PCWorld

JANUARY 2019

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SNAPDRAGON RISING

QUALCOMM'S LATEST CHIPS FOR PHONES AND PCS

INSIDE: CREATIVE LABS' SOUNDBLASTERX AE-9 WILL AMAZE YOUR EARS


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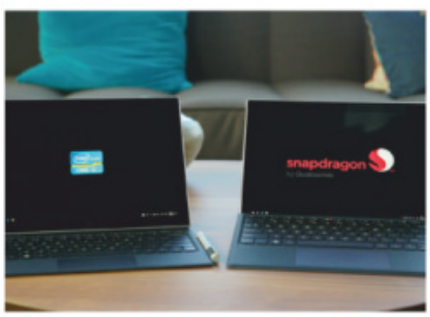
CONTENTS

PCWorld JANUARY 2019

» DEPARTMENTS

7 News



35 Reviews & Ratings

105 Here's How

128 Tech Spotlight

» FEATURES

90 23andMe vs. AncestryDNA. What's the difference?

96 DNA testing is more detailed for white people

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Exclusive first look: Creative Labs' high-end Sound BlasterX AE-9 breaks cover

We get hands-on with Creative Labs' newest audiophile sound card: The Sound BlasterX AE-9. **BY GORDON MAH UNG**

High-end audio lovers finally got the attention they craved when Creative Labs showed off its upcoming $300 Sound BlasterX AE-9 sound card.

Aimed at a more discriminating class of audio listeners, the AE-9 features such audiophile features as replaceable operational amplifiers, or *opamps,* to tune the flavor of sound from the card.

IMAGE: GORDON MAH UNG

Following the introduction of the gaming-focused Sound BlasterX AE-5 (go.pcworld.com/xae5) and Sound BlasterX AE-5 Pure (go.pcworld.com/ae5p) last year, the AE-9 kicks it up a notch or two.

Although still based on the same Sound Core 3D chip as the AE-5 and AE-5 Pure, the AE-9 jettisons the on-chip digital analog converter, or DAC, in favor of an external DAC. The premise being that a high-end DAC will make the sound even more pristine.

Creative officials said the card is rated at a 129dB signal-to-noise ratio and uses an ESS Sabre 32 digital analog converter. Since the AE-5 and AE-5 Pure both use an ESS ES9016 DAC, we figure the AE-9 is a step up to perhaps a Pro ESS DAC.

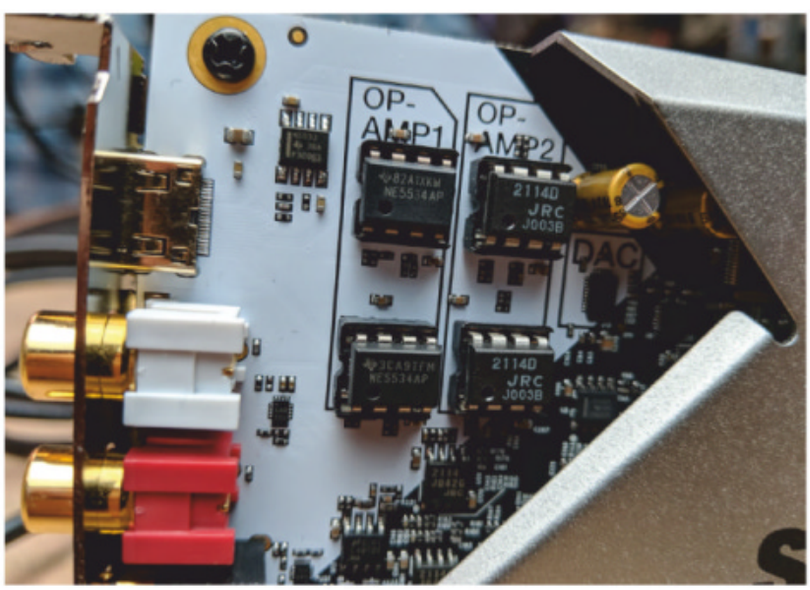
Audio-fidelity folks will appreciate how the AE-9 gives them control over the operational amplifiers, which can be mixed and matched for desired tuning.

Like the AE-5 cards, the AE-9 features XAMP, which amplifies each stereo channel of headphones out separately as well.

In a first for a sound card—the AE-9 relies on a 6-pin PCIe connector for power. That's up to 75 watts of power for the AE-9. Besides direct power being cleaner, the added power for the card is to help run the ports on the new breakout box.

The new breakout box features a single

The card appears to have standard 3.5mm jacks for rear, center, and sub, as well as RCA stereo-out and optical-in and -out ports.



The Sound BlasterX AE-9 will feature replaceable opamps so consumers can tailor the audio if they so wish. We're not sure if these are final shipping opamps or not.

The AE-9 gets the bulk of its power through a 6-pin PCIe connector. That means the AE-9 can draw up to 75 watts of juice.

The breakout box for the new Sound Blaster AE-9 features 45-volt phantom power support for microphones using XLR and TRS connections. And yes, this card is so new that the protective plastic has not been peeled from it yet.

combo jack that supports both TRS and XLR connectors for microphones and 48-volt phantom power. The mic jack is a nod to musicians and likely YouTubers who prefer very high-end microphones.

The front features a 3.5mm mic and headphone port along with a quarter-inch headphone jack. There's a button to enable 48-volt phantom power and what looks to be a switch for high-impedance headphones. The SBX lets you control the 3D

virtualization technology without going into software. The knob, obviously, is for volume.

The back of the breakout box features a pair of RCA-style connections that we'd guess are analog-in for those times when you want to record audio from, say, FM radio, which is how people used to do it.

The cable that connects the breakout box to the sound card looks like it appropriated a mini-HDMI connector. We suspect it's not electrically the same (since it doesn't carry video) but it's not uncommon for companies to use existing parts as a shortcut to avoid creating something new. Since mini-HDMI pretty much went nowhere, it's unlikely to ever get mixed up.

At $299, the AE-9 is a pricey sound card.

The rear of the new AE-9 breakout box likely features two RCA analog ports.

With a decent video card selling for the same or less, this card isn't for the typical gamer. Officials said to expect the card on store shelves by the end of December.

A single cable that connects the Sound Blaster AE-9 to the breakout box looks awfully similar to a mini-HDMI connector.

Hands on: Qualcomm's Snapdragon 8cx reference laptop is a fresh attempt to be faster

Qualcomm Snapdragon-powered PCs have struggled with performance. Demos suggest the 8cx could turn the tide. **BY MARK HACHMAN**

The Qualcomm Snapdragon 8cx is the chip the company hopes will scale the performance mountain, reaching the heights that competing Intel Core chips have already surmounted. After trying it at Qualcomm's Snapdragon Technology Summit in Maui, we can say it seems promising.

As we learned, the Snapdragon 8cx was designed as a ground-up, optimized design (go.pcworld.com/8cpc) specifically for laptops. Its mission is to achieve performance comparable to that of an Intel U-series Core i5 chip.

Qualcomm supplied a limited number of Snapdragon 8cx reference notebooks at the event, all running Windows 10 Pro. We tried to navigate to one of the web-based benchmarks we've used to test previous Snapdragon PCs, but we were told that benchmarking wasn't

IMAGE: MARK HACHMAN

allowed. In part, that's because the clock speeds of the chip haven't been formally determined.

We were nevertheless able to take a look at three things: the overall responsiveness of the Snapdragon 8cx platform, and two browsers: a Firefox Nightly build optimized for ARM64 chips like the 8cx, as well as a first look at the Chromium (not Google Chrome!) open-source browser that Qualcomm is helping develop.

(For a closer look at the challenges facing Qualcomm as it pursues Intel, check out my colleague Gordon Mah Ung's video, which compares Intel and Qualcomm chips in a pretty unique shootout [go.pcworld.com/yxcr].)

The SIM slot on the side of the 8cx reference notebook.

PLAIN-JANE HARDWARE

Because Qualcomm's a chip company, we didn't expect to see much in the way of unique hardware—and we didn't. The reference notebook was a fairly standard touchscreen convertible (360-degree hinge), with a pair of USB-C ports along the side. That's a plus, because the first Snapdragon-based Asus NovaGo (go.pcworld.com/n0va) used a proprietary charger.

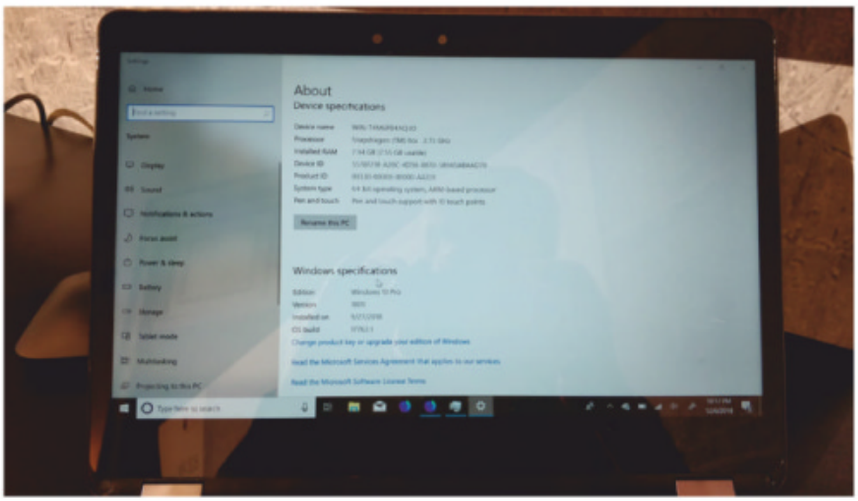
The other side of the laptop included a SIM slot. While the initial Snapdragon 8cx machines will be built around LTE, they'll eventually gain 5G capabilities, Qualcomm executives said.

SNAPPY AND RESPONSIVE

Qualcomm set up demo stations to show the 8cx in action, showing some basic work with media-heavy sites and YouTube. Elsewhere in the demo room, Qualcomm employees loaded up the new ARM64-optimized Firefox browser as well as Edge, alongside Photoshop, then navigated back and forth, scrolling up and down.

We were told later that Verizon was throttling the download speeds of 4K YouTube videos, prompting a start-and-stop behavior. Vimeo was left unthrottled, and played back 4K videos just fine. We also managed to crash the prototype device, hard-locking it in the course of normal use. Apparently some bugs still need to be worked out before the chips are expected to ship in actual products, in Q3 2019.

Still, we can hope that these demos represent final performance expectations. We



This is the configuration screen of the Snapdragon 8cx reference notebook. This is not indicative of the final configuration.

also hope the long battery life, pervasive connection, and "instant on" wakefulness persist into shipping products.

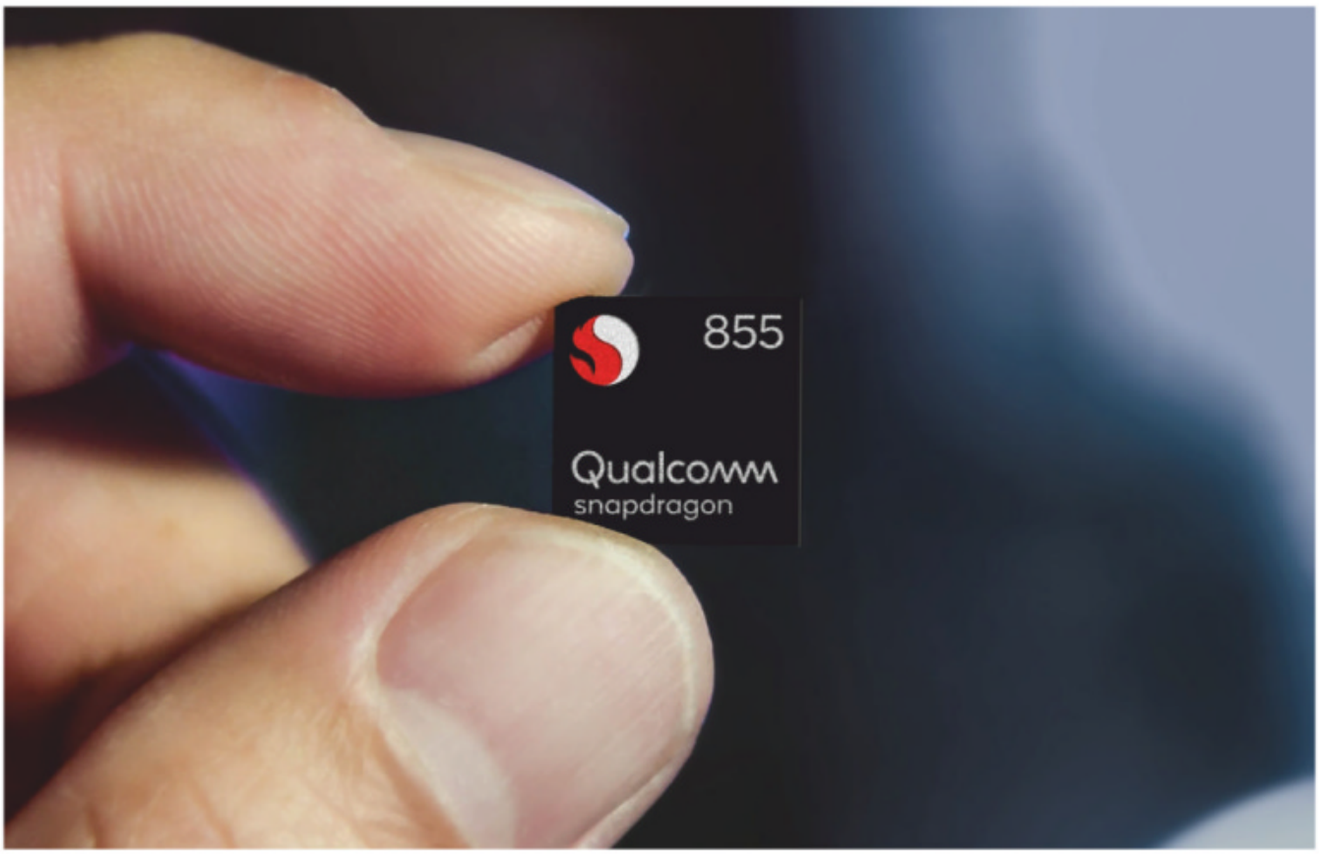
FIREFOX AND CHROMIUM

We looked at how Firefox runs on the Snapdragon 8cx, specifically the version coded for the ARM64 instruction set. Through we didn't push it hard, it certainly looked and felt like the Firefox desktop browser we know. (The darker logo is used to distinguish the Nightly beta builds from the more stable, regular builds.)

This video (go.pcworld.com/6zn3) shows off both Chromium and Firefox Nightly, with several media-rich tabs, running on the same machine. There's little slowdown, which is a testament to the browser developers as well as to Qualcomm. (Note: To correct something I say in the video, the Edge browser hasn't been required by a Snapdragon chip. Rather, because the first Snapdragon-based notebooks shipped with Windows 10 in S Mode, they were limited to using Edge.)

All in all, the Qualcomm Snapdragon 8cx looks good—but so did the first Snapdragon 835-powered Asus NovaGo. We also don't know what Intel and AMD will have up their sleeves in the meantime. It appears that 2019 will be a busy year for mobile CPUs.

A Qualcomm employee shows off the Firefox Nightly browser on the left screen, with Chromium on the right. Both are coded for ARM64, the instruction set used by the Qualcomm Snapdragon 8cx.



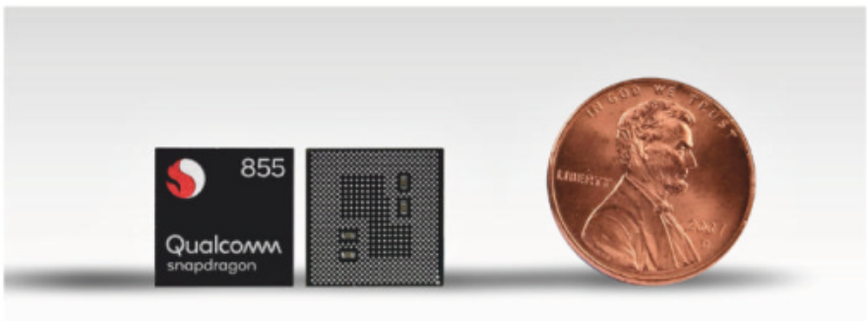
Meet Qualcomm's Snapdragon 855: AI boosts, a smarter camera, and mobile gaming

Qualcomm's making dozens of improvements to the Snapdragon 855, both large and small. **BY MARK HACHMAN**

One year ago, Qualcomm unveiled the Snapdragon 845 (go.pcworld.com/s845), the brains behind flagship smartphones like the Google Pixel 3, the U.S. version of the Samsung Galaxy S9, OnePlus phones, and others. Now, Qualcomm's next-generation Snapdragon 855 promises those platforms even more enhancements: dedicated logic blocks for digital assistants, revamped camera logic for computer vision, specific gaming boosts. It also gives the traditional JPEG file format the boot.

