Iteration 669: Arm selected 1, Reward 0
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Iteration 674: Arm selected 1, Reward 0
Iteration 675: Arm selected 1, Reward 0
Iteration 676: Arm selected 1, Reward 0
Iteration 677: Arm selected 1, Reward 0
Iteration 678: Arm selected 1, Reward 0
Iteration 679: Arm selected 1, Reward 1
Iteration 680: Arm selected 1, Reward 1
Iteration 681: Arm selected 1, Reward 0
Iteration 682: Arm selected 1, Reward 1
Iteration 683: Arm selected 1, Reward 1
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Iteration 694: Arm selected 1, Reward 0
Iteration 695: Arm selected 1, Reward 1
Iteration 696: Arm selected 1, Reward 0
Iteration 697: Arm selected 1, Reward 0
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Iteration 699: Arm selected 1, Reward 0
Iteration 700: Arm selected 1, Reward 0
Iteration 701: Arm selected 1, Reward 1
Iteration 702: Arm selected 1, Reward 0
Iteration 703: Arm selected 1, Reward 0
Iteration 704: Arm selected 1, Reward 1
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Iteration 720: Arm selected 1, Reward 1

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Iteration 950: Arm selected 1, Reward 0
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Iteration 960: Arm selected 1, Reward 1

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Iteration 961: Arm selected 1, Reward 0
Iteration 962: Arm selected 1, Reward 1
Iteration 963: Arm selected 1, Reward 1
Iteration 964: Arm selected 1, Reward 0
Iteration 965: Arm selected 1, Reward 0
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Iteration 978: Arm selected 1, Reward 1
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Iteration 992: Arm selected 1, Reward 0
Iteration 993: Arm selected 1, Reward 0
Iteration 994: Arm selected 1, Reward 1
Iteration 995: Arm selected 1, Reward 1
Iteration 996: Arm selected 1, Reward 1
Iteration 997: Arm selected 1, Reward 0
Iteration 998: Arm selected 1, Reward 0
Iteration 999: Arm selected 1, Reward 1
Iteration 1000: Arm selected 1, Reward 1

```

Using Epsilon-Greedy Policy (1.5M)

- Implement the ϵ -Greedy policy with $\epsilon = 0.1, 0.2, 0.5$.
- Report iteration-wise selections and rewards.
- Determine which ϵ yields the best result.

```

In [40]: # Run the environment with an agent that is guided by a epsilon-greedy po
class EpsilonGreedyPolicy(GreedyPolicy):
    """
    Extends GreedyPolicy to occasionally explore with probability  $\epsilon$ .
    """
    def __init__(self, n_arms, epsilon):
        """
        Initialize epsilon-greedy with given exploration rate.
        Args:
            n_arms (int): Number of treatment arms.
            epsilon (float): Probability of exploration at each step.

```

```

        """
        super().__init__(n_arms)
        self.epsilon = epsilon # Exploration probability

    def select_arm(self, arms):
        """
        With probability  $\epsilon$ , select a random arm; otherwise, exploit best-
        Args:
            arms (list): List of arm indices.
        Returns:
            int: Selected arm.
        """
        if random.random() < self.epsilon:
            return random.choice(arms) # Explor
        return super().select_arm(arms) # Exploi

# Run epsilon-greedy for each  $\epsilon$  value and collect rewards
epsilon_values = [0.1, 0.2, 0.5]
epsilon_rewards = {}

for eps in epsilon_values:
    policy = EpsilonGreedyPolicy(len(clinical_trial_env.arms), eps)
    rewards = [] # Track r

    print(f"\n---  $\epsilon$ -Greedy ( $\epsilon$ ={{eps}}) ---")

    for i in range(NUM_ITERATIONS):
        arm = policy.select_arm_with_highest_average_reward(clinical_trial_env)
        reward = clinical_trial_env.compute_reward(arm)
        policy.update(arm, reward)
        rewards.append(reward)
        print(f"Iteration {i+1}: Arm {arm}, Reward {reward}")

