CSC270

Garbage Collection Fundamentals

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Objectives

1. Explain the Garbage Collector

Explain the Garbage Collector

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Tasks

1. Advantages to using a GC
2. What triggers a GC?
3. Monitoring GCs in your app
4. Generational garbage collectors
5. Helping out the GC

Memory Management

- .NET/Mono use a **Garbage Collector** (referred to as **GC**) which periodically stops your program and frees the memory your app is no longer using

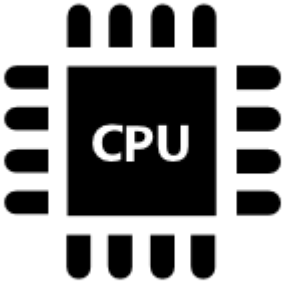
- GC in Mono and .NET are similar, but the implementation is quite different, so some strategies you use in .NET may need adjustment

Advantages to using a GC

- Most modern languages/runtimes include some form of GC because of the benefits associated with it

Simple to work with

Reduces Memory Leaks



Cache Locality

Demonstration

Show allocations and collections

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Working with the GC

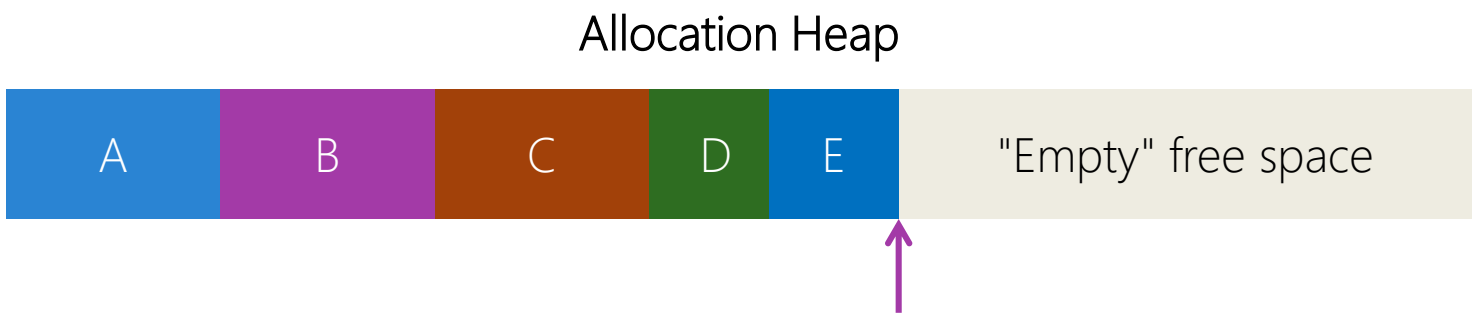
- Cannot *disable* GC, but understanding how it works can help you avoid performance issues in your application, there are two things you will be concerned with

What triggers a GC?

Minimizing the pause time introduced by GC

What triggers a GC?

- GC runs as part of the memory allocation process

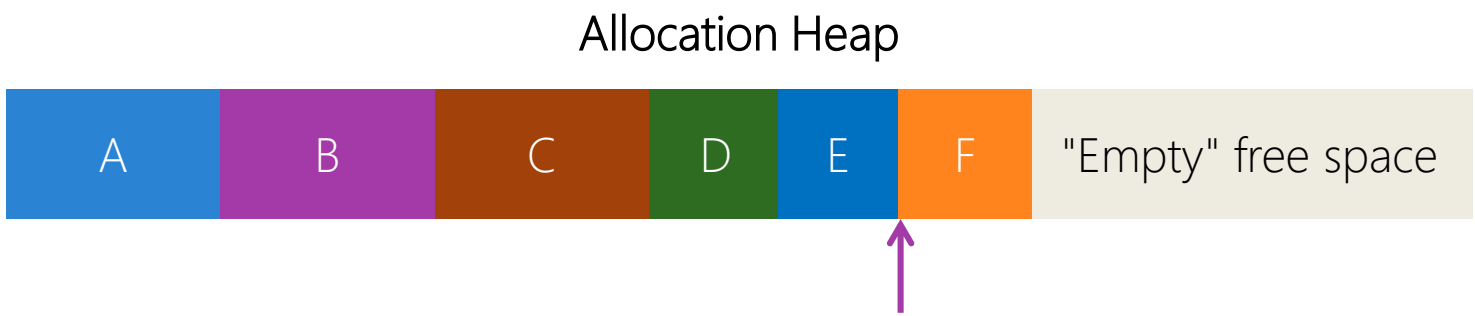



```
var f = new F();
```

Current allocation location
(pointer to free space)

What triggers a GC?