IMAGE: QUALCOMM

According to Qualcomm executives, the goal for the Snapdragon 855 is to "unlock" AI and XR (mixed reality), with the new 5G capabilities leading the way. The company claims that it's offering the first commercial mobile platform to support this trifecta.



Qualcomm hasn't disclosed specifics such as the power consumption of the Snapdragon 855, but we know the chip is small.

Qualcomm's next-generation 855 is due to ship during the first half of 2019, meaning that phone makers will be able to design and announce their own Snapdragon 855–based phones for launch later in 2019.

Qualcomm's Snapdragon chips are truly systems-on-a-chip (SoC), with an improved Adreno GPU and Kryo CPU, a Hexagon DSP that's being repurposed for AI, and an increasingly more intelligent Spectra camera signal processor—often a key feature for phone buyers. Though each of the 855's subsystems has been improved in its own right, Qualcomm also made one significant, overall improvement: While the Snapdragon 845 was manufactured on a 10nm process, Qualcomm has made the leap to 7nm with the Snapdragon 855.

Travis Lanier, Qualcomm's senior director of product management, put it simply: The Snapdragon 855 will deliver 45 percent more performance than the 845 in the Kryo GPU, and 20 percent more performance in the Adreno GPU.

CONNECTIVITY: IMPROVEMENTS BEYOND JUST 5G

Keith Kressin, senior vice president of product management at Qualcomm, suggested that every generation of wireless technology took a decade to develop. What's 5G bringing? "Massive amounts of connectivity," Kressin said, together with a new ecosystem of applications that no one quite understands yet.

"One question that comes up quite frequently: What is 5G going to do for me?" said Durga Malladi, the senior vice president for 4G and 5G for Qualcomm. For a network operator, it means that users will stream more high-bandwidth movies, with less latency. 5G also enables connected PCs, he said.

More than 20 global operators and 20 global hardware makers are on board with 5G, Malladi said.

Though Qualcomm executives touted the advantages of 5G, cellular connectivity is just one portion of the Snapdragon 855,

While 5G is revolutionary, you'll probably see more benefit in the LTE enhancements.

executives said. And for now, while the chip will work with 5G (go.pcworld.com/ql5g), the spec is not native to the platform: Though the Qualcomm X50 modem will perform 5G millimeter wave and operate in the sub-6GHz spectrum bands, the X50 isn't integrated into the Snapdragon 855. (AT&T and Verizon appeared on stage to support Qualcomm's 5G initiative [go.pcworld.com/s855].)

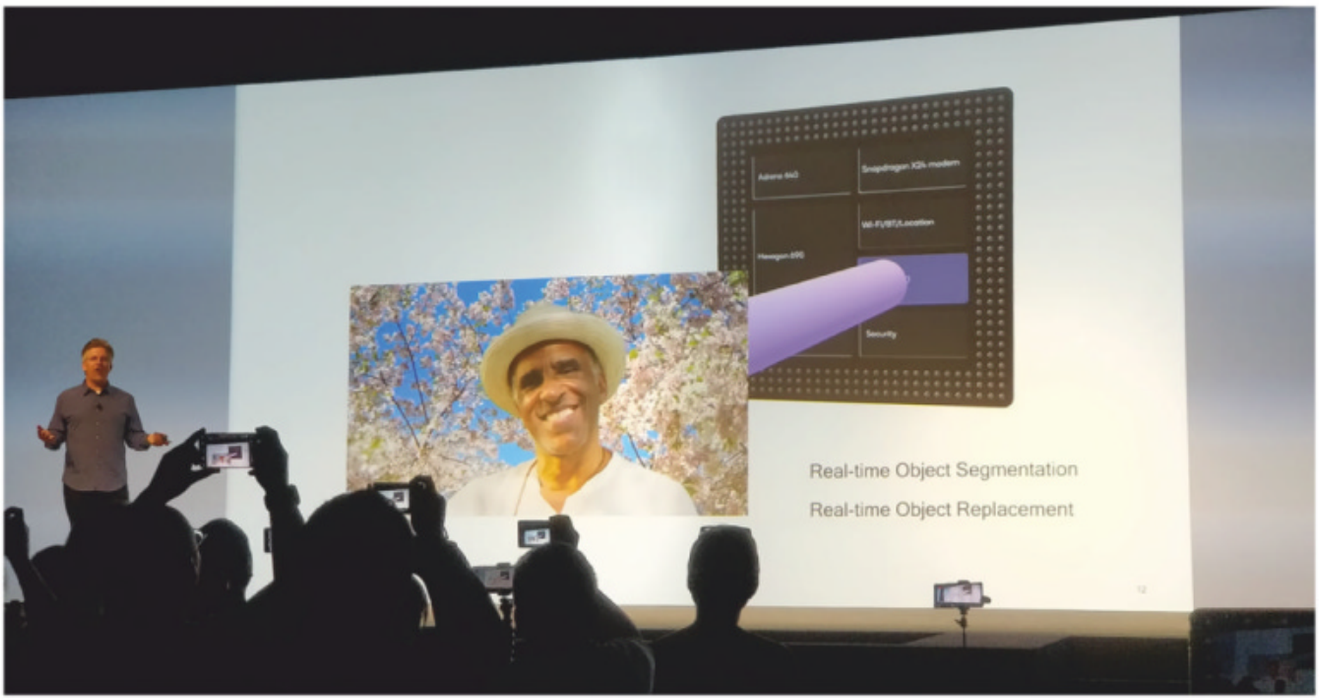
Instead, it's far more likely that phones will connect using what Qualcomm calls the world's first 2Gbps LTE modem, the X24 modem, which Qualcomm announced in February and which is integrated into the Snapdragon 855.

But phones connect via Wi-Fi as well as cellular, and the Snapdragon 855 makes improvements here, too. Qualcomm is also characterizing the 855 as 802.11ax "ready," also known as WiFi6. While today's 802.11ac devices can push a maximum of 3Gbps, shared between several devices, 802.11ax (go.pcworld.com/11ax) will be able to support up to 14Gbps. It will also support 802.11ay, a 60GHz Wi-Fi solution, capable of 7Gbps, and believed to be most applicable for short-range, high-bandwidth apps like untethered VR (go.pcworld.com/ay11). There's Bluetooth 5.0, too.

MAKING CAMERAS SMARTER WITH THE SPECTRA ISP

Each time you point a Snapdragon-equipped smartphone at a subject and take a picture, the first core that image passes through is the Spectra image signal processor, or ISP. Within the Snapdragon 855, the new core is called the Spectra 850.

Traditional smartphones process color, white balance, exposure, and other optical characteristics to create an image. But as cameras have become smarter, they've begun recognizing objects, people, and other details of a scene. Until now, that's required tapping into the CPU, GPU, and DSP for extra processing power. The result, has been features like portrait mode, which can intelligently recognize the subject of a picture



In the Snapdragon 855, the Spectra ISP combines the color pipeline and the AI pipeline for features like dynamic background replacement.

and then blur the remaining background. Now, Snapdragon-equipped smartphone cameras will be able to do that for video, too.

What Qualcomm did was to recognize what portions of the CPU, GPU, and DSP the Snapdragon accessed, merged them with the color pipeline, and pulled the whole thing into a separate logic core. In the 855, Qualcomm created what it calls the first ISP optimized for computer vision.

That's resulted in a "huge speed boost" in computer-vision applications as well as 4X reduction in power savings. Put another way, it will enable the 855 to perform all the traditional camera functions more quickly and at lower power, while enabling a new range of features.

From a performance standpoint, the Spectra ISP can support 22 megapixels at 30 frames per second using concurrent dual cameras; or 48MP at 30fps using a single camera. The 855 will do 4K, HDR10+ video capture in portrait mode at 60fps, and at 30 percent less power than the 845, said Judd Heape, senior director of product management at Qualcomm.

Even better, the Spectra 850 can now perform depth sensing at 60Hz, meaning that Snapdragon 855–equipped cameras will now be able to take the "portrait mode" of still images and apply it to video. Likewise, since Snapdragon 855 cameras can now distinguish and identify multiple objects, phones will be able to "pull out" the subject

of a video and replace it with another background, in real time. There are even cinematograph capabilities, where part of the scene can be in motion.

All this, unfortunately, means a big change in the way Snapdragon phones store photos—Qualcomm is moving to the HEIF image format. Though JPEG has been the preferred file format for the last 20 years, it can't store the complexity of HDR, computer vision, and so forth. HEIF can, storing everything from burst-mode photos to alpha masks, and even video, all within one "image" format.

HEIF also acknowledges that more and more smartphones include multiple cameras—and with HEIF, you can store data from all of them. The goal? Shoot once, share everything.

CINEMA CORE: SAVING POWER WHILE PLAYING BACK VIDEO

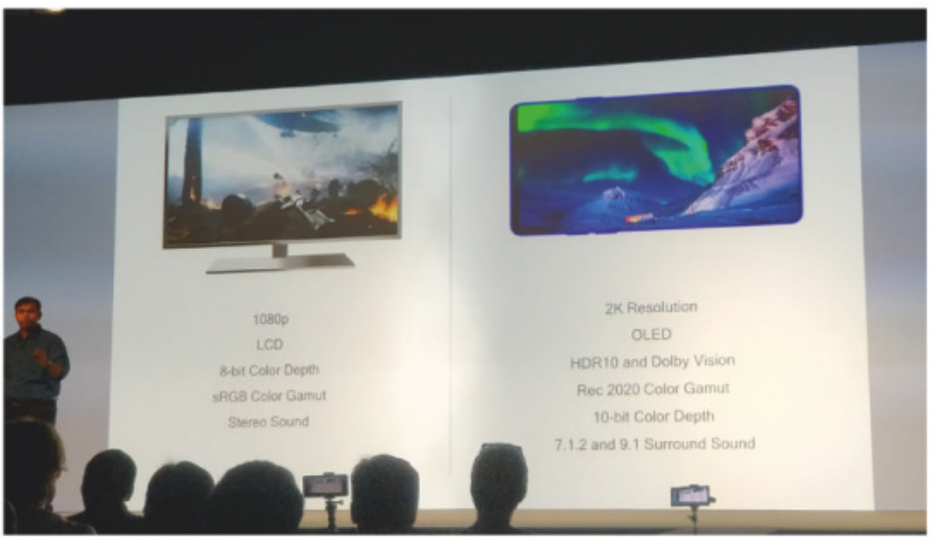
While all of those features are designed to create content, Qualcomm's introducing a "Cinema Core" optimized for video playback. Cinema Core contains both H.264 and VP9 decoders in hardware, optimizing the video format used by YouTube. Again, the goal is to significantly reduce power while playing back video.

Hiren Bhinde, a director of product management, drew a distinction between the typical desktop PC monitor (1080p with just 8-bit color depths) versus what a smartphone now offers: 2K resolution, HDR, and much deeper color depths.

Cinema Core also supports what Qualcomm calls the next generation of HDR video,

This is what HEIF will offer as a file format.

specifically HDR10+ playback, offering more dynamic range per frame than before. It will also offer 120fps playback, as well as 8K video playback of HDR video. From an audio perspective, Qualcomm's introducing Qualcomm aptX Adaptive, a low-latency audio technology, as well as what it calls True Wireless Stereo Plus, for completely wire-free stereo audio.



Compelling reasons for watching video on your smartphone.

SNAPDRAGON ELITE GAMING PLATFORM: BOOSTING MOBILE GAMING

When most people think of mobile gaming, they think of timewasters like Candy Crush. In Asia, however, mobile games are increasingly thought of as mobile counterparts to desktop games like Fortnite. Qualcomm is introducing what it calls the Snapdragon Elite Gaming Platform to satisfy that market.

Mobile games will generate over $70 billion in revenues in 2018 alone, said Qualcomm's Hiren Bhinde. Over 586 million mobile gamers are in China alone—twice the population of the United States, he said.

All the benefits of Snapdragon's Elite Gaming Platform.

Qualcomm's putting a number of different features in its Elite Gaming Platform basket, but it all centers around the Adreno 640 GPU found within the Snapdragon 855, offering a 30 percent boost in performance over the Snapdragon 845. The Snapdragon 835 added HDR video playback; the 845 added HDR video capture.

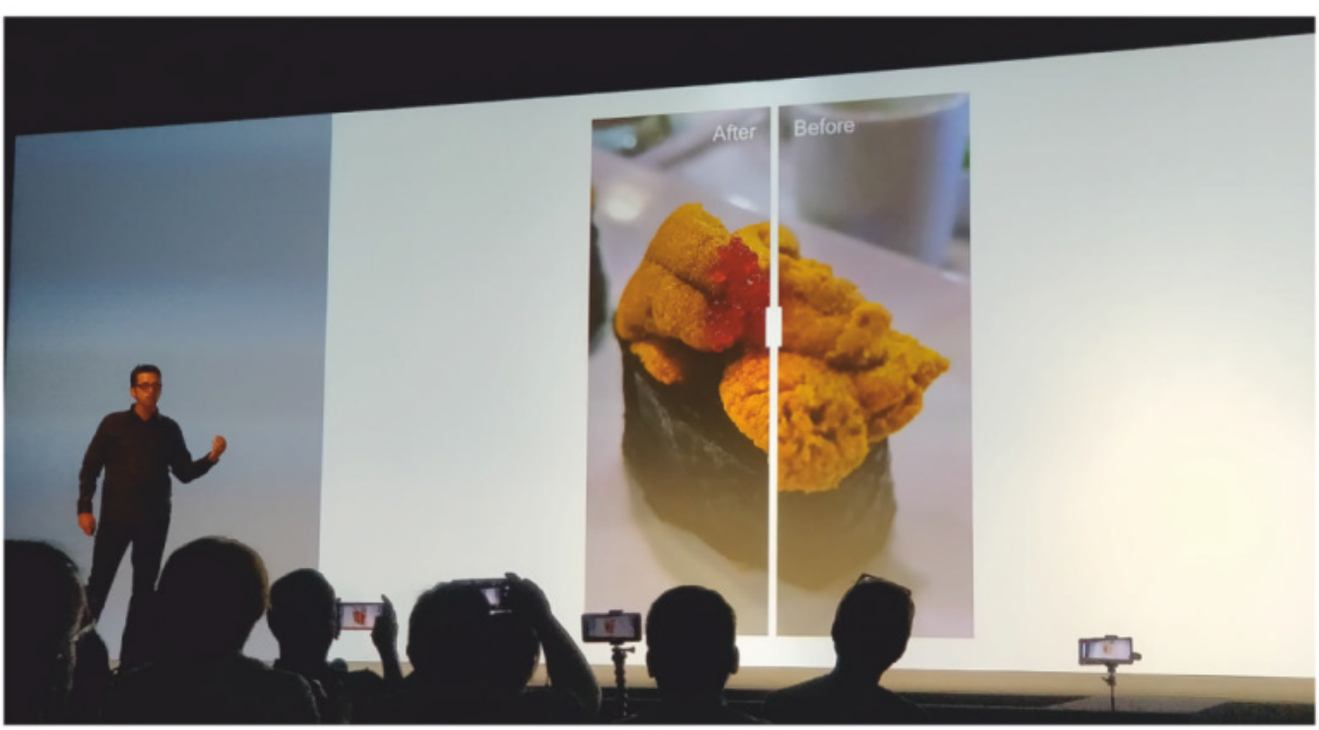
With the 855, the company is adding true HDR rendering gaming capabilities, supporting 10-bit color depths and the Rec 2020 color gamut (go.pcworld.com/rc20). All told, over a billion colors are supported.

Qualcomm's also banking on what it calls physical-based rendering—though it's the surface textures that are being modeled on physical objects, such as stone. Small imperfections and porosity are modeled, with the idea that rendered objects will have a more lifelike look. About 30 different surfaces will be modeled.

HEXAGON DSP: MAKING AI SMARTER

Although the Kryo GPU, Adreno GPU, and Hexagon DSP are all capable of running the complex math libraries that power AI, Qualcomm executives said that the Hexagon 690 has been literally rebuilt for AI. In fact, AI performance will be three times more powerful than on the Snapdragon 845, Qualcomm executives said, processing 7 trillion AI operations per second.

While Qualcomm added a pair of vector engines and a tensor engine as additional accelerators, a more interesting addition is a dedicated voice assistant core, specifically designed to power assistants like the Google Assistant. That core is designed to help assistants identify your voice. Google also said that in Android 9, the Android Neural Networks API is running entirely on the Hexagon 690, said PJ Jacobowitz, a senior marketing



Qualcomm's Snapdragon 855 chip, and its Hexagon DSP, can power apps like this that can interpolate extra detail in an image, executives said.

manager at Qualcomm. That core is designed to be always on, in a low-power mode, listening for a "wake word" like "OK, Google."