    epsilon_rewards[eps] = rewards # Store

```


--- ϵ -Greedy ($\epsilon=0.1$) ---

Iteration 1: Arm 2, Reward 1
Iteration 2: Arm 3, Reward 0
Iteration 3: Arm 1, Reward 1
Iteration 4: Arm 0, Reward 0
Iteration 5: Arm 2, Reward 0
Iteration 6: Arm 1, Reward 1
Iteration 7: Arm 1, Reward 1
Iteration 8: Arm 1, Reward 1
Iteration 9: Arm 1, Reward 1
Iteration 10: Arm 1, Reward 1
Iteration 11: Arm 1, Reward 1
Iteration 12: Arm 1, Reward 1
Iteration 13: Arm 1, Reward 0
Iteration 14: Arm 1, Reward 1
Iteration 15: Arm 1, Reward 0
Iteration 16: Arm 1, Reward 1
Iteration 17: Arm 1, Reward 0
Iteration 18: Arm 1, Reward 1
Iteration 19: Arm 1, Reward 1
Iteration 20: Arm 1, Reward 0
Iteration 21: Arm 1, Reward 1
Iteration 22: Arm 1, Reward 1
Iteration 23: Arm 1, Reward 1
Iteration 24: Arm 1, Reward 0
Iteration 25: Arm 1, Reward 1
Iteration 26: Arm 1, Reward 0
Iteration 27: Arm 1, Reward 0
Iteration 28: Arm 1, Reward 1
Iteration 29: Arm 1, Reward 0
Iteration 30: Arm 1, Reward 1
Iteration 31: Arm 1, Reward 1
Iteration 32: Arm 1, Reward 0
Iteration 33: Arm 1, Reward 1
Iteration 34: Arm 1, Reward 0
Iteration 35: Arm 1, Reward 0
Iteration 36: Arm 1, Reward 1
Iteration 37: Arm 1, Reward 0
Iteration 38: Arm 1, Reward 0
Iteration 39: Arm 1, Reward 0
Iteration 40: Arm 1, Reward 1
Iteration 41: Arm 1, Reward 0
Iteration 42: Arm 1, Reward 0
Iteration 43: Arm 1, Reward 1
Iteration 44: Arm 1, Reward 1
Iteration 45: Arm 1, Reward 1
Iteration 46: Arm 1, Reward 1
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Iteration 48: Arm 1, Reward 1
Iteration 49: Arm 1, Reward 1
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Iteration 51: Arm 1, Reward 0
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Iteration 902: Arm 1, Reward 0
Iteration 903: Arm 1, Reward 1
Iteration 904: Arm 1, Reward 1
Iteration 905: Arm 1, Reward 0
Iteration 906: Arm 1, Reward 1
Iteration 907: Arm 1, Reward 0
Iteration 908: Arm 1, Reward 0
Iteration 909: Arm 1, Reward 1
Iteration 910: Arm 1, Reward 0
Iteration 911: Arm 1, Reward 0
Iteration 912: Arm 1, Reward 1
Iteration 913: Arm 1, Reward 0
Iteration 914: Arm 1, Reward 0
Iteration 915: Arm 1, Reward 0
Iteration 916: Arm 1, Reward 1
Iteration 917: Arm 1, Reward 1
Iteration 918: Arm 1, Reward 0
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Iteration 921: Arm 1, Reward 0
Iteration 922: Arm 1, Reward 1
Iteration 923: Arm 1, Reward 1
Iteration 924: Arm 1, Reward 1
Iteration 925: Arm 1, Reward 0
Iteration 926: Arm 1, Reward 1
Iteration 927: Arm 1, Reward 0
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Iteration 929: Arm 1, Reward 1
Iteration 930: Arm 1, Reward 0
Iteration 931: Arm 1, Reward 1
Iteration 932: Arm 1, Reward 1
Iteration 933: Arm 1, Reward 1
Iteration 934: Arm 1, Reward 1
Iteration 935: Arm 1, Reward 0
Iteration 936: Arm 1, Reward 0
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Iteration 946: Arm 1, Reward 0
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Iteration 949: Arm 1, Reward 1
Iteration 950: Arm 1, Reward 0
Iteration 951: Arm 1, Reward 1
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Iteration 953: Arm 1, Reward 0
Iteration 954: Arm 1, Reward 1
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Iteration 956: Arm 1, Reward 0
Iteration 957: Arm 1, Reward 1
Iteration 958: Arm 1, Reward 0
Iteration 959: Arm 1, Reward 1

Iteration 960: Arm 1, Reward 1
Iteration 961: Arm 1, Reward 0
Iteration 962: Arm 1, Reward 1
Iteration 963: Arm 1, Reward 1
Iteration 964: Arm 1, Reward 0
Iteration 965: Arm 1, Reward 1
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Iteration 973: Arm 1, Reward 0
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Iteration 993: Arm 1, Reward 0
Iteration 994: Arm 1, Reward 1
Iteration 995: Arm 1, Reward 1
Iteration 996: Arm 1, Reward 0
Iteration 997: Arm 1, Reward 1
Iteration 998: Arm 1, Reward 1
Iteration 999: Arm 1, Reward 1
Iteration 1000: Arm 1, Reward 1

--- ϵ -Greedy ($\epsilon=0.2$) ---

Iteration 1: Arm 2, Reward 0
Iteration 2: Arm 3, Reward 0
Iteration 3: Arm 0, Reward 0
Iteration 4: Arm 1, Reward 1
Iteration 5: Arm 1, Reward 1
Iteration 6: Arm 1, Reward 1
Iteration 7: Arm 1, Reward 1
Iteration 8: Arm 1, Reward 1
Iteration 9: Arm 1, Reward 1
Iteration 10: Arm 1, Reward 0
Iteration 11: Arm 1, Reward 1
Iteration 12: Arm 1, Reward 1
Iteration 13: Arm 1, Reward 0
Iteration 14: Arm 1, Reward 0
Iteration 15: Arm 1, Reward 0
Iteration 16: Arm 1, Reward 1
Iteration 17: Arm 1, Reward 0

Iteration 18: Arm 1, Reward 1
Iteration 19: Arm 1, Reward 1
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Iteration 22: Arm 1, Reward 1
Iteration 23: Arm 1, Reward 1
Iteration 24: Arm 1, Reward 0
Iteration 25: Arm 1, Reward 0
Iteration 26: Arm 1, Reward 1
Iteration 27: Arm 1, Reward 1
Iteration 28: Arm 1, Reward 1
Iteration 29: Arm 1, Reward 1
Iteration 30: Arm 1, Reward 1
Iteration 31: Arm 1, Reward 0
Iteration 32: Arm 1, Reward 1
Iteration 33: Arm 1, Reward 1
Iteration 34: Arm 1, Reward 0
Iteration 35: Arm 1, Reward 1
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Iteration 39: Arm 1, Reward 0
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Iteration 48: Arm 1, Reward 1
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Iteration 68: Arm 1, Reward 0
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Iteration 73: Arm 1, Reward 1
Iteration 74: Arm 1, Reward 0
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Iteration 85: Arm 1, Reward 0
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Iteration 121: Arm 1, Reward 1
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Iteration 123: Arm 1, Reward 0
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Iteration 137: Arm 1, Reward 0

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Iteration 433: Arm 1, Reward 1
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Iteration 438: Arm 1, Reward 1
Iteration 439: Arm 1, Reward 0
Iteration 440: Arm 1, Reward 1
Iteration 441: Arm 1, Reward 0
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Iteration 549: Arm 1, Reward 0
Iteration 550: Arm 1, Reward 1
Iteration 551: Arm 1, Reward 1
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Iteration 561: Arm 1, Reward 1
Iteration 562: Arm 1, Reward 0
Iteration 563: Arm 1, Reward 0
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Iteration 566: Arm 1, Reward 1
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Iteration 571: Arm 1, Reward 1
Iteration 572: Arm 1, Reward 0
Iteration 573: Arm 1, Reward 0
Iteration 574: Arm 1, Reward 1
Iteration 575: Arm 1, Reward 0
Iteration 576: Arm 1, Reward 0
Iteration 577: Arm 1, Reward 0
Iteration 578: Arm 1, Reward 0
Iteration 579: Arm 1, Reward 0
Iteration 580: Arm 1, Reward 1
Iteration 581: Arm 1, Reward 1
Iteration 582: Arm 1, Reward 0
Iteration 583: Arm 1, Reward 0
Iteration 584: Arm 1, Reward 1
Iteration 585: Arm 1, Reward 1
Iteration 586: Arm 1, Reward 1
Iteration 587: Arm 1, Reward 1
Iteration 588: Arm 1, Reward 0
Iteration 589: Arm 1, Reward 0
Iteration 590: Arm 1, Reward 0
Iteration 591: Arm 1, Reward 0
Iteration 592: Arm 1, Reward 1
Iteration 593: Arm 1, Reward 1
Iteration 594: Arm 1, Reward 1
Iteration 595: Arm 1, Reward 1
Iteration 596: Arm 1, Reward 1
Iteration 597: Arm 1, Reward 0
Iteration 598: Arm 1, Reward 1
Iteration 599: Arm 1, Reward 0
Iteration 600: Arm 1, Reward 0
Iteration 601: Arm 1, Reward 0
Iteration 602: Arm 1, Reward 0
Iteration 603: Arm 1, Reward 0
Iteration 604: Arm 1, Reward 1
Iteration 605: Arm 1, Reward 1
Iteration 606: Arm 1, Reward 0
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Iteration 612: Arm 1, Reward 1
Iteration 613: Arm 1, Reward 1
Iteration 614: Arm 1, Reward 0
Iteration 615: Arm 1, Reward 1
Iteration 616: Arm 1, Reward 1
Iteration 617: Arm 1, Reward 1

Iteration 618: Arm 1, Reward 0
Iteration 619: Arm 1, Reward 1
Iteration 620: Arm 1, Reward 1
Iteration 621: Arm 1, Reward 1
Iteration 622: Arm 1, Reward 1
Iteration 623: Arm 1, Reward 1
Iteration 624: Arm 1, Reward 1
Iteration 625: Arm 1, Reward 1
Iteration 626: Arm 1, Reward 1
Iteration 627: Arm 1, Reward 0
Iteration 628: Arm 1, Reward 0
Iteration 629: Arm 1, Reward 1
Iteration 630: Arm 1, Reward 1
Iteration 631: Arm 1, Reward 1
Iteration 632: Arm 1, Reward 1
Iteration 633: Arm 1, Reward 1
Iteration 634: Arm 1, Reward 1
Iteration 635: Arm 1, Reward 1
Iteration 636: Arm 1, Reward 1
Iteration 637: Arm 1, Reward 1
Iteration 638: Arm 1, Reward 0
Iteration 639: Arm 1, Reward 1
Iteration 640: Arm 1, Reward 0
Iteration 641: Arm 1, Reward 1
Iteration 642: Arm 1, Reward 0
Iteration 643: Arm 1, Reward 1
Iteration 644: Arm 1, Reward 1
Iteration 645: Arm 1, Reward 0
Iteration 646: Arm 1, Reward 0
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Iteration 648: Arm 1, Reward 1
Iteration 649: Arm 1, Reward 1
Iteration 650: Arm 1, Reward 0
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Iteration 654: Arm 1, Reward 0
Iteration 655: Arm 1, Reward 1
Iteration 656: Arm 1, Reward 1
Iteration 657: Arm 1, Reward 0
Iteration 658: Arm 1, Reward 0
Iteration 659: Arm 1, Reward 0
Iteration 660: Arm 1, Reward 0
Iteration 661: Arm 1, Reward 1
Iteration 662: Arm 1, Reward 0
Iteration 663: Arm 1, Reward 1
Iteration 664: Arm 1, Reward 0
Iteration 665: Arm 1, Reward 1
Iteration 666: Arm 1, Reward 1
Iteration 667: Arm 1, Reward 0
Iteration 668: Arm 1, Reward 0
Iteration 669: Arm 1, Reward 1
Iteration 670: Arm 1, Reward 1
Iteration 671: Arm 1, Reward 1
Iteration 672: Arm 1, Reward 1
Iteration 673: Arm 1, Reward 0
Iteration 674: Arm 1, Reward 0
Iteration 675: Arm 1, Reward 1
Iteration 676: Arm 1, Reward 1
Iteration 677: Arm 1, Reward 1

Iteration 678: Arm 1, Reward 1
Iteration 679: Arm 1, Reward 0
Iteration 680: Arm 1, Reward 0
Iteration 681: Arm 1, Reward 1
Iteration 682: Arm 1, Reward 1
Iteration 683: Arm 1, Reward 1
Iteration 684: Arm 1, Reward 1
Iteration 685: Arm 1, Reward 0