- Runtime uses a lock-free "pointer bump" allocation algorithm

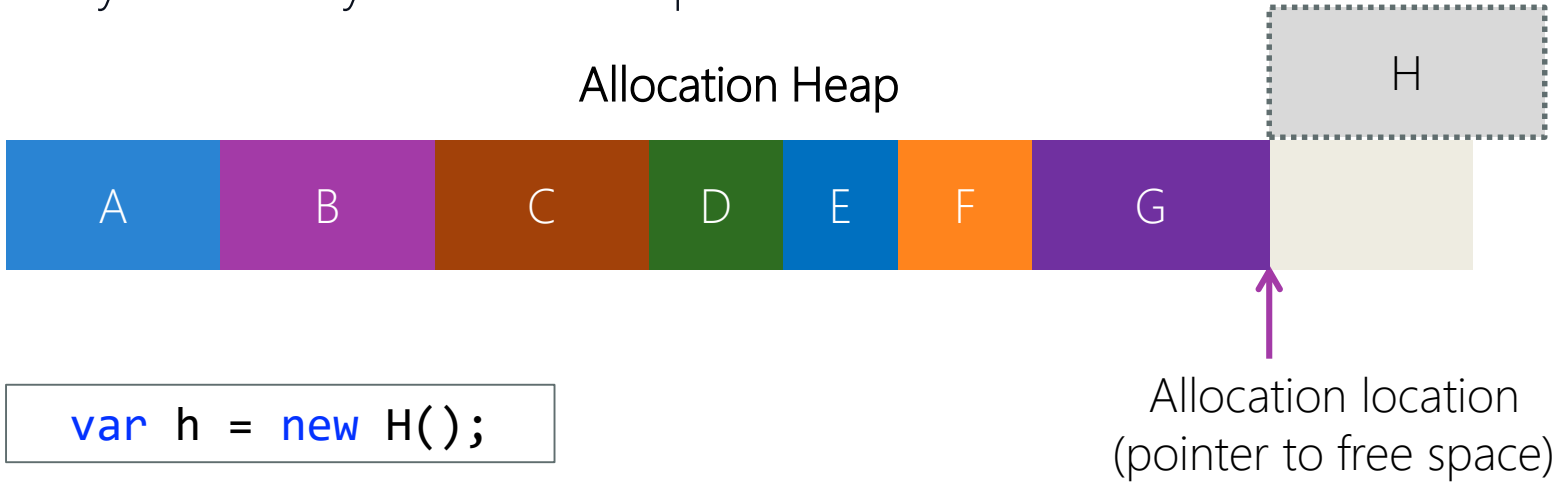


Allocator returns a memory block large enough to fit an "F" instance with the block zero'd out and moves "free" pointer

New allocation location (pointer to free space)

What triggers a GC?

- GC kicks in on the **current thread** when there's not enough space to satisfy a memory allocation request

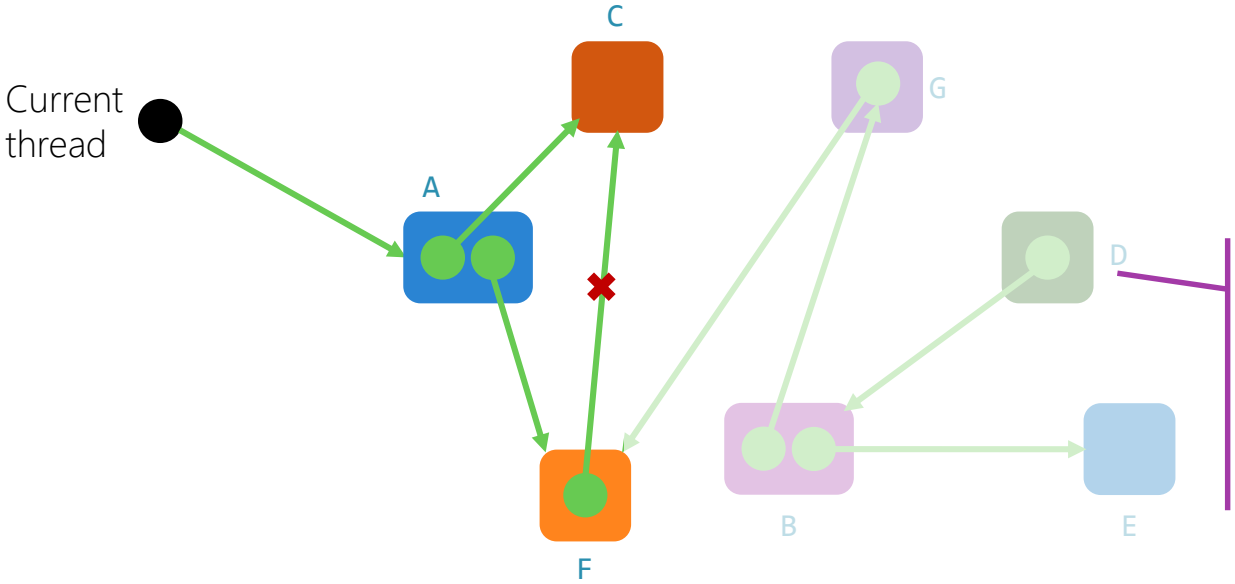



```
var h = new H();
```

There is not enough memory in allocation heap for **H** object – system triggers a GC on this thread to try to free up enough space

What happens during a GC?

- When a collection occurs, GC locates the **roots** and *traverses* the live reference graph from each one to determine what is reachable



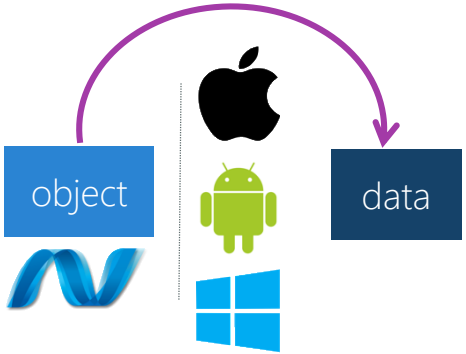
Objects left untouched are not reachable and thrown away (collected)

What is a "root"

- Live references are object instances that can be accessed from a **root object** coming from one of three places:

Static property or field

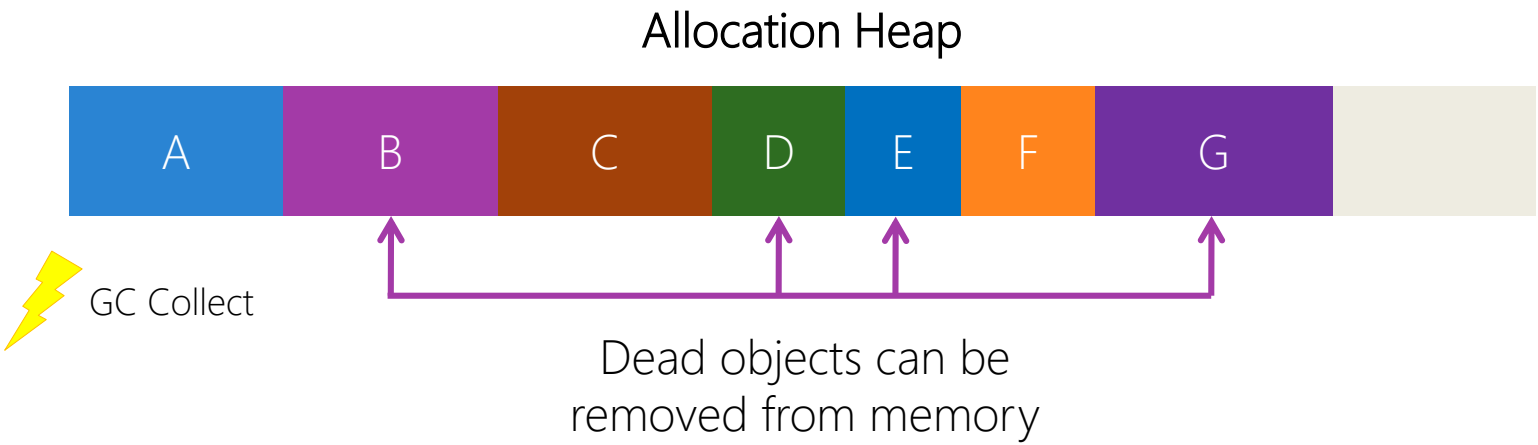
Reference on the stack of a managed thread