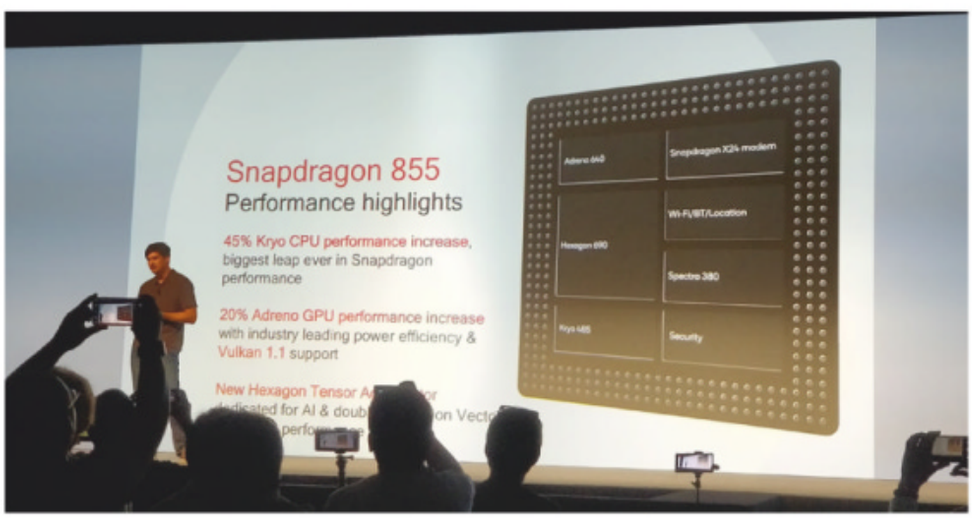
Rajan Patel, senior director of engineering for Google Augmented Reality, said that the 855 would reduce latency by about three times. A high-bandwidth, low-latency 5G connection will make it easier to download large assets for augmented reality, he said.

The Hexagon is also used for real-time noise-reduction algorithms to cut background noise in video calls from airports or clubs, and for third-party apps that can even show you what you might look like with a different hairstyle.

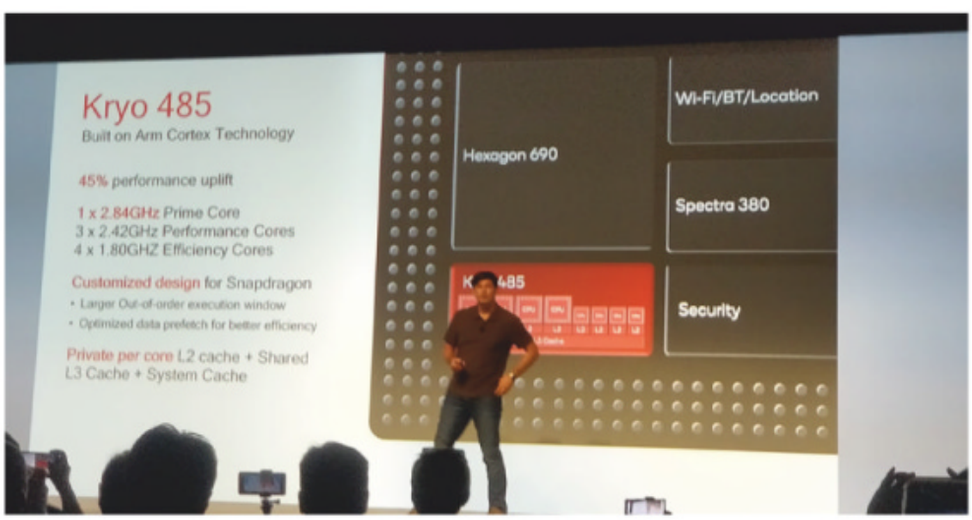
The Hexagon DSP will also be used to power what Qualcomm is calling a "3D Sonic Sensor," an ultrasonic biometric sensor that can be mounted underneath a display to log in users via their fingerprints. Most smartphones use capacitive sensors, which detect the electrical impulses given off by a fingertip. Qualcomm believes that the way in which an ultrasonic sensor "paints" your fingertip's whorls and lines with ultrasonic sound is the future, in that it works while wet and through contaminants like oil.

A LESS POWERFUL KRYO CPU?

If a phone were a PC, the microprocessor inside of it would be front and center.



A performance summary of the Kryo CPU and Adreno GPU.



Here are the speeds of each of the Snapdragon 855's Kryo cores.

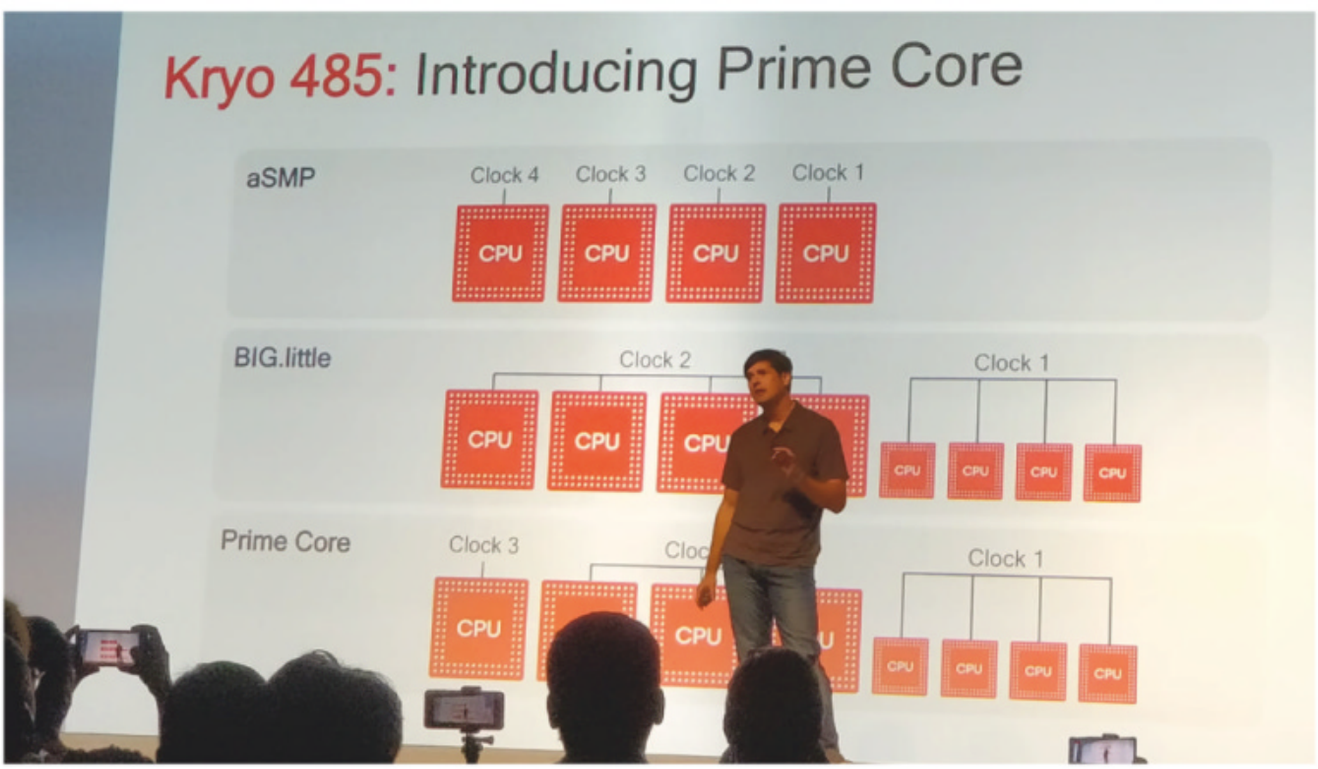
However, the prevalence of apps, services, camera hardware, and other features tend to diminish the importance of the CPU hardware. Who buys a phone for its processor?

In part, that's why Qualcomm doesn't usually talk much about its Kryo CPUs. But the new Kryo 485 core includes something unusual: a "prime core."

Typically, a Snapdragon chip includes four "performance" cores and four "efficiency" cores, the latter optimized for lower power. The Snapdragon 845 uses four ARM A75 cores at 2.8GHz and four A55 cores running at 1.8GHz. Qualcomm says the Kryo 485 within the Snapdragon 855 is 45 percent more powerful.

But there are some interesting differences between the 845 and the 855. With the Snapdragon 855's Kryo 485, there's still the low-power "efficiency" cores, also running at 1.8GHz. But now there are three "performance" cores running at a slower 2.42GHz. But Qualcomm has added a new, even faster "prime" core running at a faster 2.84GHz.

That raised a few questions: Is the CPU running at diminished performance? If so, is that deliberate, perhaps because those tasks are being handed off to some of the other specialized logic blocks? Or is the CPU architecture simply more efficient? The latter answer turned out to be correct, Lanier said in a Q&A after the keynote: the Snapdragon 855 architecture is more powerful because of a higher instructions-per-clock efficiency, including larger caches.



The Kryo core introduces a new "prime" CPU core.

Meet T-Rex: Nvidia's Titan RTX is the new graphics card mega-monster

But gamers should stick with the GeForce RTX 2080 Ti instead. **BY BRAD CHACOS**

When the GeForce RTX 2080 Ti (go.pcworld.com/20ti) launched with a sky-high $1,000 theoretical price tag and $1,200-plus actual price tag, some people speculated that it simply took the place of the Titan at the top of Nvidia's graphics card lineup. Nope. Recently, Nvidia revealed the Titan RTX, a $2,499 behemoth that the company also calls "T-Rex."

It's certainly monstrous enough. Like its Titan V predecessor (go.pcworld.com/tinv), the Titan RTX returns to the Titan's roots as a prosumer card, with a focus on AI, data science, and content creation tasks. Nvidia's flagship TU102 GPU packs 72 dedicated RT cores for real-time ray tracing and 576 tensor cores so beloved by machine learning tasks. That's identical to the GeForce RTX 2080 Ti's loadout.

While Nvidia's announcement didn't specify the Titan RTX's CUDA core count, an Nvidia spokesperson confirmed that it holds more than the GeForce card. The Titan RTX matches the 4,608 CUDA cores inside the Quadro RTX 6000 and RTX 8000 (go.pcworld.com/qdro) professional GPUs,

IMAGE: NVIDIA

rather than the RTX 2080 Ti's 4,352 cores. That gives the newest Titan fewer total CUDA cores than its predecessor—the Titan V crammed in 5,120—but the Turing GPU's CUDA cores are much more effective (go.pcworld.com/gpus) than the ones inside older Pascal GPUs. The extra cores also help the card perform deep-learning tasks more efficiently: The RTX 2080 Ti performs FP16 tasks at 110 teraflops, while Nvidia said the Titan RTX churns through the same tasks at 130 TFLOPS.

Data tasks can require much more memory than gaming, so Nvidia loaded the T-Rex with VRAM. The Titan RTX comes with 24GB of cutting-edge GDDR6 memory, for a total memory bandwidth of 672GB per second. That matches the Quadro RTX 6000's configuration, and more than doubles up the GeForce RTX 2080 Ti, which has "only" 11GB of VRAM.

It's an interesting decision by Nvidia. The Titan V included only 12GB of onboard memory, presumably to differentiate it from the pricier Quadro options. While the Titan RTX's $2,499 price may stagger gamers, the Quadro RTX 6000 costs $6,300.

Such a powerful arsenal of cutting-edge hardware should make the Titan RTX stomp through machine-learning tasks. Nvidia's supporting it on the software side with RAPIDS open-source software libraries (go.pcworld.com/rpds) that rely on CUDA. Nvidia also says that the tensor cores and ray-tracing hardware

unlock new possibilities in creative applications, and the card's fearsome firepower and massive memory pool gives it potent chops in traditional rendering tasks, too. The Titan RTX can even perform real-time 8K video editing, Nvidia says.

The new Titan sports the upgraded dual-axial cooler design introduced with the consumer GeForce RTX cards, but its aluminum shroud comes clad in gold, not silver.

Look for the Titan RTX to launch in the United States and Europe later in December for $2,499. Thanks to those extra CUDA cores, T-Rex should (slightly) outpunch the GeForce RTX 2080 Ti flagship in gaming, but at twice the price, so gamers who want to drive a 4K, 144Hz G-Sync HDR monitor like the sublime Acer Predator X27 (go.pcworld.com/ax27) should leave the Titan RTX for the data scientists and stick to the GeForce RTX 2080 Ti instead.

How fast is 5G? This speed demo gives us an idea

It's unlikely you'll see these same amazing speeds when 5G eventually rolls out, though you'll hopefully see a dramatic speed boost, regardless. **BY MARK HACHMAN**

So how fast is 5G, anyway? About as fast as a premium-tier cable modem, according to a live test performed by Qualcomm, Motorola, and Verizon.

All three companies showed off the technology at the Snapdragon Technology Summit in Maui, demoing a prototype 5G device on a prototype 5G network. (The entire first day of the summit was devoted to 5G [go.pcworld.com/5gmc].) According to the test, the modem transferred a gigabyte's worth of data in 17 seconds. That's 0.0588 GBps, or about 470 Mbps. That's pretty damn fast.

Want to see it for yourself? Watch the demo at go.pcworld.com/jftt.

Unfortunately, you have to take this demo with a fairly large grain of salt. And you have to ask some important questions: Who owns the network? What device are you using for downloads? How far is that device from the

network antenna? Is there network congestion? All of these factors will affect wireless speeds. While the International Telecommunications Union draft spec (go.pcworld.com/itud) calls for 5G to deliver a whopping 20Gbps download speed, such bandwidth will be shared with thousands to millions of devices, all connecting and disconnecting, and that affects performance.

Sharp-eyed viewers will notice that the 1GB file in the demo downloaded in 34 seconds in a subsequent test, as the image at the top of this article indicates. Interestingly, that's much more in line with what network provider Ericsson told The Verge was the actual speed of the backhaul network (go.pcworld.com/mtst)—about 140 Mbps. It seems that the company used some compression hanky-panky to game the results, though the network was functional.

In fact, once we were able to find a second Moto Z3 and run a speed test on it, we recorded far lower throughput. Verizon executives manning the demo booth told us they were showing off the technology merely to prove that it works.

The network in the demo used back-end equipment from Ericsson, and tapped into Verizon's network, which we can assume was tuned for the experience. But the phone itself was interesting: a Moto Z3 with a dedicated 5G MotoMod that snapped into the back of the handset.

While we criticized the 5G MotoMod (go.pcworld.com/z35g) as gimmicky, it's the underlying technology that made this 5G experience work. And, yes, it's kind of crazy—inside the MotoMod (not the phone!) there's a Snapdragon 855, Qualcomm's dedicated X50 modem chip, and a 2,000 milliamp-hour battery. It contains 10 separate antennas inside, and is optimized for the high-speed millimeter wave portion of the 5G spec. Executives said they didn't plan to update the MotoMod with sub-6GHz technology, as that portion of the spectrum is designed for slower speeds and a broader coverage area.

The 5G MotoMod will all ship in early 2019, though Motorola isn't saying exactly when or for how much.

Carolina Milanesi, a consumer technology analyst for Creative Strategies, thinks that worrying about 5G's actual speed is a red herring. Instead, she said, 5G will do for the phone what the home gateway did for the home—connect all of your devices, as well as provide a speed bump. "But consumers aren't thinking of it that way yet," she said. "They don't have an existing frame of reference."

We now know that 5G will roll out slowly, though handset manufacturers and Verizon are trying to buck the trend and push it out faster. So will you get crazy-fast 58.8 Mbps downloads when 5G finally arrives? Probably not—though you'll hopefully get a sizable speed boost nonetheless.

Intel publishes its first Modern Windows Driver for PCs, and there's no going back

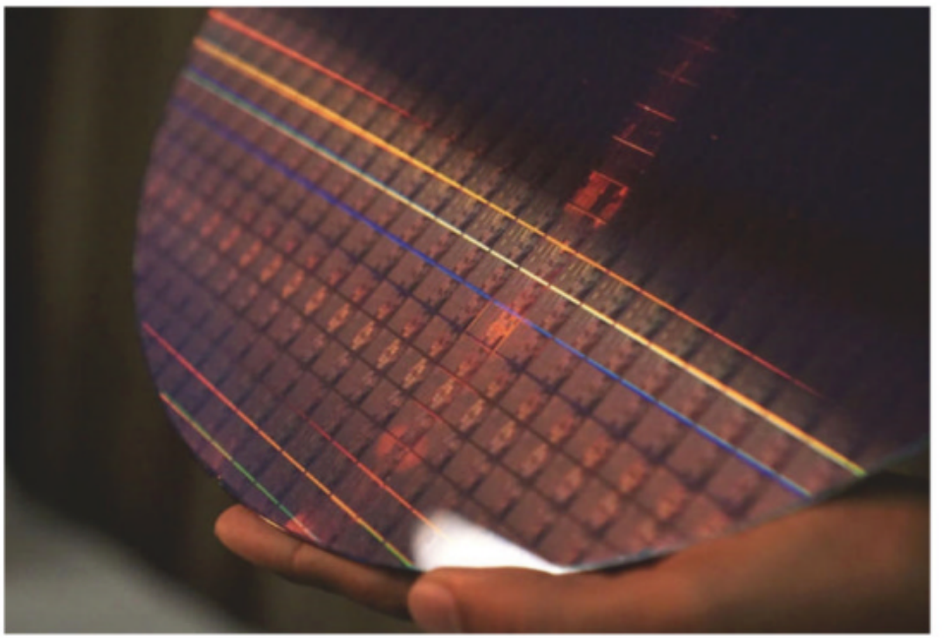
Drivers will be provided by your PC or card maker, although some support apps will be published on the Microsoft Store, too. **BY MARK HACHMAN**

Intel has published its first Modern Windows Driver for several of its modern integrated GPUs, representing a new way for graphics drivers to be pushed to your PC—and something to keep an eye on until the new driver infrastructure settles in.