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Iteration 687: Arm 1, Reward 1
Iteration 688: Arm 1, Reward 1
Iteration 689: Arm 1, Reward 1
Iteration 690: Arm 1, Reward 1
Iteration 691: Arm 1, Reward 1
Iteration 692: Arm 1, Reward 1
Iteration 693: Arm 1, Reward 0
Iteration 694: Arm 1, Reward 1
Iteration 695: Arm 1, Reward 1
Iteration 696: Arm 1, Reward 1
Iteration 697: Arm 1, Reward 1
Iteration 698: Arm 1, Reward 1
Iteration 699: Arm 1, Reward 1
Iteration 700: Arm 1, Reward 1
Iteration 701: Arm 1, Reward 0
Iteration 702: Arm 1, Reward 1
Iteration 703: Arm 1, Reward 0
Iteration 704: Arm 1, Reward 0
Iteration 705: Arm 1, Reward 0
Iteration 706: Arm 1, Reward 1
Iteration 707: Arm 1, Reward 1
Iteration 708: Arm 1, Reward 1
Iteration 709: Arm 1, Reward 0
Iteration 710: Arm 1, Reward 0
Iteration 711: Arm 1, Reward 1
Iteration 712: Arm 1, Reward 1
Iteration 713: Arm 1, Reward 1
Iteration 714: Arm 1, Reward 0
Iteration 715: Arm 1, Reward 1
Iteration 716: Arm 1, Reward 1
Iteration 717: Arm 1, Reward 1
Iteration 718: Arm 1, Reward 0
Iteration 719: Arm 1, Reward 0
Iteration 720: Arm 1, Reward 0
Iteration 721: Arm 1, Reward 0
Iteration 722: Arm 1, Reward 1
Iteration 723: Arm 1, Reward 1
Iteration 724: Arm 1, Reward 1
Iteration 725: Arm 1, Reward 0
Iteration 726: Arm 1, Reward 1
Iteration 727: Arm 1, Reward 0
Iteration 728: Arm 1, Reward 1
Iteration 729: Arm 1, Reward 0
Iteration 730: Arm 1, Reward 0
Iteration 731: Arm 1, Reward 0
Iteration 732: Arm 1, Reward 0
Iteration 733: Arm 1, Reward 1
Iteration 734: Arm 1, Reward 1
Iteration 735: Arm 1, Reward 1
Iteration 736: Arm 1, Reward 1
Iteration 737: Arm 1, Reward 1

Iteration 738: Arm 1, Reward 0
Iteration 739: Arm 1, Reward 1
Iteration 740: Arm 1, Reward 1
Iteration 741: Arm 1, Reward 1
Iteration 742: Arm 1, Reward 0
Iteration 743: Arm 1, Reward 0
Iteration 744: Arm 1, Reward 1
Iteration 745: Arm 1, Reward 1
Iteration 746: Arm 1, Reward 1
Iteration 747: Arm 1, Reward 0
Iteration 748: Arm 1, Reward 1
Iteration 749: Arm 1, Reward 1
Iteration 750: Arm 1, Reward 1
Iteration 751: Arm 1, Reward 0
Iteration 752: Arm 1, Reward 0
Iteration 753: Arm 1, Reward 1
Iteration 754: Arm 1, Reward 1
Iteration 755: Arm 1, Reward 1
Iteration 756: Arm 1, Reward 1
Iteration 757: Arm 1, Reward 1
Iteration 758: Arm 1, Reward 1
Iteration 759: Arm 1, Reward 0
Iteration 760: Arm 1, Reward 1
Iteration 761: Arm 1, Reward 1
Iteration 762: Arm 1, Reward 1
Iteration 763: Arm 1, Reward 1
Iteration 764: Arm 1, Reward 1
Iteration 765: Arm 1, Reward 1
Iteration 766: Arm 1, Reward 0
Iteration 767: Arm 1, Reward 1
Iteration 768: Arm 1, Reward 0
Iteration 769: Arm 1, Reward 0
Iteration 770: Arm 1, Reward 0
Iteration 771: Arm 1, Reward 1
Iteration 772: Arm 1, Reward 1
Iteration 773: Arm 1, Reward 1
Iteration 774: Arm 1, Reward 1
Iteration 775: Arm 1, Reward 1
Iteration 776: Arm 1, Reward 1
Iteration 777: Arm 1, Reward 1
Iteration 778: Arm 1, Reward 0
Iteration 779: Arm 1, Reward 1
Iteration 780: Arm 1, Reward 1
Iteration 781: Arm 1, Reward 1
Iteration 782: Arm 1, Reward 1
Iteration 783: Arm 1, Reward 1
Iteration 784: Arm 1, Reward 0
Iteration 785: Arm 1, Reward 1
Iteration 786: Arm 1, Reward 1
Iteration 787: Arm 1, Reward 1
Iteration 788: Arm 1, Reward 1
Iteration 789: Arm 1, Reward 1
Iteration 790: Arm 1, Reward 0
Iteration 791: Arm 1, Reward 1
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Iteration 793: Arm 1, Reward 1
Iteration 794: Arm 1, Reward 0
Iteration 795: Arm 1, Reward 1
Iteration 796: Arm 1, Reward 0
Iteration 797: Arm 1, Reward 1

Iteration 798: Arm 1, Reward 0
Iteration 799: Arm 1, Reward 0
Iteration 800: Arm 1, Reward 1
Iteration 801: Arm 1, Reward 1
Iteration 802: Arm 1, Reward 0
Iteration 803: Arm 1, Reward 1
Iteration 804: Arm 1, Reward 1
Iteration 805: Arm 1, Reward 0
Iteration 806: Arm 1, Reward 0
Iteration 807: Arm 1, Reward 1
Iteration 808: Arm 1, Reward 0
Iteration 809: Arm 1, Reward 1
Iteration 810: Arm 1, Reward 1
Iteration 811: Arm 1, Reward 1
Iteration 812: Arm 1, Reward 1
Iteration 813: Arm 1, Reward 1
Iteration 814: Arm 1, Reward 1
Iteration 815: Arm 1, Reward 0
Iteration 816: Arm 1, Reward 0
Iteration 817: Arm 1, Reward 1
Iteration 818: Arm 1, Reward 0
Iteration 819: Arm 1, Reward 1
Iteration 820: Arm 1, Reward 0
Iteration 821: Arm 1, Reward 1
Iteration 822: Arm 1, Reward 1
Iteration 823: Arm 1, Reward 0
Iteration 824: Arm 1, Reward 0
Iteration 825: Arm 1, Reward 1
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Iteration 827: Arm 1, Reward 0
Iteration 828: Arm 1, Reward 1
Iteration 829: Arm 1, Reward 0
Iteration 830: Arm 1, Reward 1
Iteration 831: Arm 1, Reward 1
Iteration 832: Arm 1, Reward 0
Iteration 833: Arm 1, Reward 1
Iteration 834: Arm 1, Reward 0
Iteration 835: Arm 1, Reward 1
Iteration 836: Arm 1, Reward 1
Iteration 837: Arm 1, Reward 0
Iteration 838: Arm 1, Reward 0
Iteration 839: Arm 1, Reward 1
Iteration 840: Arm 1, Reward 1
Iteration 841: Arm 1, Reward 1
Iteration 842: Arm 1, Reward 1
Iteration 843: Arm 1, Reward 1
Iteration 844: Arm 1, Reward 0
Iteration 845: Arm 1, Reward 1
Iteration 846: Arm 1, Reward 0
Iteration 847: Arm 1, Reward 1
Iteration 848: Arm 1, Reward 0
Iteration 849: Arm 1, Reward 1
Iteration 850: Arm 1, Reward 0
Iteration 851: Arm 1, Reward 1
Iteration 852: Arm 1, Reward 0
Iteration 853: Arm 1, Reward 1
Iteration 854: Arm 1, Reward 1
Iteration 855: Arm 1, Reward 0
Iteration 856: Arm 1, Reward 1
Iteration 857: Arm 1, Reward 1

Iteration 858: Arm 1, Reward 0
Iteration 859: Arm 1, Reward 1
Iteration 860: Arm 1, Reward 1
Iteration 861: Arm 1, Reward 0
Iteration 862: Arm 1, Reward 1
Iteration 863: Arm 1, Reward 1
Iteration 864: Arm 1, Reward 0
Iteration 865: Arm 1, Reward 0
Iteration 866: Arm 1, Reward 1
Iteration 867: Arm 1, Reward 1
Iteration 868: Arm 1, Reward 0
Iteration 869: Arm 1, Reward 1
Iteration 870: Arm 1, Reward 1
Iteration 871: Arm 1, Reward 1
Iteration 872: Arm 1, Reward 1
Iteration 873: Arm 1, Reward 1
Iteration 874: Arm 1, Reward 1
Iteration 875: Arm 1, Reward 1
Iteration 876: Arm 1, Reward 0
Iteration 877: Arm 1, Reward 1
Iteration 878: Arm 1, Reward 1
Iteration 879: Arm 1, Reward 1
Iteration 880: Arm 1, Reward 0
Iteration 881: Arm 1, Reward 0
Iteration 882: Arm 1, Reward 1
Iteration 883: Arm 1, Reward 0
Iteration 884: Arm 1, Reward 1
Iteration 885: Arm 1, Reward 0
Iteration 886: Arm 1, Reward 0
Iteration 887: Arm 1, Reward 1
Iteration 888: Arm 1, Reward 1
Iteration 889: Arm 1, Reward 0
Iteration 890: Arm 1, Reward 0
Iteration 891: Arm 1, Reward 1
Iteration 892: Arm 1, Reward 1
Iteration 893: Arm 1, Reward 0
Iteration 894: Arm 1, Reward 1
Iteration 895: Arm 1, Reward 1
Iteration 896: Arm 1, Reward 0
Iteration 897: Arm 1, Reward 1
Iteration 898: Arm 1, Reward 0
Iteration 899: Arm 1, Reward 0
Iteration 900: Arm 1, Reward 1
Iteration 901: Arm 1, Reward 1
Iteration 902: Arm 1, Reward 1
Iteration 903: Arm 1, Reward 1
Iteration 904: Arm 1, Reward 0
Iteration 905: Arm 1, Reward 1
Iteration 906: Arm 1, Reward 1
Iteration 907: Arm 1, Reward 1
Iteration 908: Arm 1, Reward 0
Iteration 909: Arm 1, Reward 0
Iteration 910: Arm 1, Reward 0
Iteration 911: Arm 1, Reward 1
Iteration 912: Arm 1, Reward 0
Iteration 913: Arm 1, Reward 1
Iteration 914: Arm 1, Reward 1
Iteration 915: Arm 1, Reward 1
Iteration 916: Arm 1, Reward 0
Iteration 917: Arm 1, Reward 0

Iteration 918: Arm 1, Reward 0
Iteration 919: Arm 1, Reward 1
Iteration 920: Arm 1, Reward 1
Iteration 921: Arm 1, Reward 0
Iteration 922: Arm 1, Reward 0
Iteration 923: Arm 1, Reward 1
Iteration 924: Arm 1, Reward 1
Iteration 925: Arm 1, Reward 1
Iteration 926: Arm 1, Reward 0
Iteration 927: Arm 1, Reward 1
Iteration 928: Arm 1, Reward 1
Iteration 929: Arm 1, Reward 1
Iteration 930: Arm 1, Reward 0
Iteration 931: Arm 1, Reward 1
Iteration 932: Arm 1, Reward 0
Iteration 933: Arm 1, Reward 1
Iteration 934: Arm 1, Reward 1
Iteration 935: Arm 1, Reward 1
Iteration 936: Arm 1, Reward 0
Iteration 937: Arm 1, Reward 1
Iteration 938: Arm 1, Reward 0
Iteration 939: Arm 1, Reward 0
Iteration 940: Arm 1, Reward 1
Iteration 941: Arm 1, Reward 0
Iteration 942: Arm 1, Reward 1
Iteration 943: Arm 1, Reward 0
Iteration 944: Arm 1, Reward 0
Iteration 945: Arm 1, Reward 1
Iteration 946: Arm 1, Reward 1
Iteration 947: Arm 1, Reward 1
Iteration 948: Arm 1, Reward 1
Iteration 949: Arm 1, Reward 0
Iteration 950: Arm 1, Reward 1
Iteration 951: Arm 1, Reward 1
Iteration 952: Arm 1, Reward 1
Iteration 953: Arm 1, Reward 0
Iteration 954: Arm 1, Reward 1
Iteration 955: Arm 1, Reward 0
Iteration 956: Arm 1, Reward 1
Iteration 957: Arm 1, Reward 0
Iteration 958: Arm 1, Reward 1
Iteration 959: Arm 1, Reward 0
Iteration 960: Arm 1, Reward 1
Iteration 961: Arm 1, Reward 1
Iteration 962: Arm 1, Reward 1
Iteration 963: Arm 1, Reward 1
Iteration 964: Arm 1, Reward 0
Iteration 965: Arm 1, Reward 0
Iteration 966: Arm 1, Reward 0
Iteration 967: Arm 1, Reward 0
Iteration 968: Arm 1, Reward 1
Iteration 969: Arm 1, Reward 0
Iteration 970: Arm 1, Reward 1
Iteration 971: Arm 1, Reward 1
Iteration 972: Arm 1, Reward 0
Iteration 973: Arm 1, Reward 1
Iteration 974: Arm 1, Reward 0
Iteration 975: Arm 1, Reward 1
Iteration 976: Arm 1, Reward 0
Iteration 977: Arm 1, Reward 0

Iteration 978: Arm 1, Reward 1
Iteration 979: Arm 1, Reward 1
Iteration 980: Arm 1, Reward 1
Iteration 981: Arm 1, Reward 1
Iteration 982: Arm 1, Reward 1
Iteration 983: Arm 1, Reward 1
Iteration 984: Arm 1, Reward 1
Iteration 985: Arm 1, Reward 1
Iteration 986: Arm 1, Reward 1
Iteration 987: Arm 1, Reward 0
Iteration 988: Arm 1, Reward 1
Iteration 989: Arm 1, Reward 1
Iteration 990: Arm 1, Reward 1
Iteration 991: Arm 1, Reward 1
Iteration 992: Arm 1, Reward 1
Iteration 993: Arm 1, Reward 0
Iteration 994: Arm 1, Reward 1
Iteration 995: Arm 1, Reward 1
Iteration 996: Arm 1, Reward 1
Iteration 997: Arm 1, Reward 1
Iteration 998: Arm 1, Reward 0
Iteration 999: Arm 1, Reward 0
Iteration 1000: Arm 1, Reward 1