Objects passed into the native platform ("pinned")

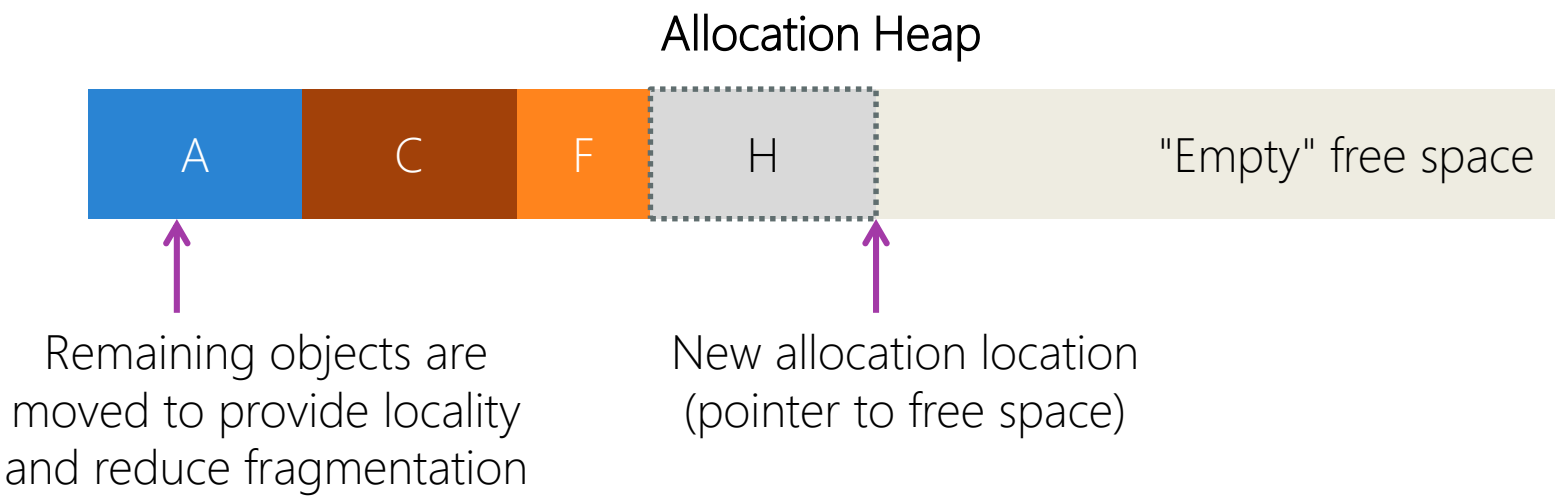
What triggers a GC?

- GC runs and identifies **live objects**, anything not referenced can be thrown away



What triggers a GC?

- Space is allocated for new object (H) and free space pointer is moved



What triggers a GC?

- Application code can also *request* that a garbage collection occur

```
Image bigPicture = ...;
...
bigPicture = null; // Image is no longer referenced

// Ask GC to run now .. to get rid of the image
GC.Collect();
```

Mono != .NET

- Mono implementation of **GC** class isn't as full featured as .NET

Does nothing	Partially implemented	Throws exception
AddMemoryPressure	Collect	WaitForFullGCApproach
RemoveMemoryPressure		WaitForFullGCComplete
		RegisterForFullGC Notification
		CancelFullGCNotification

Flash Quiz

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Flash Quiz

① The runtime triggers a garbage collection _____

a) Every two seconds on a timer

b) When you call `GC.Collect`

c) When you use the `Dispose` method on an object

d) When a memory allocation cannot be satisfied

Flash Quiz

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Flash Quiz

② GC always runs in parallel to your program code on a separate thread

a) True

b) False

Flash Quiz

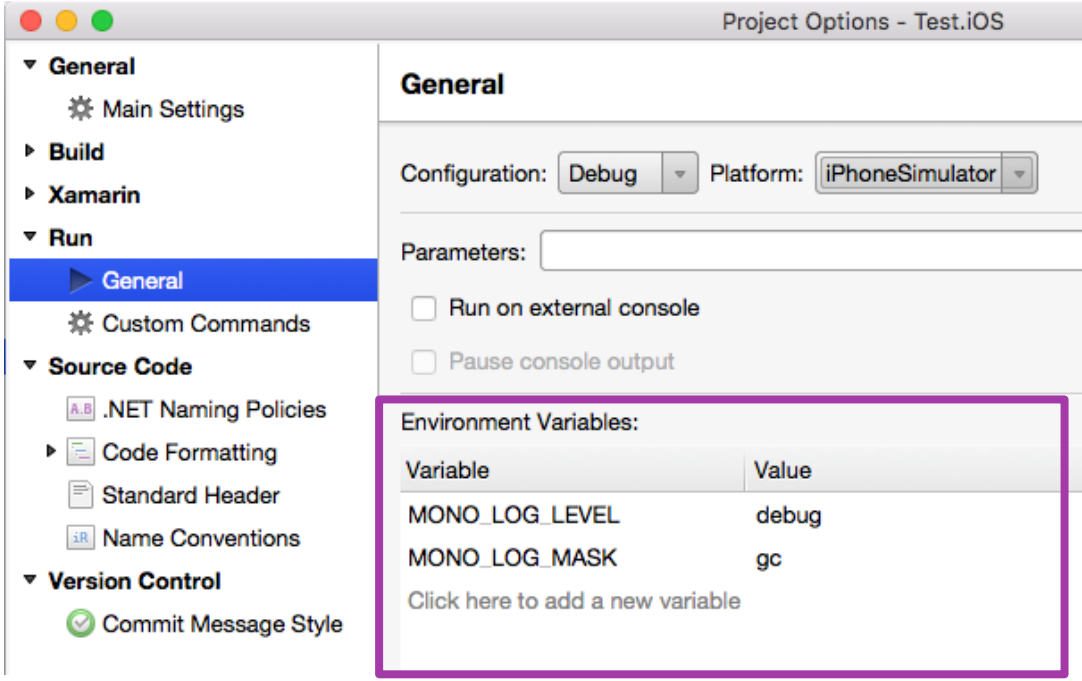
② GC always runs in parallel to your program code on a separate thread

a) True

b) False

Monitoring GCs in your app

- Xamarin.Android outputs GC traces to the debug console for all debug builds automatically
- Xamarin.iOS requires you add two environment variables to get the output in the debug console