Modern Windows Drivers, also known as Universal Windows Drivers, are a new feature of the Windows 10 October 2018 Update that takes advantage of the UWP infrastructure within Windows 10. As Microsoft explains it (go.pcworld.com/unwn), a Modern Windows Driver is a

IMAGE: INTEL

"single driver package that runs across multiple different device types, from embedded systems to tablets and desktop PCs." The first Intel driver to take advantage of this is labeled UWD 25.20.100.6444 (go.pcworld.com/dch1).



Microsoft doesn't intend for you to do anything different to obtain the new Modern drivers. If you own a prebuilt PC, the PC maker will continue to be the first place you should check for updated drivers, according to an Intel FAQ (go.pcworld.com/infq). That's because the universal driver includes a base driver, plus optional component packages and an optional hardware support app. The latter two are written by the system builder or OEM, while the former is written by the GPU maker itself. (AMD and Nvidia are expected to transition to Modern drivers, too.)

With regards to Intel, you'll be able to download them via Intel's Download Center (go.pcworld.com/down) and via Intel's Driver and Support Assistant, or IDSA (go.pcworld.com/idsa). Drivers may also be pushed by Windows 10's Windows Update, while the support apps will be (or should be) published to the Microsoft Store app.

WHAT YOU NEED TO BE CAREFUL ABOUT

Intel began publishing its first Modern Windows Drivers on November 28. The following chipsets are supported:

- Intel UHD Graphics 620/630 (formerly codenamed Coffee Lake)
- Intel Iris Plus Graphics 655 (formerly codenamed Coffee Lake)
- Intel UHD Graphics 600/605 (formerly codenamed Gemini Lake)
- Intel HD Graphics 620/630 (formerly codenamed Kaby Lake)
- Intel Iris Plus Graphics 640/650 (formerly codenamed Kaby Lake)
- Intel HD Graphics 610/615 (formerly codenamed Gemini Lake)
- Intel HD Graphics 500/505 (formerly codenamed Apollo Lake)
- Intel HD Graphics 510/515/520/530

(formerly codenamed Skylake)

- Intel Iris Pro Graphics 580 (formerly codenamed Skylake)
- Intel Iris Graphics 540 (formerly codenamed Skylake)

Here's the catch. According to Intel, you can only use the executable installer provided by Intel or your PC maker. If you use the "INF/Have disk installation" or any other method of installing drivers, Intel warns that that could cause "minor to catastrophic issues or system instability." That's because it bypasses Intel's own installation method.

In addition, there's very little leeway to roll back from a Modern Windows Driver to a legacy driver. It's a "complex process that can result in system instability," Intel writes. "We don't recommend it." If you absolutely must, contact Intel's support (go.pcworld.com/isup).

In other words, the Modern Windows Driver/Universal Windows Driver transition is a one-way street, and let's hope you don't have any issues with the new drivers.

We've asked Intel some additional questions about the transition, and we'll update this story when we hear back.

What this means to you: If you don't have the Windows 10 October 2018 Update yet, there's really nothing to do—you can manually request the October 2018 Update from Windows, but the rollout is proceeding slowly. (Microsoft hasn't provided the update to the Microsoft Surface Book 2 I'm writing this on.) It's not exactly clear whether Intel will provide this driver in a "legacy" format, either. That's kind of important, given that the new driver provides some updates to Fallout 4, Far Cry 5, and other top games, according to Neowin (go.pcworld.com/intr).

Microsoft Edge embraces open-source Chromium code, plans move to Windows 7, 8, and Macs

This move holds major implications for the World Wide Web. **BY BRAD CHACOS**

Microsoft is overhauling its struggling Edge browser in pretty much every way over the next year. The proprietary EdgeHTML engine underpinning the browser will be abandoned in favor of the Chromium code used by Google's Chrome and several other browsers. After the shift, Microsoft plans to end Edge's Windows 10 desktop exclusivity by bringing it to Macs and older versions of Windows.

How Chrome-like will Microsoft's version of Chromium be? Enough that Chrome extensions will run on top of it, Microsoft Edge project manager Kyle Alden recently wrote on Reddit (go.pcworld.com/mkwb). Existing Progressive Web Apps (web apps that feel like Win32 apps) will continue to run and be downloadable from

IMAGE: MICROSOFT

the Microsoft Store, he added.

"People using Microsoft Edge (and potentially other browsers) will experience improved compatibility with all websites, while getting the best-possible battery life and hardware integration on all kinds of Windows devices," Joe Belfiore, corporate vice president of Windows, said in the blog post announcing the shift (go.pcworld.com/wbet). He also touted compatibility benefits for web developers and corporate IT administrators.

Why this matters: The shift makes sense. The Windows-exclusive Edge has been hemorrhaging users despite being Windows 10's default (and Microsoft's heavy-handed attempts to convince users to stick with Edge when you attempt to download rival browsers). Despite developing strengths in recent years, such as excellent performance and battery life, Edge started out on the wrong foot at Windows 10's launch, lacking many of the modern features users expect. The browser never recovered, and given Chrome and Chromium's massive market share, developers started prioritizing that engine instead. Chrome is the new Internet Explorer 6 (go.pcworld.com/din6).

That said, there are concerns about one browser project dominating the web. "This is actually…bad news for browser ecosystem health," Stack Overflow and Stack Exchange cofounder Jeff Atwood wrote on Twitter (go.pcworld.com/bdbr) when rumors of the change sprouted earlier this week. "Quadrupling down on Chrome as the default HTML engine everywhere isn't the right way to go."

Chromium's status as an open-source browser may alleviate some of those fears, and Belfiore says Microsoft will lean into code contributions. "Our goal is to do this in a way that embraces the well-established open source model that's been working effectively for years: meaningful and positive contributions that align to long-standing, thoughtfully designed architecture, and collaborative engineering," he wrote.

NO LONGER AN EDGE CASE

Edge will break free of its Windows 10 shackles as part of the move. The browser will be updated on its own, separate from Windows 10's major twice-annual updates, and will come to Windows 7 and 8. "We also expect this work to enable us to bring Microsoft Edge to other platforms like macOS," Belfiore wrote. Last year, Edge appeared on iOS and Android (go.pcworld.com/edbr).

Microsoft's core browser running on Macs! Hell hath truly frozen over—though it remains to be seen how successful the move will be considering the superb state of modern browsing. Edge doesn't even crack the top three in our roundup of the best web browsers (go.pcworld.com/18wb), falling behind Chrome, Opera, and Firefox. Chrome and Opera both rely on the Chromium project as well. Look for Edge to shift over to the open-source engine sometime in 2019.

The new Samsung A8s could be our first look at the Galaxy S10's notchless 'hole-punch' display

A hole for the camera but not one for your headphones. **BY MICHAEL SIMON**

If you've been following along with the Galaxy S10 rumors (go.pcworld.com/s10r), then you know Samsung is planning something very different for its 2019 flagship: A display with a hole in the front rather than a notch. And we may have just gotten our first look at it.

Samsung has taken the wraps off the Galaxy A8s (go.pcworld.com/g8as), a midrange China-only phone that's likely to cost hundreds of dollars less than the Galaxy S10. However, the two phones might not look too much different: the A8s is the first phone to feature Samsung's new Infinity-O display, a near–edge-to-edge screen that has a small hole in the right corner for the selfie camera, rather than a notch. At 6.4 inches, it has a bigger screen than the 6.2-inch Galaxy S9+ (go.pcworld.com/gls9) but without the bulk of a camera-hiding strip above the screen.

IMAGE: SAMSUNG

Look closely and you'll see that the camera hole doesn't hide any of the front-facing sensors, so there's still a need for a slight forehead and decent-sized chin on the A8s, which matches up with rumors we've heard about the S10. We've yet to see an Android phone that has the kind of symmetry that Apple has achieved with the iPhone X, and the novel hole-punch screen doesn't bring it either, at least not on the A8s. It also remains to be seen how the hole affects the viewing experience, as developers are unlikely to optimize their apps for Samsung's unique displays.

The Samsung A8s features the new Infinity-O display.

Elsewhere, the A8s is a fairly unremarkable phone, with a Snapdragon 710 processor, 128GB of storage, and up to 8GB of RAM. It does, however, feature a triple-camera array, the likes of which we could also see on the S10:

Wide: 24 MP, f/1.7, 27mm

Ultrawide: 10 MP, f/2.4, 18mm

Depth: 5 MP, f/2.2

The Galaxy S9+ includes a dual camera while the S9 sports a single lens, so a triple-camera array would be a marked improvement on this year's model. However, reports and renders have suggested Samsung will be sticking with a dual lens for the Galaxy S10. It's also rumored that the S10 will have an in-display fingerprint sensor, rather than the traditional sensor on the rear of the A8s.

Finally, the A8s doesn't have a headphone jack, something Samsung is rumored to remove from the S10 as well. The Galaxy S9 is one of the few flagship Android phones to ship with a 3.5mm audio jack, so the lack of one could be a bone of contention with fans.

With only a few months to go until the presumed March unveiling of the Galaxy S10, the A8s is probably a pretty good representation of what Samsung's first flagship of 2019 will look like. And it might not be the only flagship phone to use the notchless tech. Honor just teased the View 20 (go.pcworld.com/hv20) and you guessed it, it also has a hole in the screen for the camera, so it's possible that parent company Huawei follows suit with its P30 and Mate 30 flagships.

So 2019 is shaping up to be a good old-fashioned fight between a hole and a notch: Which will you choose?


WHY DOES IT TAKE A DISASTER TO BRING US TOGETHER?
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love has no labels
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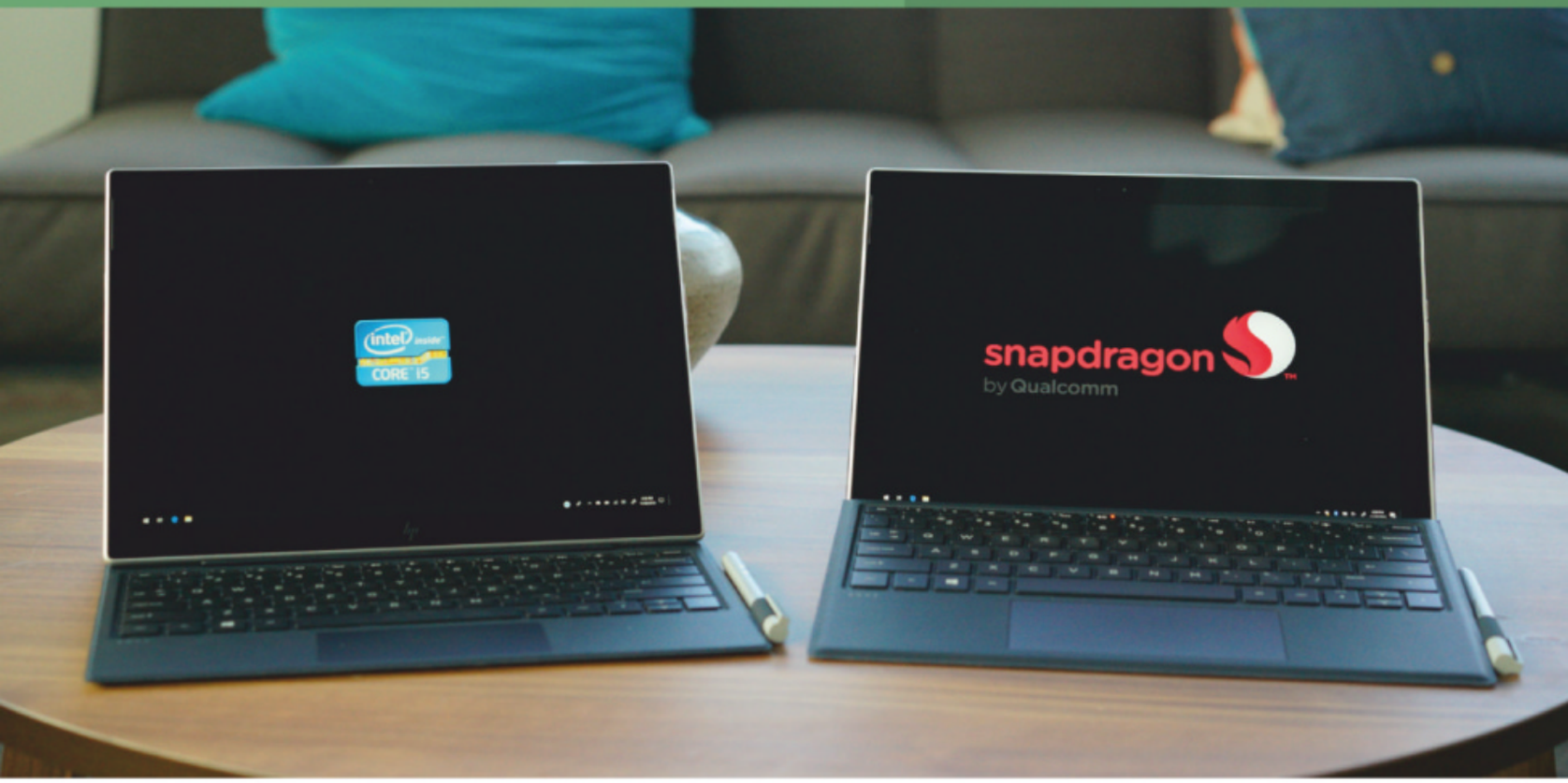


Intel vs. Snapdragon: We test HP's Envy x2 with both, on speed, battery life, and more

Two nearly identical tablets let us dig deep into the differences. **BY GORDON MAH UNG**

We just spent a week hearing about the future of Qualcomm's PC chips. Now it's time to return to the present. Until the Snapdragon 8cx (go.pcworld.com/8pcx) comes out around Q3 2019, the battle of Intel vs. Snapdragon is being played out in stores and online, with the scrappy Snapdragon 835 and 850 (go.pcworld.com/85pc) facing a small army of Intel mobile CPUs.

Should you buy a laptop with a tried-and-true Intel chip, or an upstart from mobile leader Qualcomm? While it's generally accepted that the Intel chips offer better performance, and the Snapdragon chips offer better battery life, we had a unique opportunity to dive deep into the differences when we tested two versions of HP's Envy x2: one with Qualcomm's Snapdragon 835, the other with Intel's 7th-gen, low-power, Core i5-7Y54. Both are shipping products still

IMAGE: GORDON MAH UNG

being actively sold by HP today.

It's about as apples-to-apples as you can get. And while the results aren't surprising, they do highlight the clear choices you can make if you buy today—and the challenges Qualcomm faces as it tries to catch up to Intel.

TWO HP ENVY X2S FACE OFF

The Envy x2s we tested are nearly identical. Both versions feature 12-inch, 1920x1280 touchscreens with pen support, as well as Surface-esque keyboard covers (though the Intel version's cover is horrible). Both also have 49-watt-hour batteries and run Windows 10.

The Intel Core–based tablet came from the factory with 64-bit Windows 10, while the Snapdragon-based tablet came with Windows 10 in S-mode. For this comparison, we used the option to switch the latter tablet to full Windows 10.

One last note: Although HP only sells the Envy x2 with 4GB RAM/128GB storage configurations, the Qualcomm-based Envy x2 we borrowed featured 8GB RAM/256GB of UFC storage. So while it's not quite even, the advantage here goes to the Qualcomm-based tablet.

CINEBENCH R11 PERFORMANCE

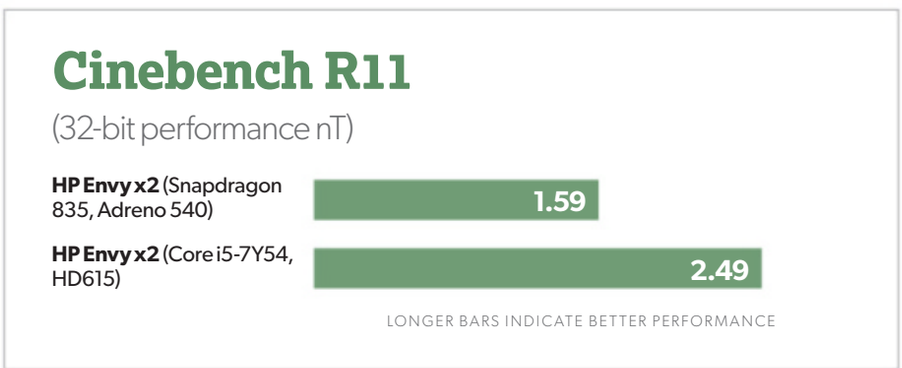
Our first test is Maxon's Cinebench R11. This benchmark is older than the popular Cinebench R15, but it runs on the 32-bit only ARM-based Envy x2. It still relies on a real-world engine used in the company's Cinema4D (albeit much older at this point.) The test is multi-threaded, and the more cores and threads you throw at it, the faster it gets.