--- ϵ -Greedy ($\epsilon=0.5$) ---

Iteration 1: Arm 1, Reward 0
Iteration 2: Arm 3, Reward 0
Iteration 3: Arm 2, Reward 0
Iteration 4: Arm 0, Reward 0
Iteration 5: Arm 3, Reward 0
Iteration 6: Arm 0, Reward 1
Iteration 7: Arm 0, Reward 0
Iteration 8: Arm 0, Reward 1
Iteration 9: Arm 0, Reward 0
Iteration 10: Arm 0, Reward 0
Iteration 11: Arm 0, Reward 0
Iteration 12: Arm 0, Reward 0
Iteration 13: Arm 0, Reward 0
Iteration 14: Arm 0, Reward 0
Iteration 15: Arm 0, Reward 0
Iteration 16: Arm 0, Reward 0
Iteration 17: Arm 0, Reward 1
Iteration 18: Arm 0, Reward 0
Iteration 19: Arm 0, Reward 1
Iteration 20: Arm 0, Reward 0
Iteration 21: Arm 0, Reward 0
Iteration 22: Arm 0, Reward 0
Iteration 23: Arm 0, Reward 0
Iteration 24: Arm 0, Reward 0
Iteration 25: Arm 0, Reward 0
Iteration 26: Arm 0, Reward 0
Iteration 27: Arm 0, Reward 1
Iteration 28: Arm 0, Reward 1
Iteration 29: Arm 0, Reward 0
Iteration 30: Arm 0, Reward 1
Iteration 31: Arm 0, Reward 1
Iteration 32: Arm 0, Reward 0
Iteration 33: Arm 0, Reward 0
Iteration 34: Arm 0, Reward 0
Iteration 35: Arm 0, Reward 0

Iteration 36: Arm 0, Reward 0
Iteration 37: Arm 0, Reward 0
Iteration 38: Arm 0, Reward 1
Iteration 39: Arm 0, Reward 1
Iteration 40: Arm 0, Reward 1
Iteration 41: Arm 0, Reward 0
Iteration 42: Arm 0, Reward 1
Iteration 43: Arm 0, Reward 0
Iteration 44: Arm 0, Reward 1
Iteration 45: Arm 0, Reward 0
Iteration 46: Arm 0, Reward 1
Iteration 47: Arm 0, Reward 0
Iteration 48: Arm 0, Reward 0
Iteration 49: Arm 0, Reward 1
Iteration 50: Arm 0, Reward 1
Iteration 51: Arm 0, Reward 0
Iteration 52: Arm 0, Reward 0
Iteration 53: Arm 0, Reward 1
Iteration 54: Arm 0, Reward 0
Iteration 55: Arm 0, Reward 0
Iteration 56: Arm 0, Reward 0
Iteration 57: Arm 0, Reward 0
Iteration 58: Arm 0, Reward 0
Iteration 59: Arm 0, Reward 0
Iteration 60: Arm 0, Reward 0
Iteration 61: Arm 0, Reward 1
Iteration 62: Arm 0, Reward 0
Iteration 63: Arm 0, Reward 0
Iteration 64: Arm 0, Reward 0
Iteration 65: Arm 0, Reward 0
Iteration 66: Arm 0, Reward 1
Iteration 67: Arm 0, Reward 0
Iteration 68: Arm 0, Reward 0
Iteration 69: Arm 0, Reward 1
Iteration 70: Arm 0, Reward 1
Iteration 71: Arm 0, Reward 0
Iteration 72: Arm 0, Reward 0
Iteration 73: Arm 0, Reward 0
Iteration 74: Arm 0, Reward 0
Iteration 75: Arm 0, Reward 0
Iteration 76: Arm 0, Reward 0
Iteration 77: Arm 0, Reward 0
Iteration 78: Arm 0, Reward 1
Iteration 79: Arm 0, Reward 0
Iteration 80: Arm 0, Reward 0
Iteration 81: Arm 0, Reward 0
Iteration 82: Arm 0, Reward 1
Iteration 83: Arm 0, Reward 0
Iteration 84: Arm 0, Reward 0
Iteration 85: Arm 0, Reward 0
Iteration 86: Arm 0, Reward 0
Iteration 87: Arm 0, Reward 0
Iteration 88: Arm 0, Reward 0
Iteration 89: Arm 0, Reward 1
Iteration 90: Arm 0, Reward 0
Iteration 91: Arm 0, Reward 0
Iteration 92: Arm 0, Reward 0
Iteration 93: Arm 0, Reward 0
Iteration 94: Arm 0, Reward 0
Iteration 95: Arm 0, Reward 1

Iteration 96: Arm 0, Reward 0
Iteration 97: Arm 0, Reward 0
Iteration 98: Arm 0, Reward 1
Iteration 99: Arm 0, Reward 1
Iteration 100: Arm 0, Reward 1
Iteration 101: Arm 0, Reward 0
Iteration 102: Arm 0, Reward 0
Iteration 103: Arm 0, Reward 0
Iteration 104: Arm 0, Reward 0
Iteration 105: Arm 0, Reward 0
Iteration 106: Arm 0, Reward 0
Iteration 107: Arm 0, Reward 1
Iteration 108: Arm 0, Reward 0
Iteration 109: Arm 0, Reward 0
Iteration 110: Arm 0, Reward 0
Iteration 111: Arm 0, Reward 0
Iteration 112: Arm 0, Reward 0
Iteration 113: Arm 0, Reward 0
Iteration 114: Arm 0, Reward 0
Iteration 115: Arm 0, Reward 0
Iteration 116: Arm 0, Reward 1
Iteration 117: Arm 0, Reward 0
Iteration 118: Arm 0, Reward 0
Iteration 119: Arm 0, Reward 1
Iteration 120: Arm 0, Reward 0
Iteration 121: Arm 0, Reward 0
Iteration 122: Arm 0, Reward 0
Iteration 123: Arm 0, Reward 1
Iteration 124: Arm 0, Reward 1
Iteration 125: Arm 0, Reward 1
Iteration 126: Arm 0, Reward 0
Iteration 127: Arm 0, Reward 0
Iteration 128: Arm 0, Reward 0
Iteration 129: Arm 0, Reward 1
Iteration 130: Arm 0, Reward 1
Iteration 131: Arm 0, Reward 0
Iteration 132: Arm 0, Reward 0
Iteration 133: Arm 0, Reward 0
Iteration 134: Arm 0, Reward 0
Iteration 135: Arm 0, Reward 0
Iteration 136: Arm 0, Reward 0
Iteration 137: Arm 0, Reward 0
Iteration 138: Arm 0, Reward 0
Iteration 139: Arm 0, Reward 0
Iteration 140: Arm 0, Reward 0
Iteration 141: Arm 0, Reward 1
Iteration 142: Arm 0, Reward 0
Iteration 143: Arm 0, Reward 0
Iteration 144: Arm 0, Reward 0
Iteration 145: Arm 0, Reward 0
Iteration 146: Arm 0, Reward 0
Iteration 147: Arm 0, Reward 1
Iteration 148: Arm 0, Reward 0
Iteration 149: Arm 0, Reward 0
Iteration 150: Arm 0, Reward 0
Iteration 151: Arm 0, Reward 1
Iteration 152: Arm 0, Reward 0
Iteration 153: Arm 0, Reward 0
Iteration 154: Arm 0, Reward 1
Iteration 155: Arm 0, Reward 0

Iteration 156: Arm 0, Reward 0
Iteration 157: Arm 0, Reward 0
Iteration 158: Arm 0, Reward 1
Iteration 159: Arm 0, Reward 0
Iteration 160: Arm 0, Reward 1
Iteration 161: Arm 0, Reward 1
Iteration 162: Arm 0, Reward 0
Iteration 163: Arm 0, Reward 0
Iteration 164: Arm 0, Reward 0
Iteration 165: Arm 0, Reward 0
Iteration 166: Arm 0, Reward 0
Iteration 167: Arm 0, Reward 1
Iteration 168: Arm 0, Reward 1
Iteration 169: Arm 0, Reward 0
Iteration 170: Arm 0, Reward 0
Iteration 171: Arm 0, Reward 1
Iteration 172: Arm 0, Reward 1
Iteration 173: Arm 0, Reward 0
Iteration 174: Arm 0, Reward 0
Iteration 175: Arm 0, Reward 1
Iteration 176: Arm 0, Reward 1
Iteration 177: Arm 0, Reward 1
Iteration 178: Arm 0, Reward 0
Iteration 179: Arm 0, Reward 0
Iteration 180: Arm 0, Reward 1
Iteration 181: Arm 0, Reward 0
Iteration 182: Arm 0, Reward 0
Iteration 183: Arm 0, Reward 1
Iteration 184: Arm 0, Reward 0
Iteration 185: Arm 0, Reward 0
Iteration 186: Arm 0, Reward 1
Iteration 187: Arm 0, Reward 0
Iteration 188: Arm 0, Reward 1
Iteration 189: Arm 0, Reward 1
Iteration 190: Arm 0, Reward 0
Iteration 191: Arm 0, Reward 0
Iteration 192: Arm 0, Reward 0
Iteration 193: Arm 0, Reward 0
Iteration 194: Arm 0, Reward 1
Iteration 195: Arm 0, Reward 1
Iteration 196: Arm 0, Reward 1
Iteration 197: Arm 0, Reward 1
Iteration 198: Arm 0, Reward 1
Iteration 199: Arm 0, Reward 1
Iteration 200: Arm 0, Reward 1
Iteration 201: Arm 0, Reward 1
Iteration 202: Arm 0, Reward 0
Iteration 203: Arm 0, Reward 0
Iteration 204: Arm 0, Reward 0
Iteration 205: Arm 0, Reward 0
Iteration 206: Arm 0, Reward 0
Iteration 207: Arm 0, Reward 1
Iteration 208: Arm 0, Reward 0
Iteration 209: Arm 0, Reward 0
Iteration 210: Arm 0, Reward 1
Iteration 211: Arm 0, Reward 1
Iteration 212: Arm 0, Reward 0
Iteration 213: Arm 0, Reward 0
Iteration 214: Arm 0, Reward 0
Iteration 215: Arm 0, Reward 1

Iteration 216: Arm 0, Reward 0
Iteration 217: Arm 0, Reward 1
Iteration 218: Arm 0, Reward 0
Iteration 219: Arm 0, Reward 0
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Iteration 882: Arm 0, Reward 0
Iteration 883: Arm 0, Reward 0
Iteration 884: Arm 0, Reward 0
Iteration 885: Arm 0, Reward 1
Iteration 886: Arm 0, Reward 1
Iteration 887: Arm 0, Reward 0
Iteration 888: Arm 0, Reward 0
Iteration 889: Arm 0, Reward 1
Iteration 890: Arm 0, Reward 0
Iteration 891: Arm 0, Reward 0
Iteration 892: Arm 0, Reward 0
Iteration 893: Arm 0, Reward 1
Iteration 894: Arm 0, Reward 1
Iteration 895: Arm 0, Reward 0
Iteration 896: Arm 0, Reward 0
Iteration 897: Arm 0, Reward 0
Iteration 898: Arm 0, Reward 0
Iteration 899: Arm 0, Reward 0
Iteration 900: Arm 0, Reward 0
Iteration 901: Arm 0, Reward 0
Iteration 902: Arm 0, Reward 1
Iteration 903: Arm 0, Reward 1
Iteration 904: Arm 0, Reward 1
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Iteration 907: Arm 0, Reward 1
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Iteration 909: Arm 0, Reward 1
Iteration 910: Arm 0, Reward 1
Iteration 911: Arm 0, Reward 0
Iteration 912: Arm 0, Reward 0
Iteration 913: Arm 0, Reward 1
Iteration 914: Arm 0, Reward 0
Iteration 915: Arm 0, Reward 1
Iteration 916: Arm 0, Reward 0
Iteration 917: Arm 0, Reward 0
Iteration 918: Arm 0, Reward 0
Iteration 919: Arm 0, Reward 0
Iteration 920: Arm 0, Reward 1
Iteration 921: Arm 0, Reward 0
Iteration 922: Arm 0, Reward 1
Iteration 923: Arm 0, Reward 0
Iteration 924: Arm 0, Reward 0
Iteration 925: Arm 0, Reward 0
Iteration 926: Arm 0, Reward 0
Iteration 927: Arm 0, Reward 0
Iteration 928: Arm 0, Reward 0
Iteration 929: Arm 0, Reward 0
Iteration 930: Arm 0, Reward 1
Iteration 931: Arm 0, Reward 0
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Iteration 934: Arm 0, Reward 0
Iteration 935: Arm 0, Reward 1

Iteration 936: Arm 0, Reward 1
Iteration 937: Arm 0, Reward 0
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Iteration 940: Arm 0, Reward 0
Iteration 941: Arm 0, Reward 0
Iteration 942: Arm 0, Reward 1
Iteration 943: Arm 0, Reward 0
Iteration 944: Arm 0, Reward 0
Iteration 945: Arm 0, Reward 0
Iteration 946: Arm 0, Reward 1
Iteration 947: Arm 0, Reward 0
Iteration 948: Arm 0, Reward 0
Iteration 949: Arm 0, Reward 1
Iteration 950: Arm 0, Reward 1
Iteration 951: Arm 0, Reward 0
Iteration 952: Arm 0, Reward 1
Iteration 953: Arm 0, Reward 0
Iteration 954: Arm 0, Reward 1
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Iteration 975: Arm 0, Reward 0
Iteration 976: Arm 0, Reward 0
Iteration 977: Arm 0, Reward 0
Iteration 978: Arm 0, Reward 0
Iteration 979: Arm 0, Reward 0
Iteration 980: Arm 0, Reward 0
Iteration 981: Arm 0, Reward 0
Iteration 982: Arm 0, Reward 0
Iteration 983: Arm 0, Reward 0
Iteration 984: Arm 0, Reward 0
Iteration 985: Arm 0, Reward 1
Iteration 986: Arm 0, Reward 1
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Iteration 994: Arm 0, Reward 0
Iteration 995: Arm 0, Reward 0

Iteration 996: Arm 0, Reward 0
 Iteration 997: Arm 0, Reward 1
 Iteration 998: Arm 0, Reward 0
 Iteration 999: Arm 0, Reward 0
 Iteration 1000: Arm 0, Reward 0

Using UCB (1M)

Implement the UCB algorithm for treatment selection and print each iteration.