Debug output

- GC messages are pre-pended with **GC_** tags

What triggered this GC

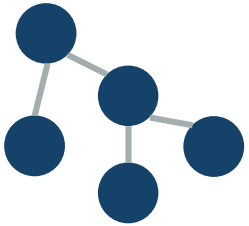
```
GC_MINOR: (Nursery full) pause 0.42ms, total 0.43ms, bridge 0.00ms promoted 5K major 5728K los 37K
GC_MAJOR: (user request) pause 6.07ms, total 6.07ms, bridge 0.00ms major 5728K/5728K los 29K/29K
```

How long did the GC take

How long does a GC take?

- The duration (pause time) it takes to do a collection depends on two primary factors:

What type, or **generation** of collection is occurring



How many objects are reachable and have to be examined

Generational garbage collectors

- GC works off the premise that *most objects die young*; Mono and Android separate objects into two *generations* (.NET uses three)

Nursery: where objects are allocated

Objects that get collected here tend to be *transient* or *temporary* objects such as strings, return values, and intermediate calculated objects used in methods

Generational garbage collectors

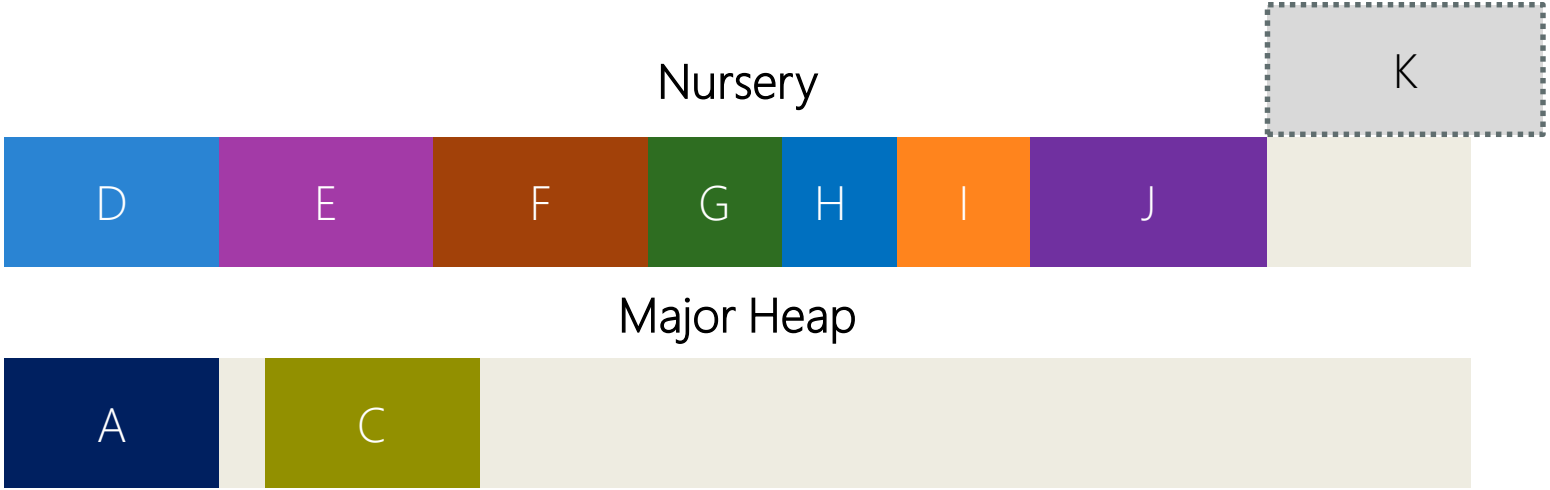
- GC works off the premise that *most objects die young*; Mono and Android separate objects into two *generations* (.NET uses three)

Objects moved here have survived a collection (matured) and statistically will likely be reachable for a while (e.g. sometimes for the entire life of the application)

Major:
objects which have survived a collection

Collecting the nursery

- Nursery collections happen anytime an allocation fails; since the nursery is small, this happens frequently and pauses tend to be short