At first glance, the results for the Snapdragon 835 aren't great. But if you look on the bright side, the Intel chip is only about 57 percent faster. Because the Snapdragon 835 is an 8-core CPU, and because this test is multi-threaded, it gets a fairly decent boost, even if four of its cores are low-power "little" cores, and only four are more powerful "big" cores.

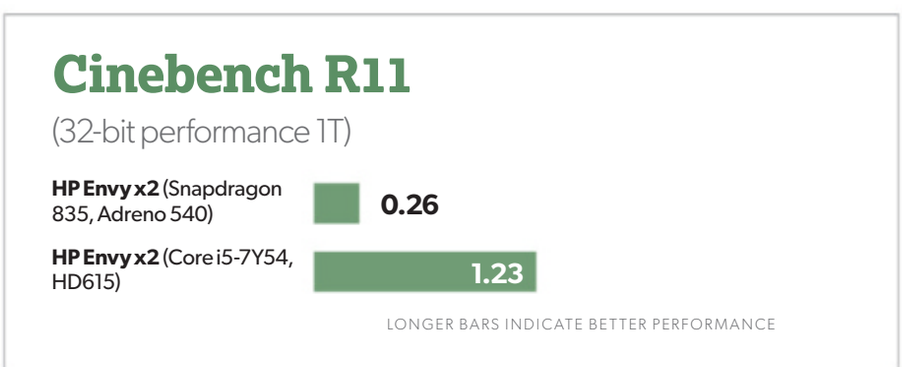
To find out the performance of each

The HP Envy X2 comes in Intel or Qualcomm ARM trim with the only discernible difference being the amount of ports (the Intel version has two USB-C while the Qualcomm one has one USB-C).

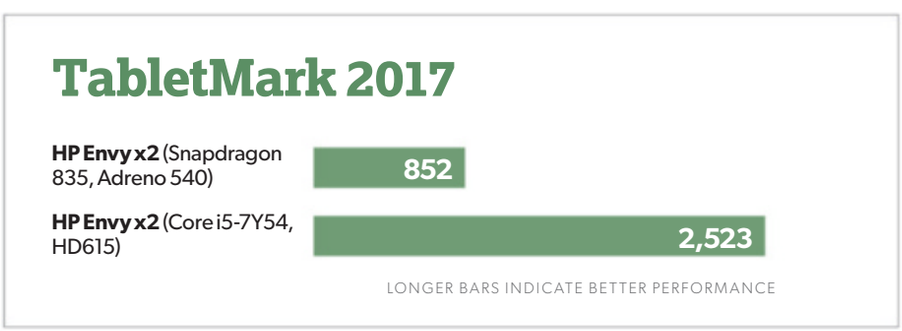
individual core, we set Cinebench R11 to run in single-threaded mode. The results are far worse for Snapdragon: The single-core performance of a 5-watt Core i5-7Y54 is about 373 percent faster than the single-core performance of a Kryo CPU inside the Snapdragon 835.



Using Maxon's older Cinebench R11 in 32-bit mode, the Snapdragon 835 trails the 7th-gen Core i5-7Y54, though by less than we thought.



The single-core performance of the Kryo 280 CPU in the Snapdragon 835 is pretty terrible compared to the 5-watt Core i5-7Y54.



TabletMark 2017 measures browsing, and photo and video sharing. The Snapdragon 835 performs about as well as an Atom X5 chip (in other words, not that great).

TABLETMARK 2017 PERFORMANCE

We next ran TabletMark 2017. This is a cross-platform benchmark made by BAPCo for measuring performance on Windows, Android, and iOS tablets. It uses custom-written applications for each OS, and each OS's APIs for basic functions such as photo and video sharing, and browsing. The latest version on Windows 10 supports UWP and was rewritten to support the new OS.

The results are better, but if TabletMark 2017 is an indication of "business application use," then the Core i5 is about 200 percent faster than the Snapdragon 835.

WHAT'S HOLDING BACK SNAPDRAGON

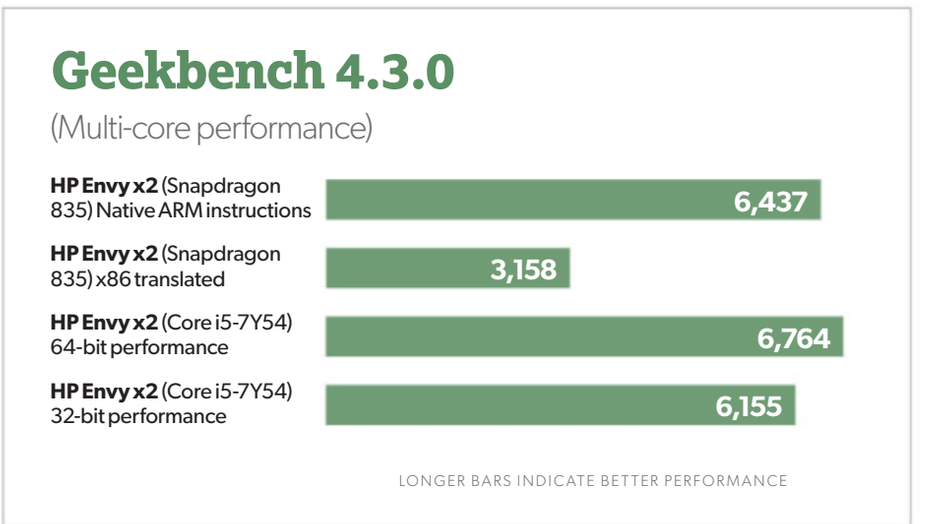
We could show more benchmarks with the Snapdragon 835 likely trailing the Core i5 (sometimes by big

margins), but the song remains the same: Running Windows 10 apps, even UWP apps from the Windows Store, doesn't end well for the Snapdragon 835. Instead, let's try to find out a little more about why the Snapdragon 835 might be so far behind even a midrange Core i5 low-power chip.

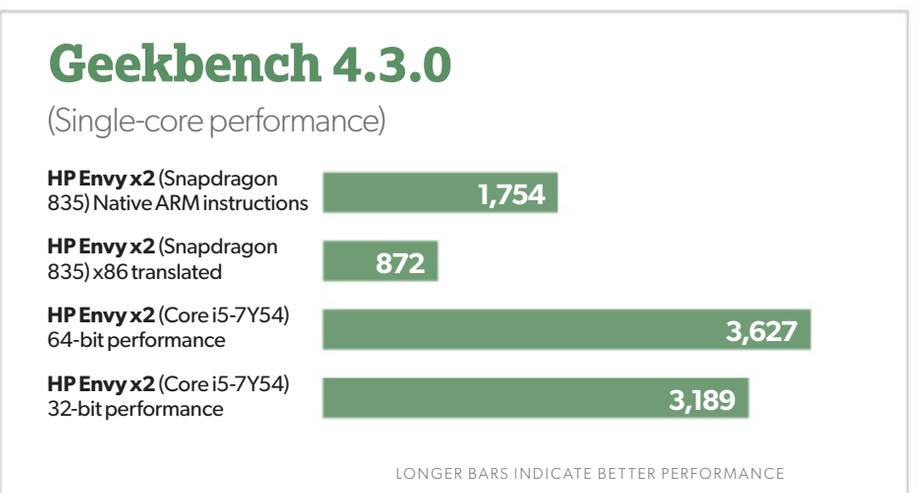
For that we turn to the latest version of Geekbench 4. The benchmark lets you measure performance in x86 and also running native ARM code. Remember, Windows has been primarily an x86 operating system; running the OS and applications on ARM is a little like speaking a different language at full speed.

To make instructions for x86 work on ARM work, Microsoft and Qualcomm translate the binary instructions in real time. This translation eats performance, and we get a glimpse of how much it costs using Geekbench 4.3.0.

The longer bar is the performance of the Snapdragon 835 running without translation in its native language. It's a huge jump in performance for the ARM chip and shows what it could do if it didn't have to struggle so much with Windows. The second purple bar below is the performance in x86 after it has been translated and executed. There's that performance gap.



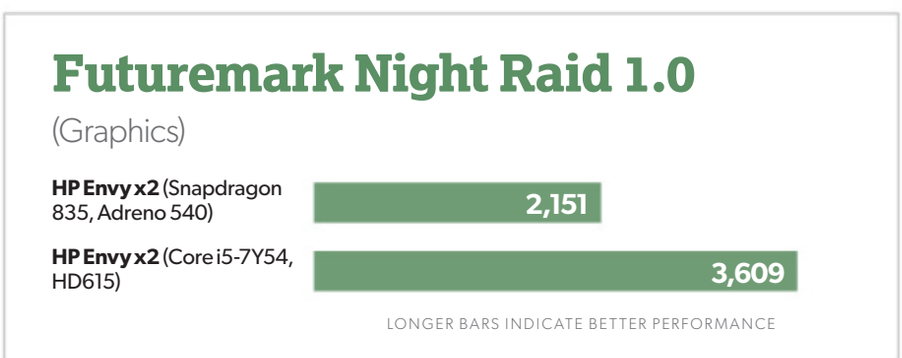
Geekbench lets you test both x86 translated performance and native ARM performance of the ARM chip inside the HP Envy x2.



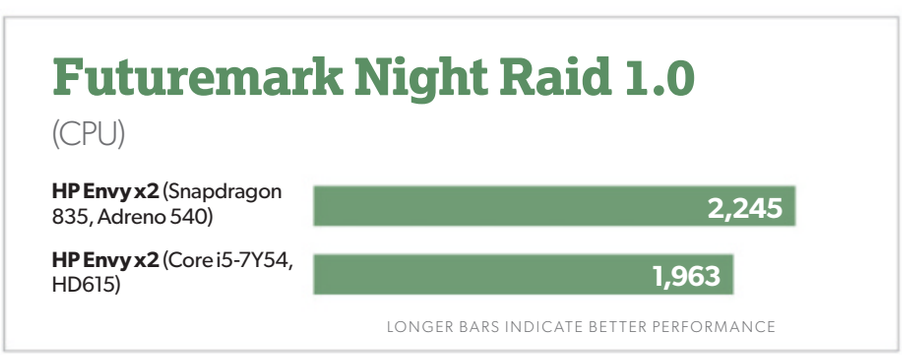
The Snapdragon 835's single-core performance is slower than an Atom X5 in Surface 3 when it has to go through the translator, but running native ARM instructions, it's actually close to a Pentium 4415Y in the new Surface Go.

If you believe the Snapdragon is magically made as good as the 7th-gen Core i5 based on the above results—remember that's the multi-core performance where we're talking eight cores on the Snapdragon 835 vs. two cores on the Intel Core chip with Hyper-Threading.

Geekbench's single-core performance gives you a better idea of how far Qualcomm has to go before it can declare victory or even parity. The shorter purple bar, again, is x86 translated, and it's performing worse than an Atom X5 in a Surface 3. Native performance, is far, far better, though still behind what you'd see in a Pentium 4415Y in the new Surface Go.



Intel's HD615 integrated graphics is about 68 percent faster than the Snapdragon's Adreno 540, even when running native ARM code.



The Intel Core i5-7Y54 finds itself at a disadvantage when running multi-core, game physics tests. We are, however, talking about an 8-core Snapdragon vs. a 2-core Intel Core.

FUTUREMARK NIGHT RAID PERFORMANCE

So far we've focused on the Kryo CPU inside the Snapdragon 835, but there's also a graphics core. UL's new Futuremark Night Raid DX12 test supports ARM-based CPUs running Windows 10. That means we should see the best performance from the Snapdragon 835's Adreno 540 GPU, rather than having to deal with real-time binary translations of instructions.

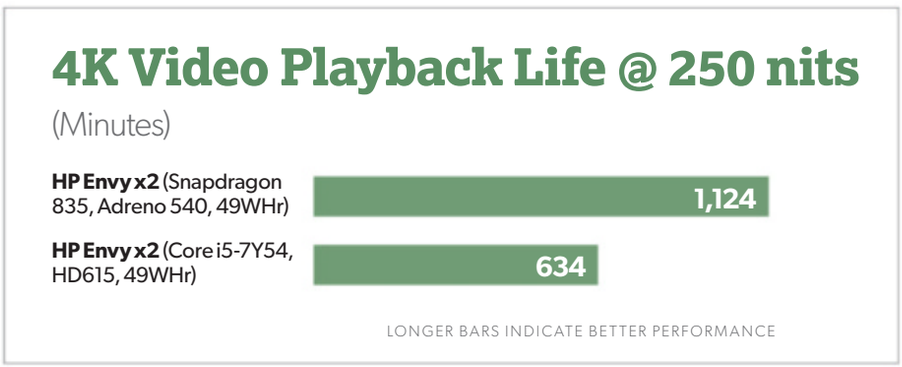
The results are what we've come to expect. The Intel HD615 in the Core i5 is about 68 percent faster than the Adreno 540 in the Snapdragon 835.

Futuremark also measures and breaks out CPU performance when doing game physics. Remember that this result is a multi-threaded test, so it's not surprising that the Snapdragon 835's eight cores prevail over the Intel Core chip's two.

BATTERY PERFORMANCE

Our last official test result is the one reason you might want to consider the HP Envy x2 with ARM over Intel—battery life.

To measure that, we



The Intel-based Envy x2 gives you a great 10 hours of video playback on battery, but the Qualcomm-based Envy x2 gives you a stupid-good 16 hours.

set both tablets to airplane mode and set the brightness to the same 250 to 260 nits. That's office-bright—not I'm-trying-to-eke-out-a-day-of-run-time brightness. We then loop a 4K video using Windows Movies & TV while playing audio through an in-ear headset. The results speak for themselves. First, we can't complain about the Envy x2 with Intel. It's basically 10 hours of playback. But when you want to go for the gold, the Envy x2 with Qualcomm gives you a stupidly long 16 hours of run time.

VERDICT

The primary conclusion is that the binary translation Microsoft and Qualcomm uses is pretty cool. It lets tablet and laptop users on ARM run their conventional Windows applications. That's what separates today's ARM-based tablets from the complete and utter failures that Windows RT tablets were in 2013.

That nifty feature though, is also what makes Windows 10 on ARM painfully slow. Using a Windows ARM tablet, you'd swear it was Core-class responsiveness in some applications like Edge, Office, or Windows. But hit a non-native application, like Google Chrome or Slack, and the ARM tablet slows to a crawl that would make a snail flash his high-beams at you so it can pass.

The choice is clear: The Intel-based Envy x2 (go.pcworld.com/x212; available at HP.com) offers the best combination of performance and battery life. It's the overall winner. But the Snapdragon-based Envy x2's 16 hours of battery life is nothing to sneeze at, assuming your priority is battery life over performance. It also currently costs about $100 less via HP.com (go.pcworld.com/11nr) than the Windows version.

Take this verdict as current rather than final, though. The Snapdragon 835 is a first-generation attempt from Qualcomm. Given the speed at which the company iterates SoCs for tablets and phones, it's entirely possible ARM will be a viable option for Windows someday. This is just round 1 in what could to be a long fight.

iPhone XR vs. Android's best: A razor-thin margin of victory

Apple's newest and cheapest handset takes on the Galaxy Note 9, Pixel 3 XL, and OnePlus 6T. **BY MICHAEL SIMON**

The new iPhone XR might not be a flagship, but it's really good. So good, in fact, that I called it Apple's best iPhone ever in my review (go.pcworld.com/xrev)—not because of its specs (which are technically inferior to those of the XS and XS Max) but because of its value proposition. That's pitting it against other, pricier iPhones, though. I wanted to see how the iPhone XR would fare against three of Android's best phones: the Galaxy Note 9, Pixel 3 XL, and OnePlus 6T.

We'll walk through all the major factors we review in a phone, discussing each phone's pros and cons and picking a winner.

DISPLAY

Ask any screen geek about the difference between the iPhone XR's LCD and an AMOLED screen, and they'll tell you that there's no comparison. Text is crisper, colors are brighter, and whites are more brilliant on the OLED displays, and blacks are as deep as they can get thanks to the ability to turn off each individual pixel completely.

IMAGE: CHRISTOPHER HERBERT

LCDs have their strengths—they're much cheaper to manufacture, and brighter and easier to read in sunlight—but they're inherently inferior to OLED due to the need for constant backlighting. That makes them thicker, less malleable, and less power-efficient, with duller colors.