```
In [41]: # run the environment with an agent that is guided by a UCB
#-----write your code below this line-----
class UCBPolicy:
    """
    Implements the Upper Confidence Bound (UCB) algorithm to balance
    exploration and exploitation via an optimism term.
    """
    def __init__(self, n_arms):
        """
        Initialize counts and values for UCB.
        Args:
            n_arms (int): Number of treatment arms.
        """
        self.counts = [0] * n_arms      # Number of pulls per arm
        self.values = [0.0] * n_arms    # Sum of rewards per arm
        self.total_count = 0            # Total number of pulls

    def select_arm_highest_ucb(self, arms):
        """
        Select the arm with the highest upper confidence bound.
        Args:
            arms (list): List of arm indices.
        Returns:
            int: Selected arm.
        """
        # Ensure each arm is tried at least once
        for arm in arms:
            if self.counts[arm] == 0:
                return arm

        # Compute UCB score for each arm
        ucb_scores = []
        for arm in arms:
            avg_reward = self.values[arm] / self.counts[arm]
            bonus = math.sqrt((2 * math.log(self.total_count)) / self.counts[arm])
            ucb_scores.append(avg_reward + bonus)
        max_score = max(ucb_scores)
        candidates = [arms[i] for i, s in enumerate(ucb_scores) if s == max_score]
        return random.choice(candidates)

    def update(self, arm, reward):
        """
        Update counts and values after observing a reward.
        Args:
            arm (int): Arm index that was pulled.
            reward (int): Observed binary reward.
        """
        self.counts[arm] += 1
        self.values[arm] += reward
        self.total_count += 1
```