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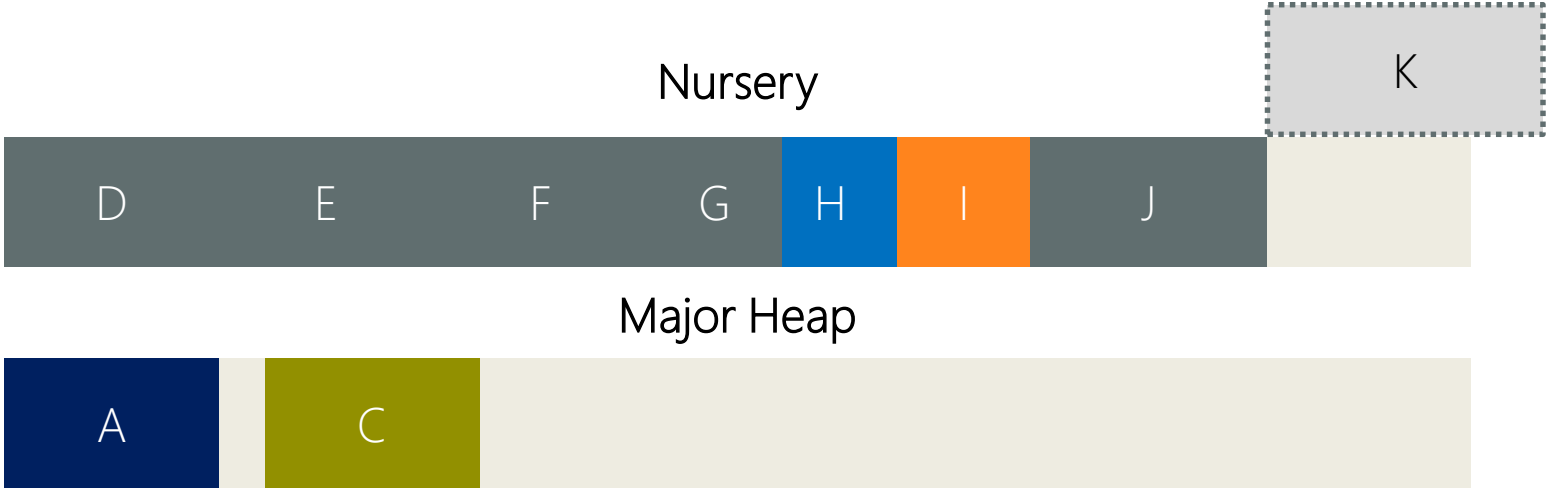
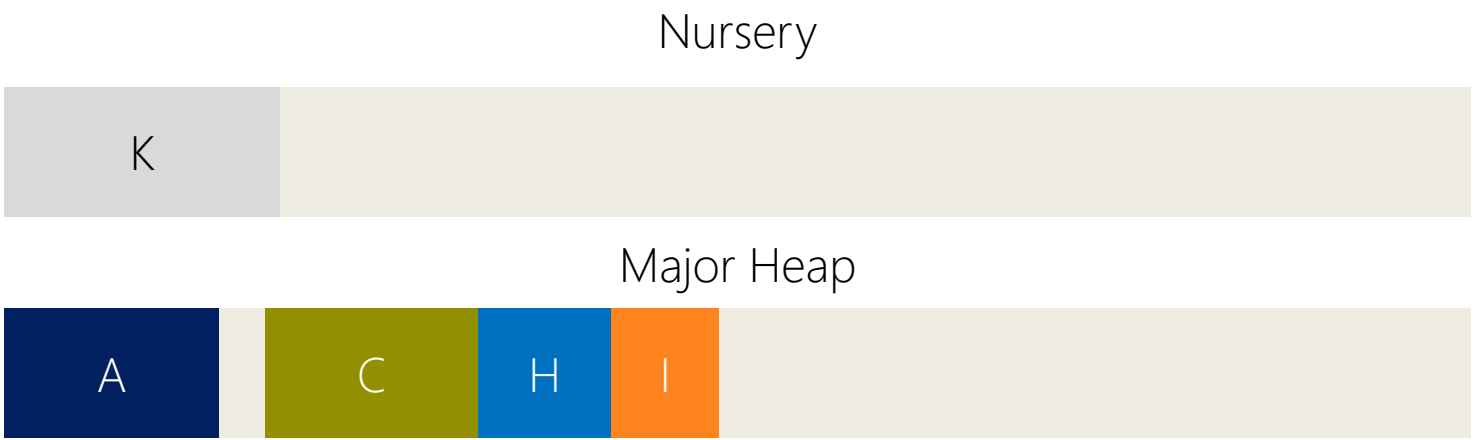


Adding generations

- Live objects are moved into **major heap** and pointer references are changed to point to the new locations



Debug log: promoting memory

- **GC_MINOR** reports promotion size and current major generation size

```
GC_MINOR: (Nursery full) pause 0.42ms, total 0.43ms, bridge 0.00ms promoted 5K major 5728K los 37K
```

How much memory survived nursery collection and was copied

How much is currently in the major generation

Debug log: memory growth

- **GC_MAJOR** reports current and previous memory usage for major heap and LOS; watch these values to identify potential leaks

```
GC_MAJOR: (user request) pause 6.53ms, total 6.54ms, bridge 0.00ms major
1008K/16912K los 64K/0K
```

How much memory is currently in use by the major generation

How much memory *was* in use prior to this collect?

Collecting the major heap

- Major heap is collected less frequently; typically due to promotion growth or when there's not enough space in the heap to complete a nursery collection

Remember: each time the GC runs, it **stops the world** and our app is not executing user code, major collections could potentially stop your app for up to a second

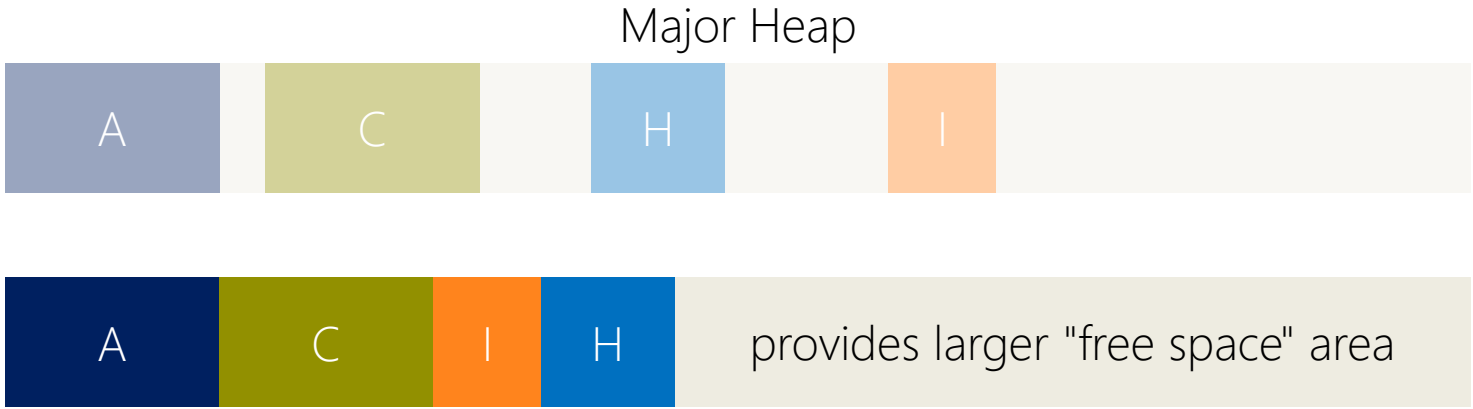
Nursery vs. Major collection ratio

- System allows the major heap to **grow by ~1/3** before initiating a full collection
- Healthy GC behavior is around **1:10** for major to minor collections, depending on what the app does
- Check debug log or use **`GC.CollectionCount`** to determine the ratio for your app

```
45.571 GC_MAJOR: ...
45.588 GC_MINOR: major 4256K
45.606 GC_MINOR: major 6320K
45.625 GC_MINOR: major 7888K
45.641 GC_MINOR: major 8336K
45.660 GC_MINOR: major 10416K
45.682 GC_MINOR: major 11840K
45.699 GC_MINOR: major 12160K
45.719 GC_MINOR: major 14240K
45.738 GC_MINOR: major 15536K
45.754 GC_MINOR: major 15728K
45.772 GC_MINOR: major 17808K
45.790 GC_MINOR: major 18976K
45.806 GC_MINOR: major 19040K
45.829 GC_MINOR: major 21104K
45.851 GC_MAJOR: ...
```