All of the screens here are very similar, but somehow the 6.2-inch iPhone XR looks tiny compared to the 6.3-inch Pixel 3 XL, and 6.4-inch OnePlus 6T and Galaxy Note 9. In addition to its size, the display in the iPhone XR's resolution is 1,792x828, or 720p, versus the 2K displays on the Note 9 and Pixel 3 XL, and the 1080p one on the OnePlus 6T. The XR's effective ppi is just 326, again a far cry from the Note 9 (516), Pixel 3 XL (523), and OnePlus 6T (402).

However, unless the phones' screens are compared side by side, most people aren't going to see a difference. It's tough unless you know what you're looking for. Scaled-down HD content still looks great, text is crisp and easy to read, and even blacks looks good. True Tone is an absolute delight.

Apple calls the screen on the XR "Liquid Retina," a fancy marketing term to draw attention to the rounded corners and "all-screen design." But I also found it extremely color-accurate, and I preferred the shape of the XR's corners to those of all the comparison phones. The Note 9's are a bit too boxy for my tastes, and the OnePlus 6T's too round. The Pixel 3 XL is the worst of the bunch, with mismatched top and bottom corners that offend my eyes.

The iPhone XR excels in brightness, too. In my testing, which turned each phone to maximum brightness and turned off the respective adaptive brightness toggles (as well as True Tone on the XR), the iPhone XR topped off at 825 nits, with the others coming in below 700.

VIDEO: **iPHONE XR TAKES ON THE BEST ANDROID PHONES OF 2018**
Watch now at go.pcworld.com/xra

The screens are all great, but the Note 9's (far right) handles color and detail just a bit better than the Pixel 3 XL (second from right) and OnePlus 6T (second from left) do. Even the iPhone XR's 720p screen (far left) looks good.

However, there's no hiding that the iPhone XR has an LCD. No matter how much work Apple put into making the XR screen realistic and vibrant, a pixel-by-pixel comparison with the three OLED-equipped phones I chose wasn't much of a contest. The OLEDs accomplish a broader range of tones and hues, most clearly when viewing something with a black background, like Apple's iPhone XR page. On the OLEDs, the blackness blends into the bezels, but on the XR there's an obvious distinction where the screen ends and the bezels begin.

The Note 9's 2K OLED screen is superior to the iPhone XR's LCD, but not as much as you'd think.

While you can tweak the color settings to your eyes' content on the Galaxy Note 9 (left), you're only able to adjust the brightness and toggle True Tone on the iPhone XR.

Out of the three OLED phones, I prefer the Note 9. Samsung makes the best OLED displays in the business—in fact, it supplies screens for the iPhone XS and Pixel 3 XL. The optimization and calibration it's done on the Note 9 is second to none. Samsung also offers a variety of display options to adjust both the resolution and the temperature.

The Pixel 3 XL is a close second—though I noticed a bit of smearing when watching videos. The OnePlus 6T does well with fewer pixels, particularly after I switched to DCI-P3 mode. In fact, I found the default setting way too saturated for all of the Android displays, a problem I didn't have with the iPhone XR. Which is good, because even if I did I couldn't do anything about it.

Even with the screen mode set to Basic, the Note 9 shines, with richly saturated colors, excellent white balance, and barely any visible banding. Though its maximum manual brightness is lower than that of all the other phones, it still lights up a room and performs extremely well in direct sunlight. I preferred the aspect ratio of the XR and other Android phones here to the Note 9's ultra-tall proportions, but ultimately I just couldn't deny the overall greatness of Samsung's display.

Winner: Galaxy Note 9

DESIGN

When I compared the iPhone X to flagship Android phones last year (go.pcworld.com/xvan), I predicted that "a couple of" Android flagships would adopt camera notches in 2018. It turns out nearly every major Android phone maker sells a phone with a camera notch. Even holdout Samsung teased a family of notched screens at its developers conference.

But a notch alone does not make a premium phone. The iPhone XR has the same cutout at the top of the screen as the iPhone XS, but the designs diverge otherwise. On the XR, the glass back comes in four new colors in addition to the standard white and black, and the sides are made of color-matched anodized aluminum. That's a material downgrade from the iPhone XS's stainless steel, but I actually prefer it. It's less prone to scuffs and scratches, but I especially like the way the color peeks over the edges of the screen. Simply put, the rear of the iPhone XR is a thing of beauty, even more so than the Pixel 3 XL's gorgeous two-tone frosted glass. And it's a small thing, but I like the placement and length of the iPhone's power button.

The bezels, on the other hand, are less beautiful. Due to the inherent engineering issues with LCD screens, Apple has increased the size of the bezels on the XR by about 50 percent compared to those on the iPhone X (4mm vs. 2.5mm). The difference is stark. For years, Apple has taught us that every millimeter matters when it comes to smartphone design, so the iPhone XR feels like a step backward from both the iPhone X and 8.

The bezels are much thicker on the iPhone XR (left), but the tiny notch on the OnePlus 6T really brings it home.

Apple could have given the iPhone XR slimmer bezels with a larger chin and forehead like the other phones here. By sticking with 4mm bezels all around, the company prioritized symmetry over slimness. I actually prefer the iPhone XR's display design to the Note 9's unbalanced Infinity Display and the Pixel 3 XL's giant chin. However, when it came to watching movies, the XR's notch was a real issue, while the 6T and even the Pixel 3 XL were able to hide it.

There's no denying the awesomeness of the OnePlus 6T in Thunder Purple (right).

The OnePlus 6T gets it right. Yes, the chin is larger than the side bezels, but it's nowhere near as large as it is on the Pixel 3 XL or the Note 9. In fact, it's no bigger than the XR's bottom bezel, with slimmer sides and a skinny forehead that's interrupted only by the smallest of notches.

The OnePlus 6T has a "teardrop" notch just large enough to include a single camera, unlike the wide notch on the iPhone XR and the ultra-deep one on the Pixel 3 XL. Like those phones, the notch extends a bit deeper than the standard status bar, but its curved design has a slimming effect. It's done so well, I prefer the visible notch to the blackout bar, and it's one of the few phones I've used where it actually feels like I'm getting more screen real estate and not just a weird compromise.

I never thought I'd see the day when OnePlus bested Samsung or Apple with a smartphone design, but the 6T is a real work of art, with the highest screen-to-body ratio of all the phones here and a notch that even haters can love. And just wait until you see the new Thunder Purple color in person (go.pcworld.com/1p6t).

Winner: OnePlus 6T

BATTERY

When Apple announced the XR alongside the XS and XS Max, the most surprising difference between the three devices wasn't the screen, it was the battery life. According to Apple's specs, the iPhone XR "lasts up to 1.5 hours

longer than iPhone 8 Plus," which is more significant than it seems. The iPhone 8 Plus was Apple's previous battery champ, lasting noticeably longer than the iPhone X.

But claims are one thing, results are another. Because Apple provides little in the way of specs for its iPhones, we have to rely on iFixit teardowns to get the goods (go.pcworld.com/ifix). We now know that the iPhone XR includes a 2,942mAh battery, a lot smaller than the ones inside the other phones here:

The Galaxy Note 9's battery capacity trounces the iPhone XR's.

Pixel 3 XL: 3,430mAh
OnePlus 6T: 3,700mAh
Galaxy Note 9: 4,000mAh

Benchmarks tell another story. Using the Geekbench 4 Battery Benchmark test with the screen set at 200 nits and adaptive/automatic brightness turned off for each of the phones, the OnePlus 6T trounced the others, with the iPhone XR and Note 9 bringing up the rear:

iPhone XR: 3463 (5:48)
Pixel 3 XL: 3640 (6:04)
OnePlus 6T: 4380 (7:18)
Galaxy Note 9: 3420 (5:42)

On paper, the iPhone XR gets smoked, plain and simple. But as usual with the iPhone, paper doesn't tell the whole story. OnePlus and other Android phone makers have been known to game benchmarks to skew results in their favor, so we should take these numbers with a grain of salt. And as such, real-world testing didn't bear out these results at all. The two best performers in day-to-day use were the iPhone XR and Note 9, which scored the lowest using Geekbench's test.

Apple has a knack for squeezing lots of juice out of relatively small batteries, and the XR is no exception. iOS 12's Auto-Brightness is either vastly superior to Android Pie's Adaptive brightness, or Apple is performing some wizardry with background processes. Each of these phones lasted through a full day of heavy use (or close to it), but the iPhone XR was the one phone that consistently ended the day with a decent amount of battery to spare (10–20 percent), without ever needing to plug it in. The Note 9 was a close second. The OnePlus 6T performed extremely well too, though it tended to get extremely dark with automatic brightness turned on, to the point where some movies were unwatchable.

Speaking of which, I watched a two-hour

Streaming an HD movie at full brightness looked great on all four phones, but the XR's notch really gets in the way.

Netflix movie with adaptive/auto brightness off, and the brightness turned all the way up for each phone. Starting with a full charge, here's what I was left with:

iPhone XR: 79 percent
Pixel 3 XL: 76 percent
OnePlus 6T: 83 percent
Galaxy Note 9: 74 percent

Pretty close, all around. Immediately after, I played an hour-long show with adaptive brightness turned on and forced lighting changes so the screen needed to adjust:

iPhone XR: 72 percent
Pixel 3 XL: 55 percent
OnePlus 6T: 66 percent
Galaxy Note 9: 52 percent

It's here where you can see how the iPhone XR's adaptive brightness and the A12 chip benefits the battery. Where the other phones took a 20-percent hit and got quite warm after a third hour of streaming, the iPhone lost just seven percent of its battery life and barely broke a sweat. Whatever Apple's doing with its phones is incredibly impressive. I can only imagine how long the next iPhone would last if Apple decided to give it a 4,000mAh battery.

Winner: iPhone XR.

CHARGING

While all of these phones are capable of fast charging, the mileage varies considerably when using each handset's bundled power adapter and cable. Here's what I ended up with after an hour of charging following a full depletion for each phone:

iPhone XR: 37 percent
Pixel 3 XL: 82 percent
OnePlus 6T: 91 percent
Galaxy Note 9: 76 percent

The iPhone percentage isn't a misprint. Apple still bundles a woefully inadequate 5W charger with the iPhone XR (as well as the thousand-dollar iPhone XS models), and

it charges the iPhone incredibly slowly. To get faster charging on the iPhone XR, you'll need to pony up $19 for Apple's 12W USB Power Adapter or buy a similar third-party plug. In any case, it's not as good as the OnePlus's fast charging.

Results pulled a bit more even with wireless charging, but the iPhone brought up the rear here too, topping off at 7.5W while the Note 9 reached 10W. The Pixel 3 XL also reached 10W, but it required its own Pixel Stand to do so and dropped to 5W on other chargers. The OnePlus 6T doesn't offer wireless charging yet, which is a bummer, but the strength of its cable system edges out its competitors.

Winner: OnePlus 6T

PERFORMANCE

The iPhone XR has the distinction of being the only phone in this comparison that isn't powered by Qualcomm's Snapdragon 845 processor. Apple's A12 chip shows them all how it's done:

Geekbench (single-core/multi-core)

iPhone XR: 4818/11326
Pixel 3 XL: 2313/8454
OnePlus 6T: 2359/8922
Galaxy Note 9: 2391/8268

Things are a bit more equal when it comes to graphics performance between the two chips, but the iPhone XR's A12 chip still showed up the Snapdragon 845:

3DMark SS Extreme (Vulkan API vs. Metal API)

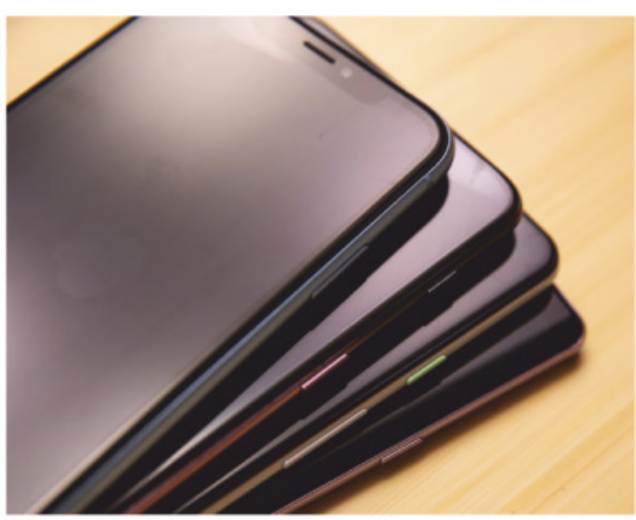
iPhone XR:3651
Pixel 3 XL: 3482
OnePlus 6T: 3842
Galaxy Note 9: 3641

Ice Storm Unlimited

iPhone XR: 77344
Pixel 3 XL: 61756
OnePlus 6T: 64264
Galaxy Note 9: 54990

And finally, I ran the AnTuTu benchmark, which is far more popular on Android than it is on iOS, with similarly lop-sided results:

iPhone XR: 335174
Pixel 3 XL: 285184
OnePlus 6T: 289691
Galaxy Note 9: 282680



It might be hard to tell any these phones apart with the screens off, but using them is a different story.

The Galaxy Note 9 (bottom) is the only phone here to offer a headphone jack.

Android fans will point out that all of these phones have more RAM than the iPhone, but Apple manages to make good use of the iPhone XR's memory, too. On average, it kept around 12 to 15 apps at the ready for switching (without needing more than a second to load), the same as the Note 9 and the OnePlus 6T, and way more than the Pixel (though Google says that's a bug that will be addressed in a future update). Rumor has it that the Snapdragon 855 will catch up, but for now, the gap is very wide.

Winner: iPhone XR

SOUND

The Galaxy Note 9 is the only phone here that still has a headphone jack, so it starts off with a big lead out of the box. To compensate, Apple offers up a set of Lightning Earbuds but opted to dump the 3.5mm adapter this time around (you can buy one from Apple for $9, go.pcworld.com/935m). OnePlus includes a USB-C–to–3.5mm adapter, but you'll need to buy a pair of $20 USB-C Bullets (go.pcworld.com/usbl). Google bests them all, bundling a set of surprisingly good USB-C Pixel Buds along with a USB-C–to–3.5mm adapter in every Pixel 3 box.

The iPhone XR, Pixel 3 XL, and Note 9 feature stereo speakers (the 6T does not), and they all sound great. When pumped to the max, the iPhone XR has excellent bass but can get a little muddled, and the Note 9 is a touch tinny for my ears. The Pixel 3 XL sounded best due to its front-firing speakers.

Winner: Pixel 3 XL

BIOMETRICS

Apple introduced Face ID with the iPhone X, and it only took a year to bring it to the rest of the iOS lineup, including the iPad Pro and iPhone XR. Apple has improved the system for its 2018 phones, and the enhancements only pads its lead. In short, Face ID makes all other biometric options seem slow, clunky, and just plain dated.

None of the Android phones here have a system to match the combination of security and simplicity that Apple delivers with Face ID on the XR. OnePlus's in-display fingerprint sensor brings a wow factor for sure, but it's slower and less reliable than traditional fingerprint sensors. While the 2D facial recognition on the 6T works incredibly fast, it can be easily spoofed, which kind of defeats the purpose. The Note 9's iris scanner is the closest thing to Face ID, but it's much too persnickety to really compete. The Pixel 3 XL doesn't even try, offering only a standard fingerprint sensor on the rear.

Winner: iPhone XR

OPERATING SYSTEM

A smartphone is only as good as its software, and you pretty much know what you're getting with the XR: the newest OS, years of updates, and strong app support. The new full-screen design means gesture navigation takes over, and it's just as intuitive, familiar, and responsive as it was with the home button.

The XR is one of three out of the four handsets here to support both gesture navigation and the latest respective OS, with the Note 9 being the odd phone out. They're all somewhat similar: Swipe up to go home, pause to multitask, swipe right to cycle through apps, etc. But while it's clearly the future for the iPhone, it's less certain on Android.

The OnePlus 6T is the only one to offer the option to switch between gesture and virtual button navigation, and I suspect lots of users will opt to leave it off. Gesture navigation in Android 9 Pie is nowhere near as fluid nor smart as it is on the iPhone, and the enhancements OnePlus has added don't move the needle. In fact,

The iPhone XR (far left) is the fastest and simplest to unlock.

without the home button or indicator line as guidance, I was often confused as to where and how to swipe on the 6T.

Even on the Pixel 3 XL, where gesture navigation is as good as it gets on Android, there's a clunkiness and half-baked nature that makes it feel stickier and slower than it does on the XR. The Pixel's tremendous speed and optimization more than make up for it, but switching between it and the XR only highlights the iPhone's advantage. On the XR, gesture navigation is smart and smooth as butter.

But the Pixel 3 is head and shoulders above the rest of the Android field. The Note 9 is still on Oreo and will be for a while, and even the minimal OnePlus 6T feels just a touch slower that it does when compared to the Note 9. Android on the Pixel 3 is the closest you're going to get to iOS on the iPhone, with tight end-to-end control over the entire system that results in a top-notch experience (no pun intended).