```
        self.values[arm] += reward
        self.total_count += 1

# Initialize and run UCB policy
ucb_policy = UCBPolicy(len(clinical_trial_env.arms))
ucb_rewards = [] #

for i in range(NUM_ITERATIONS):
    arm = ucb_policy.select_arm_highest_ucb(clinical_trial_env.arms)
    reward = clinical_trial_env.compute_reward(arm)
    ucb_policy.update(arm, reward)
    ucb_rewards.append(reward)
    print(f"Iteration {i+1}: Arm {arm}, Reward {reward}") # L
```

Iteration 1: Arm 0, Reward 1
Iteration 2: Arm 1, Reward 0
Iteration 3: Arm 2, Reward 1
Iteration 4: Arm 3, Reward 0
Iteration 5: Arm 0, Reward 0
Iteration 6: Arm 2, Reward 1
Iteration 7: Arm 2, Reward 0
Iteration 8: Arm 1, Reward 0
Iteration 9: Arm 3, Reward 0
Iteration 10: Arm 0, Reward 1
Iteration 11: Arm 0, Reward 1
Iteration 12: Arm 2, Reward 0
Iteration 13: Arm 0, Reward 1
Iteration 14: Arm 0, Reward 0
Iteration 15: Arm 2, Reward 0
Iteration 16: Arm 3, Reward 1
Iteration 17: Arm 3, Reward 0
Iteration 18: Arm 1, Reward 0
Iteration 19: Arm 0, Reward 0
Iteration 20: Arm 0, Reward 0
Iteration 21: Arm 2, Reward 0
Iteration 22: Arm 3, Reward 1
Iteration 23: Arm 3, Reward 0
Iteration 24: Arm 1, Reward 1
Iteration 25: Arm 1, Reward 0
Iteration 26: Arm 0, Reward 1
Iteration 27: Arm 0, Reward 1
Iteration 28: Arm 0, Reward 1
Iteration 29: Arm 0, Reward 0
Iteration 30: Arm 2, Reward 1
Iteration 31: Arm 2, Reward 1
Iteration 32: Arm 2, Reward 0
Iteration 33: Arm 3, Reward 1
Iteration 34: Arm 3, Reward 0
Iteration 35: Arm 1, Reward 1
Iteration 36: Arm 1, Reward 1
Iteration 37: Arm 1, Reward 0
Iteration 38: Arm 0, Reward 1
Iteration 39: Arm 0, Reward 1
Iteration 40: Arm 0, Reward 1
Iteration 41: Arm 0, Reward 1
Iteration 42: Arm 0, Reward 0
Iteration 43: Arm 2, Reward 0
Iteration 44: Arm 3, Reward 1
Iteration 45: Arm 3, Reward 0
Iteration 46: Arm 1, Reward 1
Iteration 47: Arm 1, Reward 1
Iteration 48: Arm 1, Reward 1
Iteration 49: Arm 1, Reward 1
Iteration 50: Arm 1, Reward 1
Iteration 51: Arm 1, Reward 0
Iteration 52: Arm 0, Reward 1
Iteration 53: Arm 0, Reward 0
Iteration 54: Arm 1, Reward 1
Iteration 55: Arm 1, Reward 0
Iteration 56: Arm 3, Reward 1
Iteration 57: Arm 3, Reward 1
Iteration 58: Arm 3, Reward 0
Iteration 59: Arm 2, Reward 0
Iteration 60: Arm 0, Reward 0

Iteration 61: Arm 1, Reward 1
Iteration 62: Arm 1, Reward 0
Iteration 63: Arm 3, Reward 1
Iteration 64: Arm 3, Reward 1
Iteration 65: Arm 3, Reward 1
Iteration 66: Arm 3, Reward 0
Iteration 67: Arm 0, Reward 0
Iteration 68: Arm 1, Reward 1
Iteration 69: Arm 1, Reward 0
Iteration 70: Arm 2, Reward 0
Iteration 71: Arm 3, Reward 0
Iteration 72: Arm 0, Reward 0
Iteration 73: Arm 1, Reward 1
Iteration 74: Arm 1, Reward 1
Iteration 75: Arm 1, Reward 1
Iteration 76: Arm 1, Reward 0
Iteration 77: Arm 3, Reward 1
Iteration 78: Arm 3, Reward 0
Iteration 79: Arm 1, Reward 1
Iteration 80: Arm 1, Reward 1
Iteration 81: Arm 1, Reward 1
Iteration 82: Arm 1, Reward 1
Iteration 83: Arm 1, Reward 0
Iteration 84: Arm 2, Reward 1
Iteration 85: Arm 2, Reward 0
Iteration 86: Arm 0, Reward 0
Iteration 87: Arm 1, Reward 0
Iteration 88: Arm 3, Reward 1
Iteration 89: Arm 3, Reward 0
Iteration 90: Arm 2, Reward 0
Iteration 91: Arm 1, Reward 1
Iteration 92: Arm 1, Reward 1
Iteration 93: Arm 1, Reward 1
Iteration 94: Arm 1, Reward 1
Iteration 95: Arm 1, Reward 1
Iteration 96: Arm 1, Reward 0
Iteration 97: Arm 0, Reward 0
Iteration 98: Arm 3, Reward 0
Iteration 99: Arm 1, Reward 1
Iteration 100: Arm 1, Reward 0
Iteration 101: Arm 1, Reward 0
Iteration 102: Arm 0, Reward 1
Iteration 103: Arm 0, Reward 0
Iteration 104: Arm 2, Reward 1
Iteration 105: Arm 2, Reward 0
Iteration 106: Arm 3, Reward 0
Iteration 107: Arm 1, Reward 0
Iteration 108: Arm 0, Reward 0
Iteration 109: Arm 2, Reward 1
Iteration 110: Arm 2, Reward 0
Iteration 111: Arm 1, Reward 1
Iteration 112: Arm 1, Reward 0
Iteration 113: Arm 3, Reward 1
Iteration 114: Arm 3, Reward 0
Iteration 115: Arm 2, Reward 1
Iteration 116: Arm 2, Reward 0
Iteration 117: Arm 0, Reward 0
Iteration 118: Arm 1, Reward 1
Iteration 119: Arm 1, Reward 0
Iteration 120: Arm 3, Reward 1

Iteration 121: Arm 3, Reward 0
Iteration 122: Arm 1, Reward 0
Iteration 123: Arm 2, Reward 0
Iteration 124: Arm 3, Reward 1
Iteration 125: Arm 3, Reward 0
Iteration 126: Arm 0, Reward 1
Iteration 127: Arm 0, Reward 1
Iteration 128: Arm 0, Reward 0
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Iteration 130: Arm 1, Reward 1
Iteration 131: Arm 1, Reward 1
Iteration 132: Arm 1, Reward 0
Iteration 133: Arm 3, Reward 0
Iteration 134: Arm 1, Reward 0
Iteration 135: Arm 2, Reward 1
Iteration 136: Arm 2, Reward 1
Iteration 137: Arm 2, Reward 0
Iteration 138: Arm 2, Reward 0
Iteration 139: Arm 0, Reward 0
Iteration 140: Arm 1, Reward 0
Iteration 141: Arm 3, Reward 1
Iteration 142: Arm 3, Reward 0
Iteration 143: Arm 1, Reward 1
Iteration 144: Arm 1, Reward 0
Iteration 145: Arm 0, Reward 0
Iteration 146: Arm 3, Reward 0
Iteration 147: Arm 2, Reward 1
Iteration 148: Arm 2, Reward 0
Iteration 149: Arm 1, Reward 1
Iteration 150: Arm 1, Reward 1
Iteration 151: Arm 1, Reward 1
Iteration 152: Arm 1, Reward 1
Iteration 153: Arm 1, Reward 1
Iteration 154: Arm 1, Reward 1
Iteration 155: Arm 1, Reward 0
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Iteration 172: Arm 3, Reward 0
Iteration 173: Arm 3, Reward 1
Iteration 174: Arm 3, Reward 0
Iteration 175: Arm 3, Reward 1
Iteration 176: Arm 3, Reward 1
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Iteration 178: Arm 3, Reward 1
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Iteration 186: Arm 1, Reward 1
Iteration 187: Arm 1, Reward 0
Iteration 188: Arm 2, Reward 1
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Iteration 190: Arm 2, Reward 1
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Iteration 421: Arm 2, Reward 1
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Iteration 425: Arm 2, Reward 0
Iteration 426: Arm 2, Reward 0
Iteration 427: Arm 2, Reward 0
Iteration 428: Arm 3, Reward 1
Iteration 429: Arm 3, Reward 1
Iteration 430: Arm 3, Reward 0
Iteration 431: Arm 3, Reward 0
Iteration 432: Arm 1, Reward 1
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Iteration 434: Arm 1, Reward 1
Iteration 435: Arm 1, Reward 0
Iteration 436: Arm 1, Reward 1
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Iteration 438: Arm 1, Reward 1
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Iteration 441: Arm 1, Reward 1
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Iteration 445: Arm 1, Reward 0
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Iteration 452: Arm 3, Reward 1
Iteration 453: Arm 3, Reward 1
Iteration 454: Arm 3, Reward 1
Iteration 455: Arm 3, Reward 0
Iteration 456: Arm 3, Reward 0
Iteration 457: Arm 1, Reward 0
Iteration 458: Arm 2, Reward 0
Iteration 459: Arm 3, Reward 1
Iteration 460: Arm 3, Reward 0
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Iteration 462: Arm 3, Reward 0
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Iteration 481: Arm 0, Reward 0
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Iteration 488: Arm 1, Reward 0
Iteration 489: Arm 3, Reward 0
Iteration 490: Arm 1, Reward 1
Iteration 491: Arm 1, Reward 1
Iteration 492: Arm 1, Reward 1
Iteration 493: Arm 1, Reward 1
Iteration 494: Arm 1, Reward 1
Iteration 495: Arm 1, Reward 1
Iteration 496: Arm 1, Reward 1
Iteration 497: Arm 1, Reward 0
Iteration 498: Arm 1, Reward 1
Iteration 499: Arm 1, Reward 1
Iteration 500: Arm 1, Reward 1
Iteration 501: Arm 1, Reward 1
Iteration 502: Arm 1, Reward 0
Iteration 503: Arm 1, Reward 0
Iteration 504: Arm 1, Reward 1
Iteration 505: Arm 1, Reward 0
Iteration 506: Arm 1, Reward 1
Iteration 507: Arm 1, Reward 0
Iteration 508: Arm 1, Reward 1
Iteration 509: Arm 1, Reward 1
Iteration 510: Arm 1, Reward 1
Iteration 511: Arm 1, Reward 0
Iteration 512: Arm 1, Reward 1
Iteration 513: Arm 1, Reward 1
Iteration 514: Arm 1, Reward 1
Iteration 515: Arm 1, Reward 0
Iteration 516: Arm 1, Reward 0
Iteration 517: Arm 1, Reward 1
Iteration 518: Arm 1, Reward 0
Iteration 519: Arm 1, Reward 0
Iteration 520: Arm 1, Reward 1
Iteration 521: Arm 1, Reward 0
Iteration 522: Arm 2, Reward 1
Iteration 523: Arm 2, Reward 0
Iteration 524: Arm 0, Reward 1
Iteration 525: Arm 0, Reward 0
Iteration 526: Arm 1, Reward 0
Iteration 527: Arm 2, Reward 0
Iteration 528: Arm 0, Reward 0
Iteration 529: Arm 3, Reward 1
Iteration 530: Arm 3, Reward 0
Iteration 531: Arm 1, Reward 1
Iteration 532: Arm 1, Reward 1
Iteration 533: Arm 1, Reward 0
Iteration 534: Arm 1, Reward 0
Iteration 535: Arm 3, Reward 1
Iteration 536: Arm 3, Reward 0
Iteration 537: Arm 3, Reward 0
Iteration 538: Arm 1, Reward 0
Iteration 539: Arm 2, Reward 1
Iteration 540: Arm 2, Reward 0

Iteration 541: Arm 1, Reward 1
Iteration 542: Arm 1, Reward 1
Iteration 543: Arm 1, Reward 0
Iteration 544: Arm 1, Reward 0
Iteration 545: Arm 0, Reward 0
Iteration 546: Arm 2, Reward 1
Iteration 547: Arm 2, Reward 1
Iteration 548: Arm 2, Reward 0
Iteration 549: Arm 2, Reward 0
Iteration 550: Arm 3, Reward 0
Iteration 551: Arm 1, Reward 1
Iteration 552: Arm 1, Reward 0
Iteration 553: Arm 1, Reward 1
Iteration 554: Arm 1, Reward 0
Iteration 555: Arm 2, Reward 0
Iteration 556: Arm 1, Reward 1
Iteration 557: Arm 1, Reward 1
Iteration 558: Arm 1, Reward 1
Iteration 559: Arm 1, Reward 0
Iteration 560: Arm 1, Reward 0
Iteration 561: Arm 1, Reward 1
Iteration 562: Arm 1, Reward 0
Iteration 563: Arm 3, Reward 1
Iteration 564: Arm 3, Reward 1
Iteration 565: Arm 3, Reward 1
Iteration 566: Arm 3, Reward 0
Iteration 567: Arm 3, Reward 0
Iteration 568: Arm 0, Reward 0
Iteration 569: Arm 3, Reward 1
Iteration 570: Arm 3, Reward 1
Iteration 571: Arm 3, Reward 1
Iteration 572: Arm 3, Reward 0
Iteration 573: Arm 3, Reward 0
Iteration 574: Arm 1, Reward 1
Iteration 575: Arm 1, Reward 1
Iteration 576: Arm 1, Reward 0
Iteration 577: Arm 1, Reward 1
Iteration 578: Arm 1, Reward 1
Iteration 579: Arm 1, Reward 0
Iteration 580: Arm 1, Reward 0
Iteration 581: Arm 3, Reward 0
Iteration 582: Arm 2, Reward 1
Iteration 583: Arm 2, Reward 1
Iteration 584: Arm 2, Reward 0
Iteration 585: Arm 2, Reward 0
Iteration 586: Arm 1, Reward 1
Iteration 587: Arm 1, Reward 1
Iteration 588: Arm 1, Reward 1
Iteration 589: Arm 1, Reward 1
Iteration 590: Arm 1, Reward 1
Iteration 591: Arm 1, Reward 0
Iteration 592: Arm 1, Reward 1
Iteration 593: Arm 1, Reward 1
Iteration 594: Arm 1, Reward 0
Iteration 595: Arm 1, Reward 0
Iteration 596: Arm 1, Reward 1
Iteration 597: Arm 1, Reward 1
Iteration 598: Arm 1, Reward 0
Iteration 599: Arm 1, Reward 1
Iteration 600: Arm 1, Reward 1

Iteration 601: Arm 1, Reward 1
Iteration 602: Arm 1, Reward 0
Iteration 603: Arm 1, Reward 0
Iteration 604: Arm 1, Reward 1
Iteration 605: Arm 1, Reward 1
Iteration 606: Arm 1, Reward 0
Iteration 607: Arm 1, Reward 0
Iteration 608: Arm 3, Reward 1
Iteration 609: Arm 3, Reward 0
Iteration 610: Arm 1, Reward 0
Iteration 611: Arm 2, Reward 0
Iteration 612: Arm 0, Reward 0
Iteration 613: Arm 3, Reward 0
Iteration 614: Arm 1, Reward 1
Iteration 615: Arm 1, Reward 0
Iteration 616: Arm 1, Reward 1
Iteration 617: Arm 1, Reward 1
Iteration 618: Arm 1, Reward 0
Iteration 619: Arm 1, Reward 0
Iteration 620: Arm 2, Reward 1
Iteration 621: Arm 2, Reward 0
Iteration 622: Arm 1, Reward 1
Iteration 623: Arm 1, Reward 0
Iteration 624: Arm 3, Reward 1
Iteration 625: Arm 3, Reward 1
Iteration 626: Arm 3, Reward 0
Iteration 627: Arm 3, Reward 1
Iteration 628: Arm 3, Reward 1
Iteration 629: Arm 3, Reward 0
Iteration 630: Arm 3, Reward 1
Iteration 631: Arm 3, Reward 1