Compacting the major heap

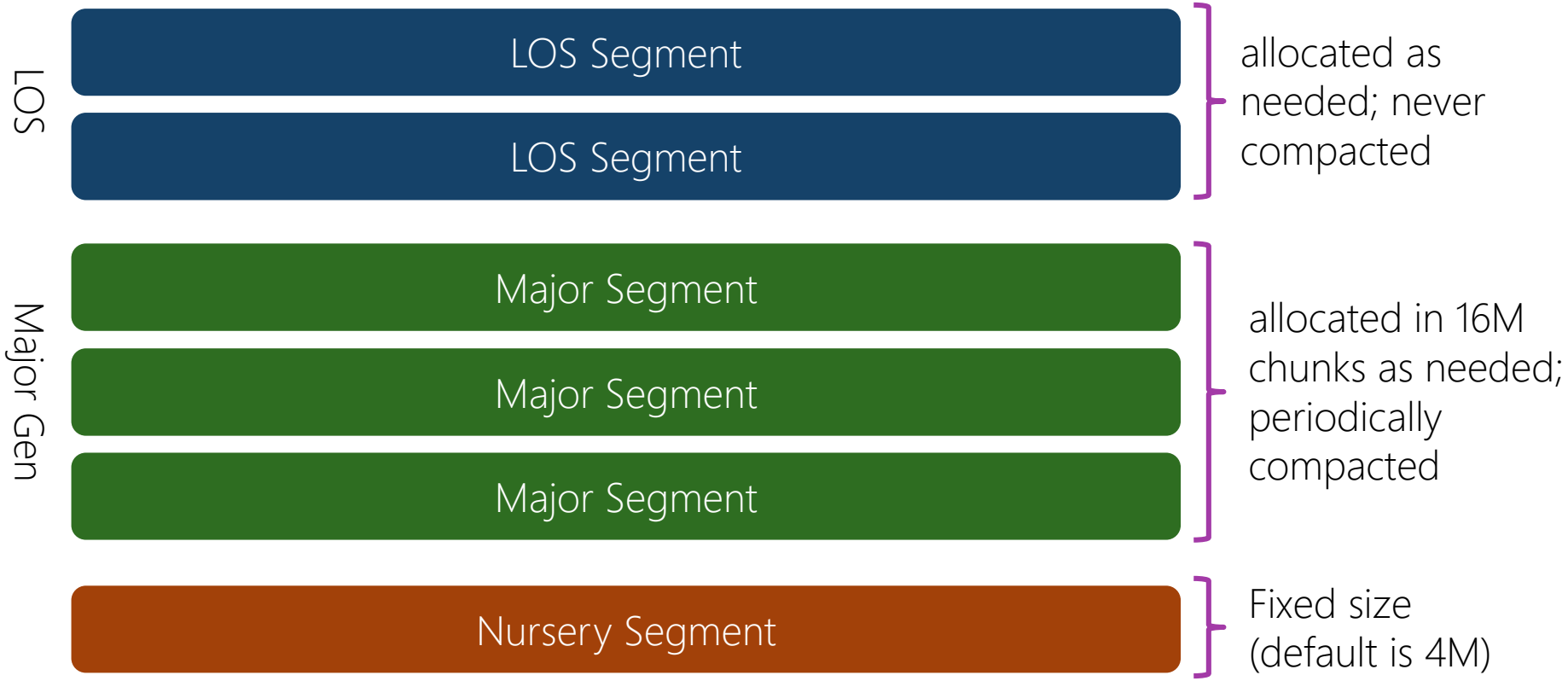
- Major heap is organized in *buckets* and objects are moved from the nursery into a specific bucket based on size; GC will *periodically compact* these buckets to reduce fragmentation



Big objects are different

- Some objects are more expensive to move/compact due to their size (i.e. large arrays)
- These *large objects* are placed into a special heap referred to as the **Large Object Space (LOS)** (or Large Object Heap in .NET)
- Collected on full collections and not compacted

SGen memory management



Flash Quiz

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Flash Quiz

① The **nursery generation** will grow and shrink based on usage

a) True

b) False

Flash Quiz

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a) True

b) False

Flash Quiz

② To turn on GC diagnostic tracing in iOS you need to _____

a) Do nothing. It's on by default.

b) Add an entry to your **info.plist**

c) Add two environment variables to the project settings

Flash Quiz

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Setting variables to null

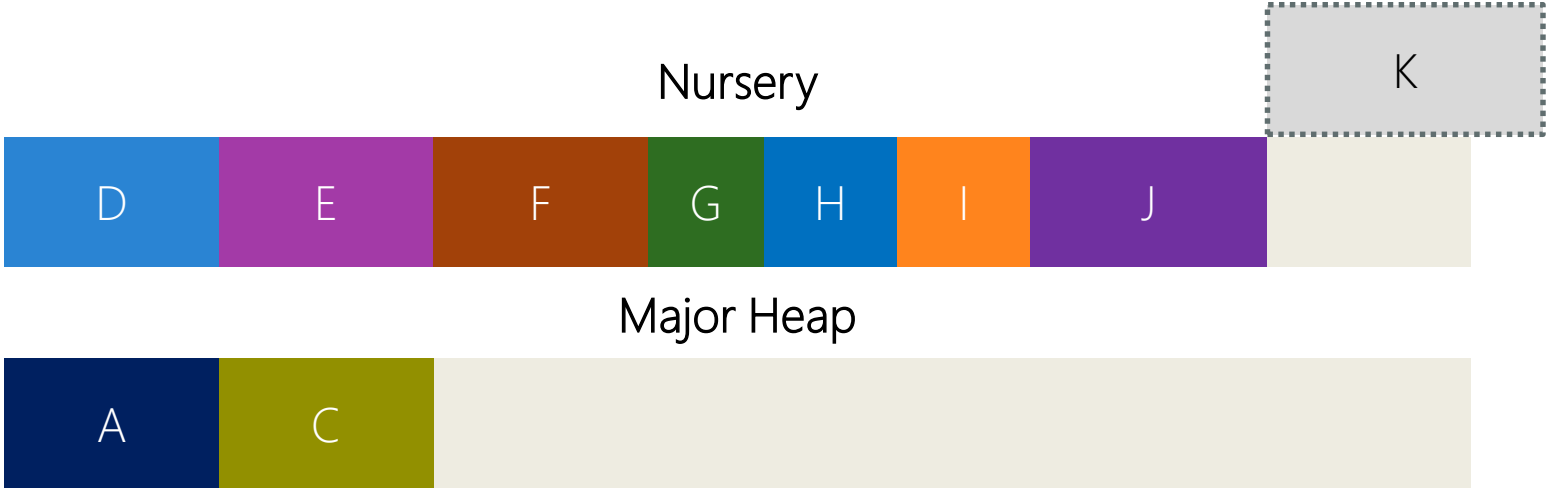
- Can set **static** or class instance fields and properties to **null** to let the GC collect the associated references

```
public class App : Application
{
    public IDBFactory DbFactory { get; set; }

    protected override void OnStart () {
        IDBRepository repo = DbFactory.Create ();
        ...
        // Don't need factory anymore.
        DbFactory = null;
    }
}
```