The OnePlus 6T (second from left), Pixel 3 XL (second from right), and Galaxy Note 9 (far right) all run Android, but the experiences are very different.

(Left to right): The iPhone XR, OnePlus 6T, and Pixel 3 XL all run the latest version of their respective operating systems, but the Galaxy Note 9 is still stuck on Android Oreo.

On its own, the Pixel 3 XL is a bland, even ugly phone, but Android 9 makes its inner beauty shine. For example, check out these startup times:

iPhone XR: 15 seconds
Pixel 3 XL: 9 seconds
OnePlus 6T: 18 seconds
Galaxy Note 9: 16 seconds

Six seconds might not seem like a lot, but when you're staring at the screen, it seems like an eternity. And it's like that all over the Pixel 3: apps, multitasking, scrolling, it all flies by and makes the other Android phones feel inferior. Google also promises two years of major

updates and three years of security updates, which is way more than you'll get on any other Android phone. It's still not as good as Apple—especially when it comes to fixing major bugs that pop up—but Pixel owners are consistently the first to get updates.

Ultimately, choosing between the Android 9 and iOS 12 is a matter of preference, and there are strong opinions on either side. Let's call this one a tie.

Winner: iPhone XR/Pixel 3 XL

STORAGE

Internal storage is finally becoming less of an issue when buying a smartphone, especially a premium one. All of the phones here offer at least 64GB of base storage. To simplify things to a base level, here's the gigabyte-to-dollar ratio (for the full price of each handset):

iPhone XR (64GB): $11.70

Pixel 3 XL (64GB): $14.05

OnePlus 6T (128GB: $4.28

To get an even better sense of the storage value, take a look at the upgrade prices for each of these phones:

iPhone XR: $0.78 XR (64GB upgrade)

Pixel 3 XL: $1.56 Pixel 3 XL (64GB upgrade)

OnePlus 6T: $0.62 (128GB upgrade)

Galaxy Note 9: $0.65 (384GB upgrade)

Apple actually offers a decent upgrade for the XR, letting you go from 64GB to 128GB for just $50. Google charges $100 for the same storage bump. Samsung offers a good value, but forces users to upgrade to more storage than they probably need (though it does bump the RAM to 8GB). It's also the only phone to offer an SD slot for expandable storage, so you could bump it up to a full terabyte, which is just nuts.

I still have to give the crown to the OnePlus 6T here. It offers the best per-gigabyte value—and also bumps the RAM to 8GB in the 256GB model—and it's not overcharging or forcing heaps of storage on its users, like Samsung does with the Note. That's why I like the 128GB option on the XR for $50, which Apple doesn't offer on the iPhone XS.

Winner: OnePlus 6T

Only the Galaxy Note 9 lets you pop in an SD card and double the storage to 1TB.

In Portrait Mode, the Pixel 3 XL (top right) once again blew everyone away with a stronger unadjusted bokeh effect and crisp definition. The iPhone XR (top left) nailed the color of my son's cheeks, while the Galaxy Note 9 (bottom right) and OnePlus 6T (bottom left) smoothed his features a bit too much.

All four phones have optical image stabilization on the main camera, but the iPhone XR (top left) and Pixel 3 XL (top right) handled motion much better than the OnePlus 6T (bottom left) and Galaxy Note 9 (bottom right).

CAMERA

If you look at the specs for each of these cameras, you'd probably think the OnePlus 6T is the best:

iPhone XR: 12MP, f/1.8, OIS

Pixel 3 XL: 12.2MP, f/1.8, OIS

OnePlus 6T: 16MP (OIS, f/1.7) + 20MP (f/1.7)

Galaxy Note 9: 12MP (OIS, f/1.5) + 12MP (OIS, f/2.4)

But like battery capacity, specs don't mean much when it comes to smartphone cameras. More and more work is being done by the image signal processor, and it's gotten to the point where the computational work is far more important than hardware. Quite frankly, OnePlus's camera doesn't even really compete against these phones.

The iPhone XR uses the same lens as the XS, so the only thing you're losing from Apple's thousand-dollar phone is 2X optical zoom and the depth necessary for true

Night Sight on the Pixel 3 XL (top right) is just remarkable, showing up the OnePlus 6T's own Night mode (bottom left). The Note 9 did OK with its f/1.5 camera (bottom right). The iPhone XR (top left) just plain struggled in this nighttime scene.

portrait mode. Apple does offer portrait mode on the XR (unlike prior single-camera iPhones), but only for people, a limitation that isn't on any of the other phones. For pet lovers, that alone is probably a deal-breaker.

With low-light images, the Pixel's Night Mode blows the XR and everything else away. It's astounding. The OnePlus 6T has a Night mode as well, but it doesn't come close—adding a weird sepia glow to things and completely blowing out any available light. Dark scenes that are barely recognizable on other phones are gorgeous on the Pixel 3 XL, with even light and details that the XR and Note 9 simply can't see. Some might argue that the photos are unnatural and soft, but unless you're inspecting them closely, they'll look perfectly fine to most eyes. When they're taking a picture of their kids in a dark room and the end result looks like it was professionally lit, parents aren't going to care about a little facial smoothing.

The Pixel 3 XL doesn't just take better pictures than the rest; it's downright remarkable what it can do with a single lens (and a lot of background processing). The iPhone XR and Note 9 were often close (though the XR really struggled with low-light shots), but from portraits to low-light photos, the Pixel 3 XL truly raises the bar for smartphone cameras.

Winner: Pixel 3 XL

PRICE

Apple generally gets trounced when it comes to price, but the iPhone XR is different. It was created as a lower-priced alternative to the iPhone XS, and at $749, it offers a surprising value for what you get. That's $150 cheaper than the Pixel 3 XL and $250 less than the Note 9.

The OnePlus 6T costs even less, starting at $549. You're giving up a few important features, namely wireless charging, water resistance, and stereo speakers, and the camera is unremarkable. But the specs are

otherwise top-of-the-line, the screen is great, and the design is simply gorgeous. Even if you max it out with 8GB of RAM and 256GB of storage, it'll still cost you $120 less than the iPhone XR.

Apple might have pulled off a nice trick by trimming 25 percent off the price of the iPhone XS without sacrificing too much of what makes it such a great phone, but I just can't overlook the tremendous value offered by the 6T.

Winner: OnePlus 6T

VERDICT

While last year's battle produced a clear winner in the iPhone X, the competition is a lot closer this year. The iPhone XR lost a few main categories, namely design, display, and camera.

Priorities matter, too. If you care about pixel density, the extra $250 for the Galaxy Note 9 will be well worth it. The same goes for the $899 Pixel 3 XL (or $799 Pixel 3, which I didn't test but has the same camera) if you want to take the best possible photos. And if design's your thing, definitely take a look at the Thunder Purple OnePlus 6T.

But if you want the best all-around phone that won't cost a thousand bucks, that delivers incredible performance and battery life, next-gen biometrics, a strong OS, and an attractive price, the iPhone XR is the way to go. No Android phone has quite the same combination of specs, features, and power, even if the XR falls a little short in the areas where iPhones usually excel. When I looked at the results, the XR's performance and update guarantee were enough to push it over the edge. But again, it's very close.

The best phones of the year also come in some of the best colors of the year.

Sapphire Radeon RX 590 Nitro+: New 1080p gaming champion

Heavy metal, refined. **BY BRAD CHACOS**

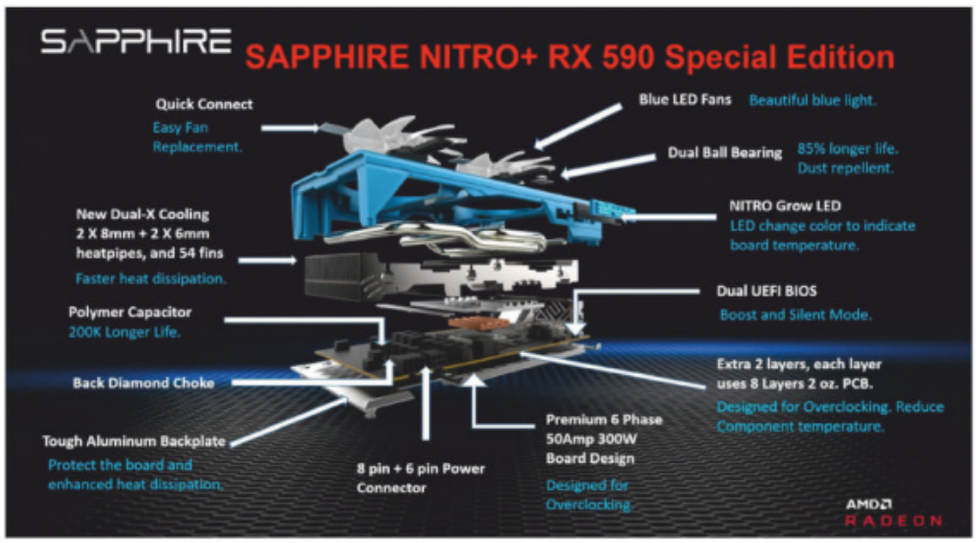
AMD's Radeon RX 590 is the best 1080p graphics card you can buy, and at $280, it won't break the bank. But the Sapphire Radeon RX 590 Nitro+ we're reviewing today proves it's even better than we originally thought.

The card draws an immense amount of power, and the XFX Radeon RX 590 Fatboy (go.pcworld.com/r590) that AMD sent U.S. reviewers ran hot despite coming equipped with a massive triple-slot cooler. Pushing AMD's Polaris architecture so far—this is the same GPU's third incarnation, after the Radeon RX 480 and 580—requires heavy metal, we concluded at the time. While that's still true, Sapphire's graphics card shows that the Radeon RX 590 doesn't have to be gargantuan.

The bright blue Sapphire Radeon RX 590 Nitro+ ($280 on Newegg (go.pcworld.com/590r)) comes loaded with features. Even more impressively, it manages to hit higher frame rates and lower temperatures

IMAGE: SAPPHIRE

than the XFX Fatboy despite fitting in a standard two-slot design. This is the best Radeon RX 590 we've tested.



SPECS, FEATURES, AND PRICE

The Radeon RX 590 is almost identical to the Radeon RX 580 under the hood, utilizing the same underlying configuration, but on an improved 12nm manufacturing process. That process shrink lets AMD's new GPU hit much faster speeds than the Radeon RX 580 and RX 570, which will continue to be sold as well.

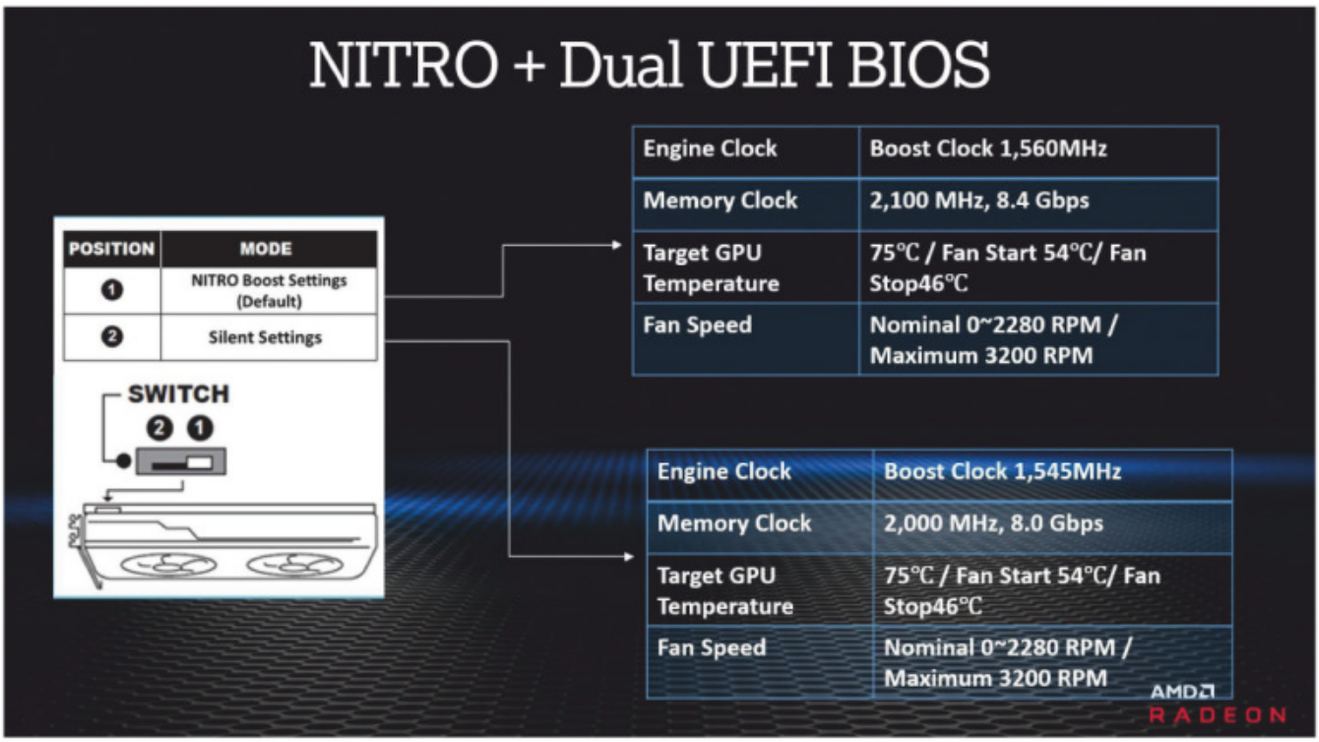
Here's how all three of AMD's mainstream graphics options compare spec-wise:

The Sapphire Radeon RX 590 Nitro+ pushes performance even further. It ships with a 400Mbps effective memory overclock, and the GPU clock speeds hit 1,560MHz, a slight boost over the 1,545MHz reference spec. That's also slightly slower than the 1,580MHz XFX Fatboy on paper. But as you'll see in our benchmarks later, Sapphire's card manages to meet or even slightly exceed the Fatboy's performance in games, thanks to its memory overclock and potent custom cooling system.

Sapphire relies on its flagship Nitro+ custom cooler to tame the RX 590. Starting at the core, Sapphire switched to a new thermal paste that it claims improves thermal conductivity between the GPU and heatsink by 30 percent. The 54-fin heatsink is augmented by a pair of 6mm and a pair of 8mm heatpipes. The fins are aligned with the length of the card to help dump hot air out of the back of your system.

A pair of large, dual ball-bearing fans infused with blue LEDs are centered in the card's attractive blue shroud. Those fans remain idle when the Nitro+ is under light loads—even in the menu of games—and use Sapphire's Quick Connect technology for easy replacement if needed. You can use Sapphire's Trixx software to check on the status of your fans.

The card comes with dual BIOSs, which you may toggle via a switch on the Nitro+'s edge. The default Nitro Boost profile hits the advertised 1,560MHz clock speeds by ramping up the fans. Shifting the BIOS switch to the left enables a Silent setting—called



"optimized for compute" on the packaging, oddly enough—that greatly reduces fan noise but drops down to the reference speeds for the memory and GPU clock. We conducted full testing on the default high-performance profile only, but even that didn't get overly loud. The Silent setting lives up to its name.

Sapphire designed the Radeon RX 590 Nitro+ with overclocking in mind. The PCB has two extra layers for more power and lower temperatures, and the card's equipped with Sapphire's signature black diamond choke and a 200,000-hour polymer capacitor. The 6-phase board was designed to handle up to 300 watts via its 6-pin and 8-pin connectors, and if something somehow goes wrong, Sapphire equipped the Nitro+ with an extra PCIe fuse for protection.

The card's topped off with a sturdy gray-and-blue metal backplate, completing the Sapphire Radeon RX 590 Nitro+'s sleek futuristic look. Looks are subjective, but to my eye, this graphics card is gorgeous, especially if a PC has blue, silver, or white parts. A pair of DisplayPorts, two HDMI connections, and a DVI-D port offer plenty of audio/visual options.