Iteration 632: Arm 3, Reward 1
Iteration 633: Arm 3, Reward 0
Iteration 634: Arm 3, Reward 0
Iteration 635: Arm 3, Reward 0
Iteration 636: Arm 2, Reward 0
Iteration 637: Arm 1, Reward 1
Iteration 638: Arm 1, Reward 1
Iteration 639: Arm 1, Reward 1
Iteration 640: Arm 1, Reward 1
Iteration 641: Arm 1, Reward 1
Iteration 642: Arm 1, Reward 0
Iteration 643: Arm 1, Reward 1
Iteration 644: Arm 1, Reward 0
Iteration 645: Arm 1, Reward 0
Iteration 646: Arm 1, Reward 0
Iteration 647: Arm 0, Reward 0
Iteration 648: Arm 3, Reward 1
Iteration 649: Arm 3, Reward 0
Iteration 650: Arm 1, Reward 0
Iteration 651: Arm 3, Reward 1
Iteration 652: Arm 3, Reward 0
Iteration 653: Arm 1, Reward 0
Iteration 654: Arm 3, Reward 0
Iteration 655: Arm 2, Reward 0
Iteration 656: Arm 1, Reward 1
Iteration 657: Arm 1, Reward 1
Iteration 658: Arm 1, Reward 0
Iteration 659: Arm 1, Reward 0
Iteration 660: Arm 0, Reward 1

Iteration 661: Arm 0, Reward 1
Iteration 662: Arm 0, Reward 0
Iteration 663: Arm 0, Reward 0
Iteration 664: Arm 1, Reward 1
Iteration 665: Arm 1, Reward 0
Iteration 666: Arm 3, Reward 0
Iteration 667: Arm 1, Reward 0
Iteration 668: Arm 0, Reward 0
Iteration 669: Arm 2, Reward 1
Iteration 670: Arm 2, Reward 0
Iteration 671: Arm 2, Reward 1
Iteration 672: Arm 2, Reward 0
Iteration 673: Arm 1, Reward 1
Iteration 674: Arm 1, Reward 1
Iteration 675: Arm 1, Reward 1
Iteration 676: Arm 1, Reward 0
Iteration 677: Arm 1, Reward 1
Iteration 678: Arm 1, Reward 0
Iteration 679: Arm 1, Reward 0
Iteration 680: Arm 3, Reward 1
Iteration 681: Arm 3, Reward 0
Iteration 682: Arm 2, Reward 1
Iteration 683: Arm 2, Reward 0
Iteration 684: Arm 1, Reward 1
Iteration 685: Arm 1, Reward 0
Iteration 686: Arm 3, Reward 1
Iteration 687: Arm 3, Reward 1
Iteration 688: Arm 3, Reward 0
Iteration 689: Arm 3, Reward 0
Iteration 690: Arm 2, Reward 0
Iteration 691: Arm 1, Reward 0
Iteration 692: Arm 0, Reward 0
Iteration 693: Arm 1, Reward 1
Iteration 694: Arm 1, Reward 1
Iteration 695: Arm 1, Reward 0
Iteration 696: Arm 1, Reward 1
Iteration 697: Arm 1, Reward 0
Iteration 698: Arm 3, Reward 1
Iteration 699: Arm 3, Reward 0
Iteration 700: Arm 1, Reward 1
Iteration 701: Arm 1, Reward 1
Iteration 702: Arm 1, Reward 0
Iteration 703: Arm 1, Reward 1
Iteration 704: Arm 1, Reward 1
Iteration 705: Arm 1, Reward 1
Iteration 706: Arm 1, Reward 1
Iteration 707: Arm 1, Reward 1
Iteration 708: Arm 1, Reward 1
Iteration 709: Arm 1, Reward 0
Iteration 710: Arm 1, Reward 0
Iteration 711: Arm 1, Reward 0
Iteration 712: Arm 1, Reward 0
Iteration 713: Arm 3, Reward 0
Iteration 714: Arm 1, Reward 1
Iteration 715: Arm 1, Reward 1
Iteration 716: Arm 1, Reward 1
Iteration 717: Arm 1, Reward 0
Iteration 718: Arm 1, Reward 0
Iteration 719: Arm 2, Reward 1
Iteration 720: Arm 2, Reward 1

Iteration 721: Arm 2, Reward 1
Iteration 722: Arm 2, Reward 1
Iteration 723: Arm 2, Reward 0
Iteration 724: Arm 2, Reward 1
Iteration 725: Arm 2, Reward 1
Iteration 726: Arm 2, Reward 0
Iteration 727: Arm 2, Reward 0
Iteration 728: Arm 2, Reward 1
Iteration 729: Arm 2, Reward 1
Iteration 730: Arm 2, Reward 1
Iteration 731: Arm 2, Reward 1
Iteration 732: Arm 2, Reward 0
Iteration 733: Arm 2, Reward 1
Iteration 734: Arm 2, Reward 1
Iteration 735: Arm 2, Reward 0
Iteration 736: Arm 2, Reward 0
Iteration 737: Arm 2, Reward 1
Iteration 738: Arm 2, Reward 0
Iteration 739: Arm 2, Reward 0
Iteration 740: Arm 2, Reward 1
Iteration 741: Arm 2, Reward 0
Iteration 742: Arm 2, Reward 0
Iteration 743: Arm 1, Reward 1
Iteration 744: Arm 1, Reward 1
Iteration 745: Arm 1, Reward 0
Iteration 746: Arm 1, Reward 1
Iteration 747: Arm 1, Reward 1
Iteration 748: Arm 1, Reward 0
Iteration 749: Arm 1, Reward 1
Iteration 750: Arm 1, Reward 0
Iteration 751: Arm 1, Reward 1
Iteration 752: Arm 1, Reward 1
Iteration 753: Arm 1, Reward 0
Iteration 754: Arm 1, Reward 1
Iteration 755: Arm 1, Reward 1
Iteration 756: Arm 1, Reward 1
Iteration 757: Arm 1, Reward 1
Iteration 758: Arm 1, Reward 0
Iteration 759: Arm 1, Reward 0
Iteration 760: Arm 1, Reward 0
Iteration 761: Arm 2, Reward 0
Iteration 762: Arm 0, Reward 0
Iteration 763: Arm 3, Reward 1
Iteration 764: Arm 3, Reward 0
Iteration 765: Arm 1, Reward 1
Iteration 766: Arm 1, Reward 1
Iteration 767: Arm 1, Reward 1
Iteration 768: Arm 1, Reward 1
Iteration 769: Arm 1, Reward 0
Iteration 770: Arm 1, Reward 1
Iteration 771: Arm 1, Reward 1
Iteration 772: Arm 1, Reward 1
Iteration 773: Arm 1, Reward 0
Iteration 774: Arm 1, Reward 1
Iteration 775: Arm 1, Reward 0
Iteration 776: Arm 1, Reward 1
Iteration 777: Arm 1, Reward 1
Iteration 778: Arm 1, Reward 0
Iteration 779: Arm 1, Reward 1
Iteration 780: Arm 1, Reward 0

Iteration 781: Arm 1, Reward 1
Iteration 782: Arm 1, Reward 1
Iteration 783: Arm 1, Reward 1
Iteration 784: Arm 1, Reward 0
Iteration 785: Arm 1, Reward 1
Iteration 786: Arm 1, Reward 0
Iteration 787: Arm 1, Reward 1
Iteration 788: Arm 1, Reward 0
Iteration 789: Arm 1, Reward 0
Iteration 790: Arm 3, Reward 0
Iteration 791: Arm 1, Reward 1
Iteration 792: Arm 1, Reward 0
Iteration 793: Arm 1, Reward 1
Iteration 794: Arm 1, Reward 1
Iteration 795: Arm 1, Reward 1
Iteration 796: Arm 1, Reward 0
Iteration 797: Arm 1, Reward 1
Iteration 798: Arm 1, Reward 1
Iteration 799: Arm 1, Reward 1
Iteration 800: Arm 1, Reward 0
Iteration 801: Arm 1, Reward 1
Iteration 802: Arm 1, Reward 1
Iteration 803: Arm 1, Reward 1
Iteration 804: Arm 1, Reward 1
Iteration 805: Arm 1, Reward 1
Iteration 806: Arm 1, Reward 0
Iteration 807: Arm 1, Reward 1
Iteration 808: Arm 1, Reward 1
Iteration 809: Arm 1, Reward 0
Iteration 810: Arm 1, Reward 1
Iteration 811: Arm 1, Reward 1
Iteration 812: Arm 1, Reward 1
Iteration 813: Arm 1, Reward 1
Iteration 814: Arm 1, Reward 1
Iteration 815: Arm 1, Reward 1
Iteration 816: Arm 1, Reward 0
Iteration 817: Arm 1, Reward 1
Iteration 818: Arm 1, Reward 0
Iteration 819: Arm 1, Reward 1
Iteration 820: Arm 1, Reward 1
Iteration 821: Arm 1, Reward 1
Iteration 822: Arm 1, Reward 1
Iteration 823: Arm 1, Reward 1
Iteration 824: Arm 1, Reward 1
Iteration 825: Arm 1, Reward 1
Iteration 826: Arm 1, Reward 0
Iteration 827: Arm 1, Reward 0
Iteration 828: Arm 1, Reward 1
Iteration 829: Arm 1, Reward 0
Iteration 830: Arm 1, Reward 1
Iteration 831: Arm 1, Reward 0
Iteration 832: Arm 1, Reward 1
Iteration 833: Arm 1, Reward 1
Iteration 834: Arm 1, Reward 1
Iteration 835: Arm 1, Reward 1
Iteration 836: Arm 1, Reward 1
Iteration 837: Arm 1, Reward 1
Iteration 838: Arm 1, Reward 1
Iteration 839: Arm 1, Reward 1
Iteration 840: Arm 1, Reward 1

Iteration 841: Arm 1, Reward 0
Iteration 842: Arm 1, Reward 0
Iteration 843: Arm 1, Reward 0
Iteration 844: Arm 1, Reward 1
Iteration 845: Arm 1, Reward 1
Iteration 846: Arm 1, Reward 1
Iteration 847: Arm 1, Reward 1
Iteration 848: Arm 1, Reward 1
Iteration 849: Arm 1, Reward 0
Iteration 850: Arm 1, Reward 1
Iteration 851: Arm 1, Reward 1
Iteration 852: Arm 1, Reward 0
Iteration 853: Arm 1, Reward 1
Iteration 854: Arm 1, Reward 1
Iteration 855: Arm 1, Reward 1
Iteration 856: Arm 1, Reward 1
Iteration 857: Arm 1, Reward 0
Iteration 858: Arm 1, Reward 1
Iteration 859: Arm 1, Reward 0
Iteration 860: Arm 1, Reward 1
Iteration 861: Arm 1, Reward 1
Iteration 862: Arm 1, Reward 1
Iteration 863: Arm 1, Reward 0
Iteration 864: Arm 1, Reward 1
Iteration 865: Arm 1, Reward 0
Iteration 866: Arm 1, Reward 0
Iteration 867: Arm 1, Reward 1
Iteration 868: Arm 1, Reward 0
Iteration 869: Arm 1, Reward 1
Iteration 870: Arm 1, Reward 0
Iteration 871: Arm 1, Reward 0
Iteration 872: Arm 1, Reward 0
Iteration 873: Arm 1, Reward 1
Iteration 874: Arm 1, Reward 1
Iteration 875: Arm 1, Reward 0
Iteration 876: Arm 1, Reward 0
Iteration 877: Arm 1, Reward 1
Iteration 878: Arm 1, Reward 1
Iteration 879: Arm 1, Reward 0
Iteration 880: Arm 1, Reward 0
Iteration 881: Arm 1, Reward 0
Iteration 882: Arm 1, Reward 0
Iteration 883: Arm 1, Reward 0
Iteration 884: Arm 2, Reward 0
Iteration 885: Arm 1, Reward 1
Iteration 886: Arm 1, Reward 1
Iteration 887: Arm 1, Reward 0
Iteration 888: Arm 1, Reward 0
Iteration 889: Arm 1, Reward 0
Iteration 890: Arm 3, Reward 1
Iteration 891: Arm 3, Reward 0
Iteration 892: Arm 0, Reward 1
Iteration 893: Arm 0, Reward 1
Iteration 894: Arm 0, Reward 0
Iteration 895: Arm 0, Reward 1
Iteration 896: Arm 0, Reward 0
Iteration 897: Arm 0, Reward 0
Iteration 898: Arm 1, Reward 0
Iteration 899: Arm 3, Reward 0
Iteration 900: Arm 2, Reward 0

Iteration 901: Arm 1, Reward 0
Iteration 902: Arm 0, Reward 0
Iteration 903: Arm 1, Reward 0
Iteration 904: Arm 3, Reward 1
Iteration 905: Arm 3, Reward 0
Iteration 906: Arm 1, Reward 1
Iteration 907: Arm 1, Reward 1
Iteration 908: Arm 1, Reward 1
Iteration 909: Arm 1, Reward 1
Iteration 910: Arm 1, Reward 0
Iteration 911: Arm 1, Reward 0
Iteration 912: Arm 1, Reward 0
Iteration 913: Arm 2, Reward 1
Iteration 914: Arm 2, Reward 0
Iteration 915: Arm 3, Reward 1
Iteration 916: Arm 3, Reward 0
Iteration 917: Arm 1, Reward 1
Iteration 918: Arm 1, Reward 1
Iteration 919: Arm 1, Reward 0
Iteration 920: Arm 1, Reward 1
Iteration 921: Arm 1, Reward 1
Iteration 922: Arm 1, Reward 1
Iteration 923: Arm 1, Reward 0
Iteration 924: Arm 1, Reward 0
Iteration 925: Arm 2, Reward 0
Iteration 926: Arm 1, Reward 1
Iteration 927: Arm 1, Reward 0
Iteration 928: Arm 3, Reward 0
Iteration 929: Arm 1, Reward 0
Iteration 930: Arm 1, Reward 1
Iteration 931: Arm 1, Reward 1
Iteration 932: Arm 1, Reward 0
Iteration 933: Arm 1, Reward 1
Iteration 934: Arm 1, Reward 1
Iteration 935: Arm 1, Reward 0
Iteration 936: Arm 1, Reward 1
Iteration 937: Arm 1, Reward 1
Iteration 938: Arm 1, Reward 1
Iteration 939: Arm 1, Reward 0
Iteration 940: Arm 1, Reward 0
Iteration 941: Arm 0, Reward 0
Iteration 942: Arm 1, Reward 0
Iteration 943: Arm 2, Reward 0
Iteration 944: Arm 3, Reward 1
Iteration 945: Arm 3, Reward 1
Iteration 946: Arm 3, Reward 0
Iteration 947: Arm 3, Reward 1
Iteration 948: Arm 3, Reward 1
Iteration 949: Arm 3, Reward 0
Iteration 950: Arm 3, Reward 0
Iteration 951: Arm 1, Reward 0
Iteration 952: Arm 3, Reward 0
Iteration 953: Arm 1, Reward 1
Iteration 954: Arm 1, Reward 0
Iteration 955: Arm 1, Reward 1
Iteration 956: Arm 1, Reward 0
Iteration 957: Arm 1, Reward 1
Iteration 958: Arm 1, Reward 0
Iteration 959: Arm 1, Reward 1
Iteration 960: Arm 1, Reward 1

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Iteration 961: Arm 1, Reward 1
Iteration 962: Arm 1, Reward 0
Iteration 963: Arm 1, Reward 0
Iteration 964: Arm 2, Reward 1
Iteration 965: Arm 2, Reward 0
Iteration 966: Arm 1, Reward 0
Iteration 967: Arm 0, Reward 0
Iteration 968: Arm 3, Reward 1
Iteration 969: Arm 3, Reward 0
Iteration 970: Arm 2, Reward 0
Iteration 971: Arm 1, Reward 0
Iteration 972: Arm 3, Reward 0
Iteration 973: Arm 1, Reward 1
Iteration 974: Arm 1, Reward 0
Iteration 975: Arm 1, Reward 1
Iteration 976: Arm 1, Reward 1
Iteration 977: Arm 1, Reward 0
Iteration 978: Arm 1, Reward 1
Iteration 979: Arm 1, Reward 0
Iteration 980: Arm 1, Reward 1
Iteration 981: Arm 1, Reward 1
Iteration 982: Arm 1, Reward 0
Iteration 983: Arm 1, Reward 0
Iteration 984: Arm 2, Reward 0
Iteration 985: Arm 1, Reward 0
Iteration 986: Arm 3, Reward 0
Iteration 987: Arm 0, Reward 0
Iteration 988: Arm 1, Reward 0
Iteration 989: Arm 1, Reward 1
Iteration 990: Arm 1, Reward 1
Iteration 991: Arm 1, Reward 0
Iteration 992: Arm 1, Reward 1
Iteration 993: Arm 1, Reward 1
Iteration 994: Arm 1, Reward 1
Iteration 995: Arm 1, Reward 1
Iteration 996: Arm 1, Reward 0
Iteration 997: Arm 1, Reward 1
Iteration 998: Arm 1, Reward 0
Iteration 999: Arm 1, Reward 0
Iteration 1000: Arm 1, Reward 0