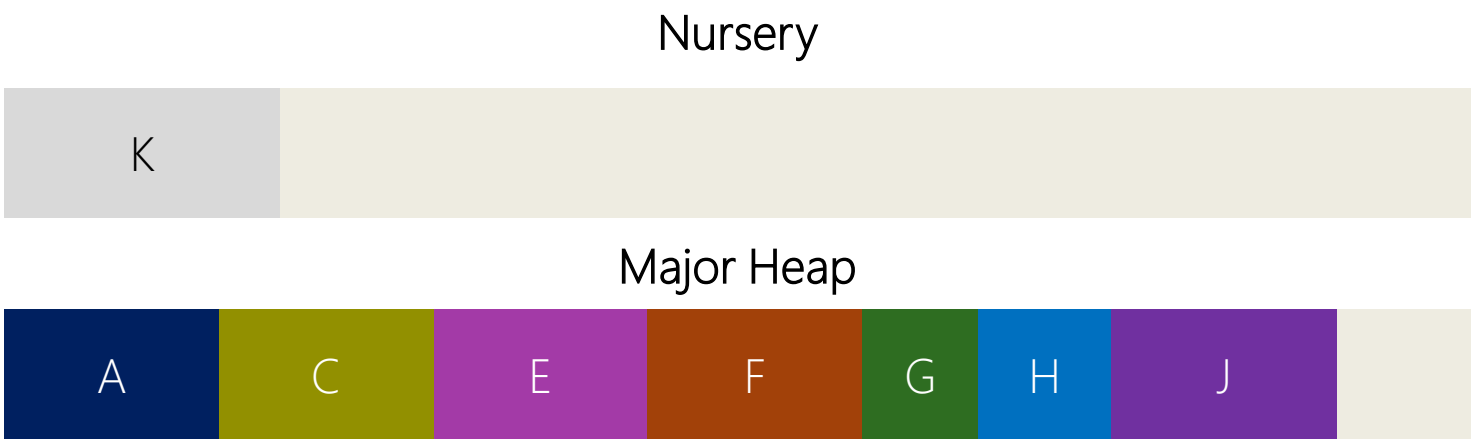
Best case scenario

- We want our objects to *either* have very short lifetimes and be removed in the nursery collection, or to live long lifetimes



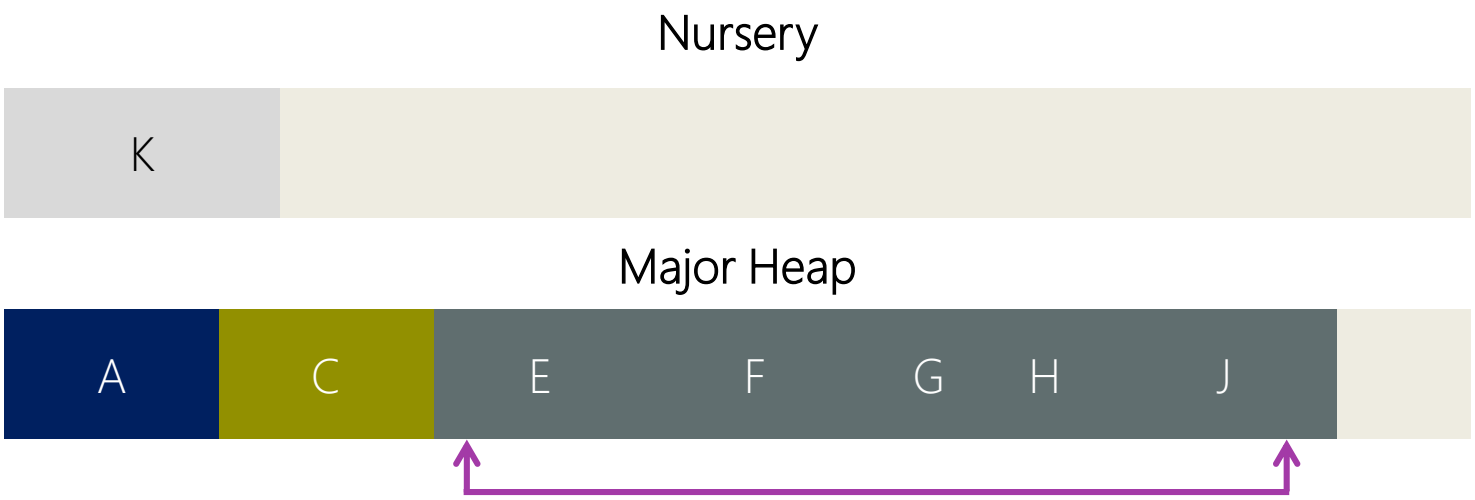
Worst case scenarios

- App is executing code which still had references to a bunch of temporary objects when a nursery collection occurs, which moves *all of these objects to the major generation!*



Worst case scenarios

- The worst thing scenario is when object(s) are promoted to the major generation *and then expires shortly thereafter*



Now these objects require a major generation collection to go away …

Minimizing the mid-life collection

- Can call **`GC.Collect`** before starting memory intensive data processing to try to avoid mid-processing collections

```
void DoSomeExpensiveThing()
{
    // Force a collect before we start so nursery is empty
    GC.Collect ();
    ... // Do work that allocates objects
}
```

Tweaking the GC

- **MONO_GC_PARAMS** environment variable can be set to tweak the GC settings based on your app needs

nursery-size=#bytes
(defaults to 4M)

Can change the fixed segment size used for the nursery to minimize the # of collections at the expensive of a larger working set

```
MONO_GC_PARAMS=nursery-size=8M
```

Tweaking the GC

- **MONO_GC_PARAMS** environment variable can be set to tweak the GC settings based on your app needs

nursery-size=#bytes
(defaults to 4M)

soft-heap-limit=#bytes
(defaults to -1)

Can set a max working set limit to reduce how often the major heap is collected

```
MONO_GC_PARAMS=soft-heap-limit=512M
```

Tweaking the GC

- **MONO_GC_PARAMS** environment variable can be set to tweak the GC settings based on your app needs

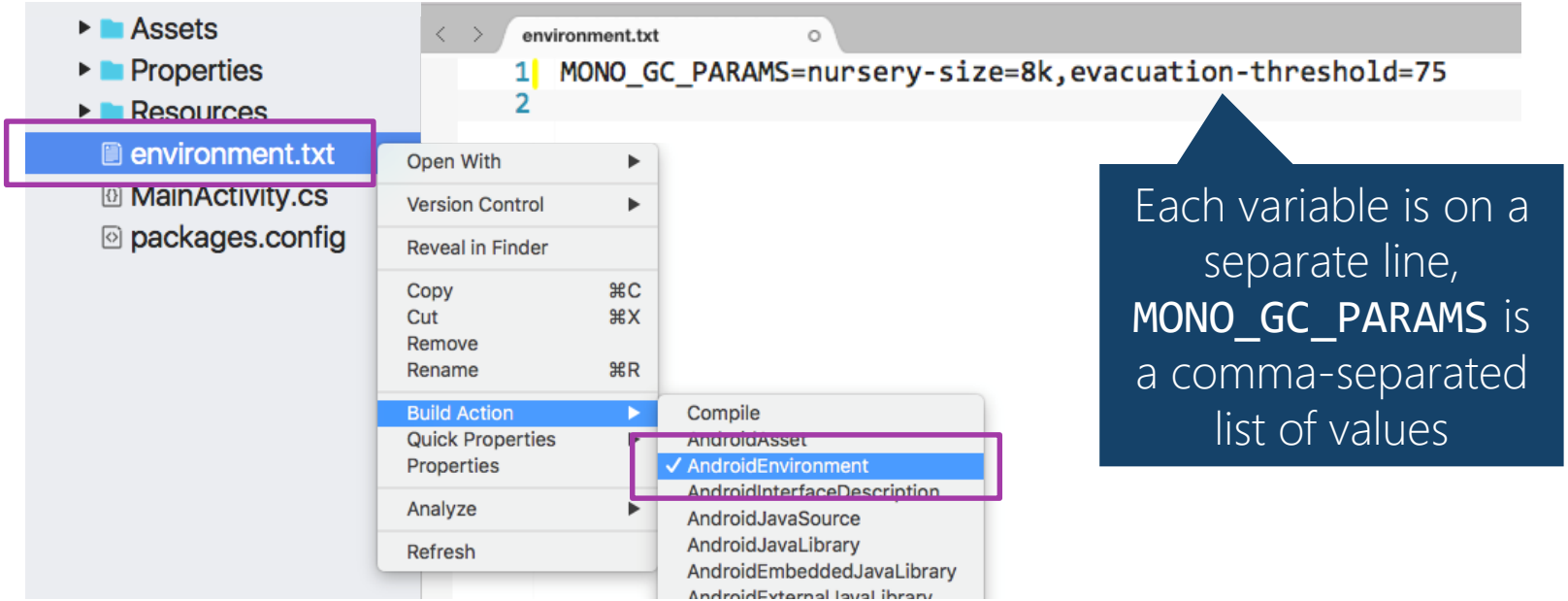
nursery-size=#bytes
(defaults to 4M)

Can adjust how often the major heap is compacted based on the fragmentation percentage

evacuation-threshold=%
(defaults to 66)

```
MONO_GC_PARAMS=evacuation-threshold=50
```

Setting environment variables in Android



Each variable is on a separate line, **MONO_GC_PARAMS** is a comma-separated list of values

Demonstration

Adjust the nursery size

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Summary

1. Advantages to using a GC
2. What triggers a GC?
3. Monitoring GCs in your app
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5. Helping out the GC

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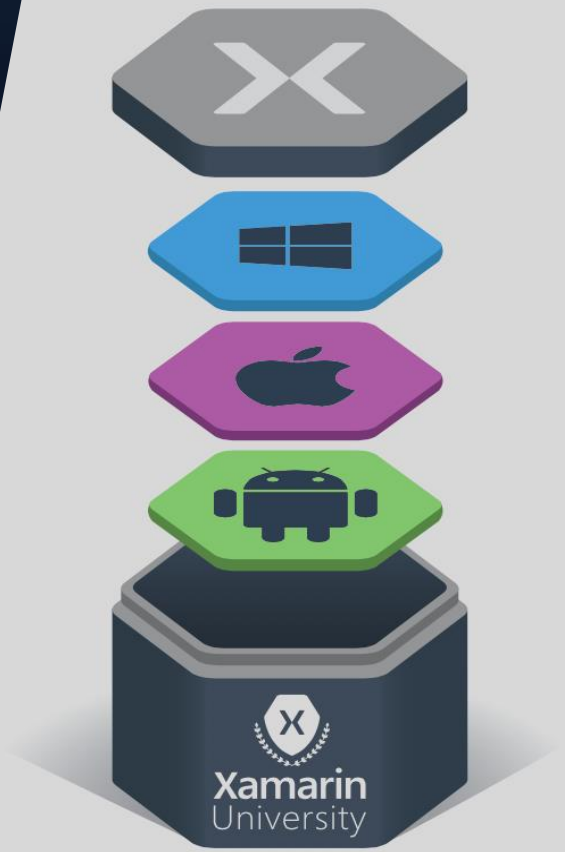

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