```

Plot the cumulative rewards for all policies on a single graph to compare their performance. (0.5M)

```

In [42]: plt.figure(figsize=(10,6)) # Set figure size

iterations = np.arange(1, NUM_ITERATIONS+1) # X-axis values

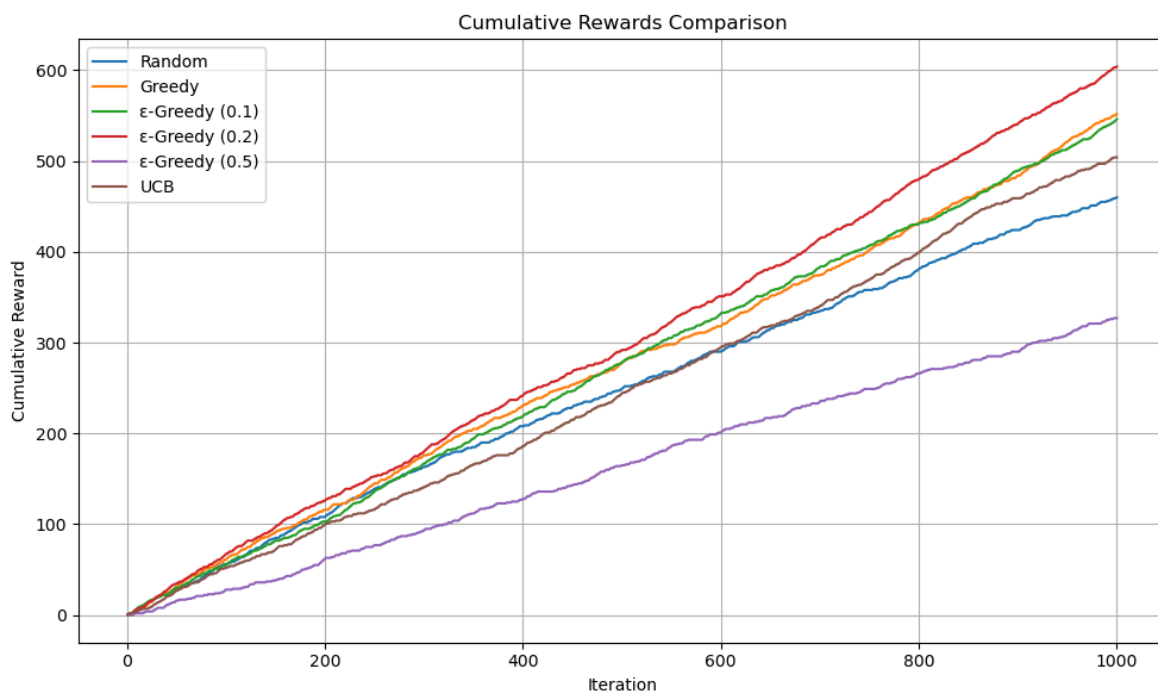
# Plot each policy's cumulative rewards
plt.plot(iterations, np.cumsum(random_rewards), label='Random')
plt.plot(iterations, np.cumsum(greedy_rewards), label='Greedy')

for eps in epsilon_values:
    plt.plot(iterations, np.cumsum(epsilon_rewards[eps]), label=f'ε-Greedy')

plt.plot(iterations, np.cumsum(ucb_rewards), label='UCB')

```

```
plt.xlabel('Iteration')           # X-axis label
plt.ylabel('Cumulative Reward')   # Y-axis label
plt.title('Cumulative Rewards Comparison') # Plot title
plt.legend()                     # Show legend
plt.grid(True)                   # Enable grid
plt.tight_layout()                # Adjust layout
plt.show()                       # Display plot
```



Conclusion: Performance of Bandit Strategies

The simulation clearly demonstrates the effectiveness of different bandit strategies over 1,000 iterations:

- ϵ -Greedy ($\epsilon=0.2$) now outperforms all other strategies, achieving the highest cumulative reward over 1,000 iterations. This suggests that a moderate exploration rate helps escape early suboptimal arms and leads to better long-term exploitation.
- Greedy and ϵ -Greedy ($\epsilon=0.1$) perform closely behind, with very similar slopes. However, they fall short of $\epsilon=0.2$ due to limited exploration, especially in the early iterations.
- Random sits in the middle — better than high- ϵ and UCB, but worse than the more strategic ϵ -Greedy variants. As expected, lack of learning limits its potential.
- ϵ -Greedy ($\epsilon=0.5$) performs the worst. Its excessive exploration delays learning and reduces exploitation of the best arm, highlighting that too much randomness is as bad as too little.
- UCB underperforms here, suggesting it may be over-conservative or ill-suited to the reward distribution in this specific environment. Its regret grows steadily due to slow adaptation.

Final Takeaway:

The sweet spot in this scenario is $\epsilon=0.2$, balancing exploration and exploitation effectively. Both Greedy and lower- ϵ variants can converge quickly but risk missing better arms. Too much exploration ($\epsilon=0.5$) or uncertainty-based approaches (UCB) may be inefficient for clinical trial environments with sparse feedback.