GeForce-beating performance isn't the only reason to consider buying this card. AMD is keen to tout the wide array of affordable FreeSync monitors available for buttery-smooth gaming (go.pcworld.com/fsgs), and rightfully so. Nvidia's rival G-Sync monitors are targeted to premium crowds, not the masses. AMD will also toss in three free games—*The Division 2, Devil May Cry 5,* and *Resident Evil 2*—when you buy a Radeon RX 590 at participating retailers,

SPECS: **SAPPHIRE RADEON RX 590, 580, 570**

	RADEON RX 590	RADEON RX 580	RADEON RX 570
GCN Architecture	4th Generation	4th Generation	4th Generation
Manufacturing Process	12-nm FinFET	14-nm FinFET	14-nm FinFET
Die Size	232 mm^2	232 mm^2	232 mm^2
Compute Units	36	36	32
Stream Processors	2304	2304	2048
Clock Speeds (Boost/Base)	1545 MHz/1469 MHz	1340 MHz/1257 MHz	1244 MHz/1168 MHz
Peak Compute Performance	Up to 7.1 TFLOPS	Up to 6.17 TFLOPS	Up to 5.1 TFLOPS
Texture Units	144	144	128
Peak Texture Fill-Rate	Up to 222.4 GT/s	Up to 193 GT/s	Up to 159.2 GT/s
ROPs	32	32	32
Peak Pixel Fill-Rate	Up to 49.5 GP/s	Up to 42.9 GP/s	Up to 39.8 GP/s
Memory Size	8 GB	8 GB	4 GB
Memory Bandwidth	256 GB/s	256 GB/s	224 GB/s
Memory Interface	256 bit	256 bit	256 bit
Memory Type	GDDR5	GDDR5	GDDR5
Board power	225W*	185W*	150W*
Radeon FreeSync Technology	Yes	Yes	Yes
DirectX 12 Support	Yes	Yes	Yes
Vulkan Support	Yes	Yes	Yes
DisplayPort Version	1.3 HBR/1.4 HDR Ready	1.3 HBR/1.4 HDR Ready	1.3 HBR/1.4 HDR Ready

* TOTAL BOARD POWER DRAW WILL VARY BY AIB DESIGN

making this card a great value if you'd planned on picking up any of those titles. They won't be available to play until early next year, though.

Enough talk! Let's take this to the bench.

OUR TEST SYSTEM

We packed our dedicated graphics card test system with some of the fastest complementary components available to put

any potential performance bottlenecks squarely on the GPU. Most of the hardware was provided by the manufacturers, but we purchased the cooler and storage ourselves.

- Intel Core i7-8700K processor ($360 on Amazon at go.pcworld.com/700k)
- EVGA CLC 240 closed-loop liquid cooler ($120 on Amazon at go.pcworld.com/c240)
- Asus Maximus X Hero motherboard ($260 on Amazon at go.pcworld.com/mxmc)
- 64GB HyperX Predator RGB DDR4/2933 ($416 for 32GB on Amazon at go.pcworld.com/hxpr)
- EVGA 1200W SuperNova P2 power supply ($180 on Amazon at go.pcworld.com/spnv)
- Corsair Crystal 570X RGB case, with front and top panels removed and an extra rear fan installed for improved airflow ($170 on Amazon at go.pcworld.com/crst)
- 2x 500GB Samsung 860 EVO SSDs ($100 on Amazon at go.pcworld.com/smev)

We're comparing the $280 Sapphire Radeon RX 590 Nitro+ against the $280 XFX Radeon RX 590 Fatboy (go.pcworld.com/xfxr), of course. We're also pitting it against the Asus Strix RX 580 Gaming Top OC (go.pcworld.com/gtoc), which cost $300 when it launched, as well as EVGA's 6GB GeForce GTX 1060 SSC ($280 at Best Buy; go.pcworld.com/1ssc)—two other customized, overclocked graphics cards. To show how these $200 to $300 cards compare against step-up options, we also tested the $400 reference Radeon RX Vega 56 (go.pcworld.com/rx56) and $380 GeForce GTX 1070 Founders Edition (go.pcworld.com/70fo).

Each game is tested using its in-game benchmark at the highest possible graphics presets, with VSync, frame rate caps, and all GPU vendor-specific technologies—like AMD TressFX, Nvidia GameWorks options, and FreeSync/G-Sync—disabled, and temporal anti-aliasing (TAA) enabled to push these high-end cards to their limits. If anything differs from that, we'll mention it. We focused our testing on 1440p and 1080p, as those are the natural resolutions for these graphics cards.

PERFORMANCE BENCHMARKS

Strange Brigade

Let's kick things off with Strange Brigade ($50 on Humble at go.pcworld.com/bysb), a cooperative third-person shooter where a team of adventurers blasts through hordes of mythological enemies. It's a technological showcase, built around the next-gen Vulkan and DirectX 12 technologies and infused with features like HDR support and the ability to toggle asynchronous compute on and off. It uses Rebellion's custom Azure engine. We test with async compute off.

Sapphire's Radeon RX 590 is equal to or just the barest of a smidge faster than XFX's, despite the latter's 20MHz clock speed advantage. The pattern repeated throughout

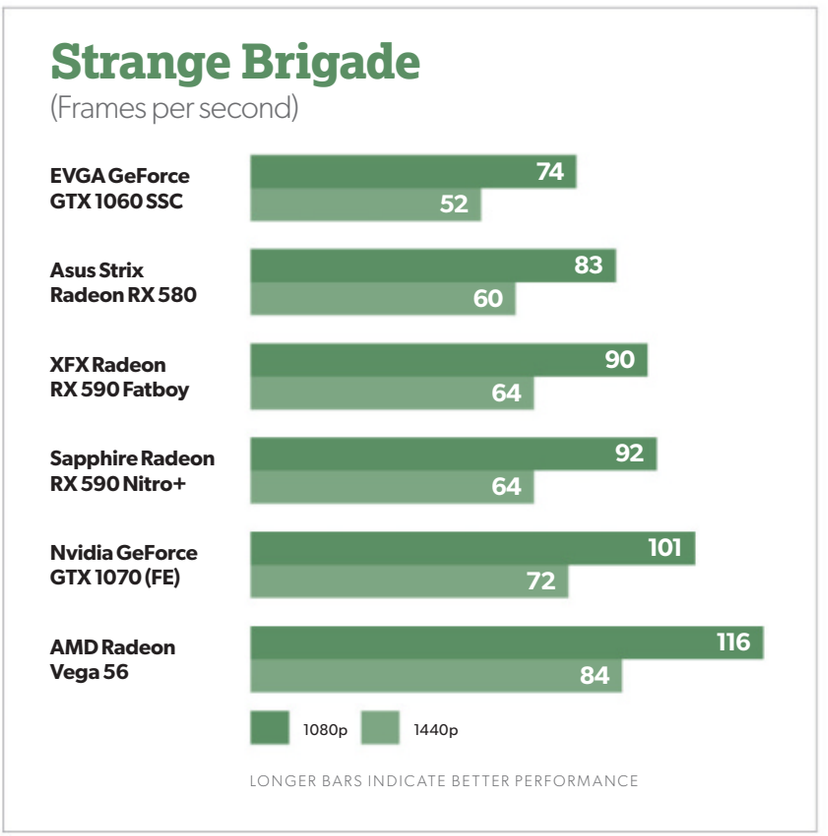
our testing. Because we extensively compared the RX 590 against rival GPUs like the RX 580 and GTX 1060 in our XFX Fatboy review (go.pcworld.com/xfxr), we'll let the benchmarks speak for themselves for the rest of the games testing.

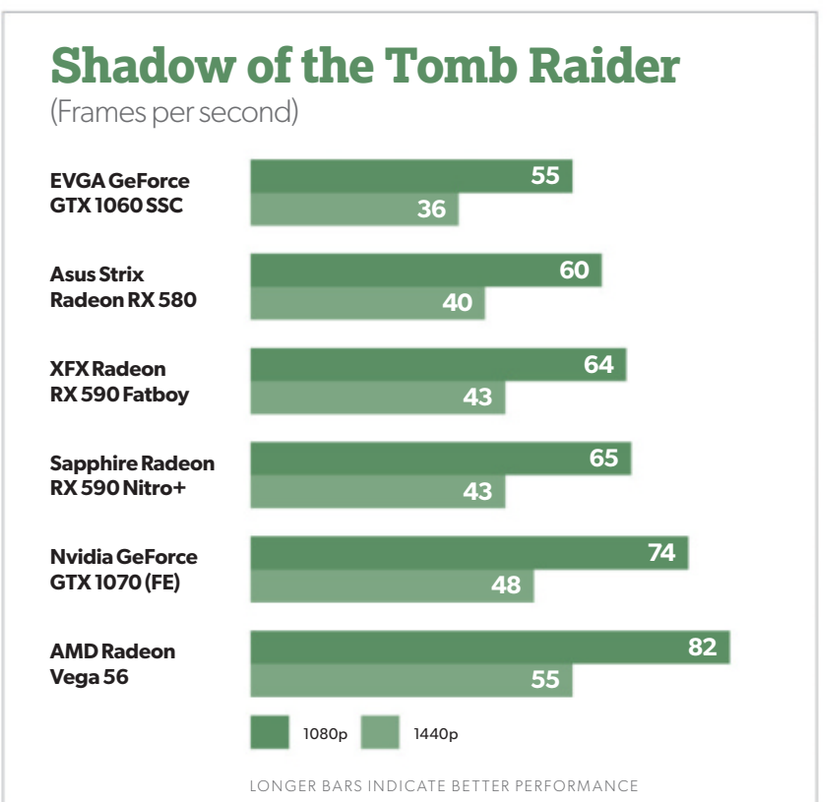
Shadow of the Tomb Raider

Shadow of the Tomb Raider ($60 on Humble at go.pcworld.com/shdw) concludes the reboot trilogy, and it's utterly gorgeous—even the state-of-the-art GeForce RTX 2080 Ti barely manages to average 60 fps with all the bells and whistles turned on at 4K resolution. Square Enix optimized this game for DX12, and recommends DX11 only if you're using older hardware or Windows 7, so we test with that. Shadow of the Tomb Raider uses an enhanced version of the Foundation engine that also powered Rise of the Tomb Raider.

Far Cry 5

Finally, a DirectX 11 game! Far Cry 5 ($60 on Humble at go.pcworld.com/fcr5) is powered by Ubisoft's long-established Dunia engine.





It's just as gorgeous as its predecessors, and even more fun.

Ghost Recon Wildlands

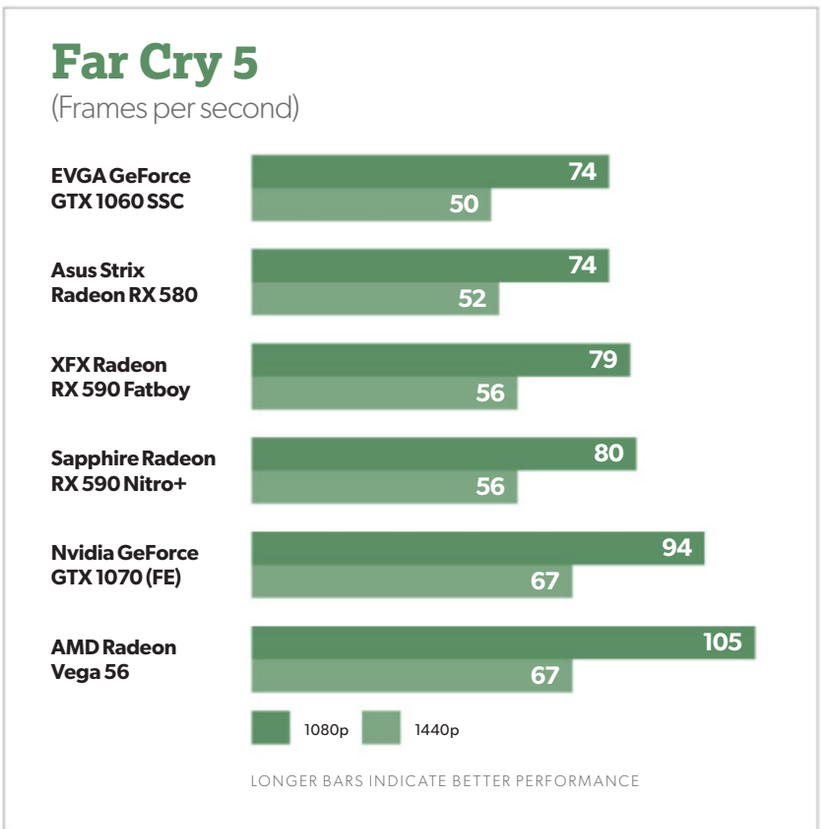
Move over, Crysis. If you crank all the graphics options up to 11, like we do for these tests, Ghost Recon Wildlands ($50 on Humble at go.pcworld.com/recn) and its AnvilNext 2.0 engine absolutely melt GPUs.

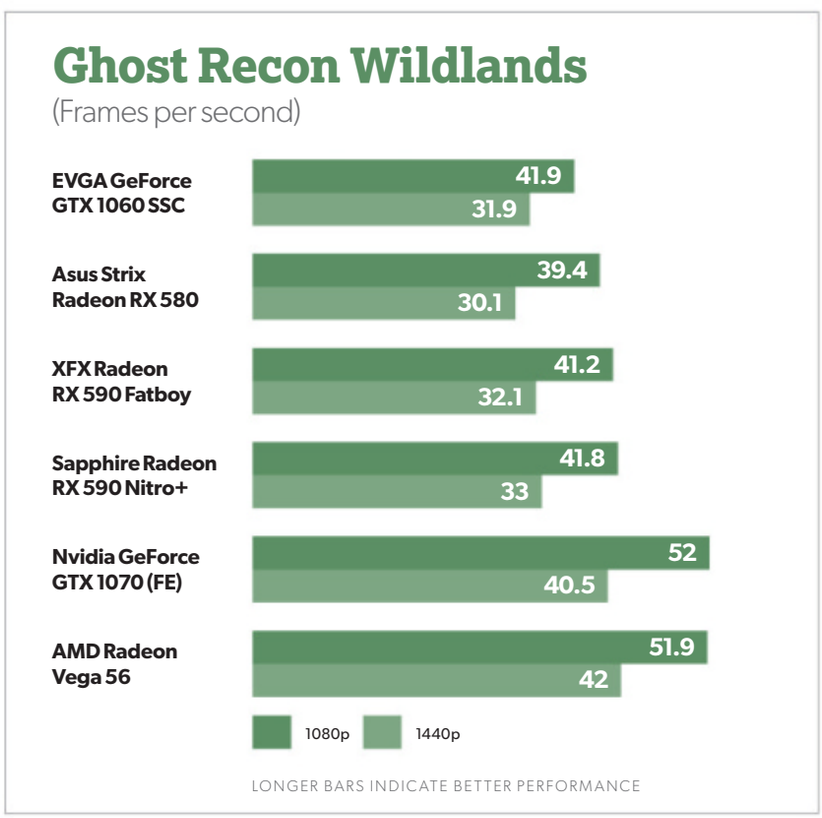
Middle-earth: Shadow of War

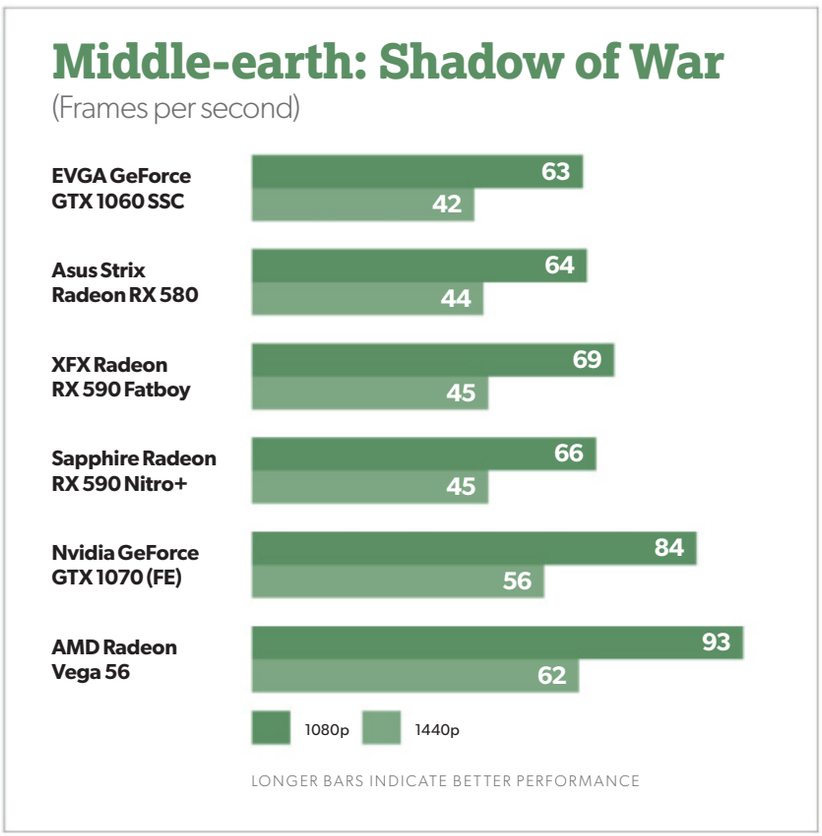
Middle-earth: Shadow of War ($50 on Humble at go.pcworld.com/shwr) adds a strategic layer to the series' sublime core gameplay loop, adapting the Nemesis system to let you create an army of personalized Orc commanders. It plays like a champ on PC, too, thanks to Monolith's custom LithTech Firebird engine. We use the Ultra graphics preset but drop the Shadow and Texture Quality settings to High to avoid exceeding 8GB of VRAM usage.

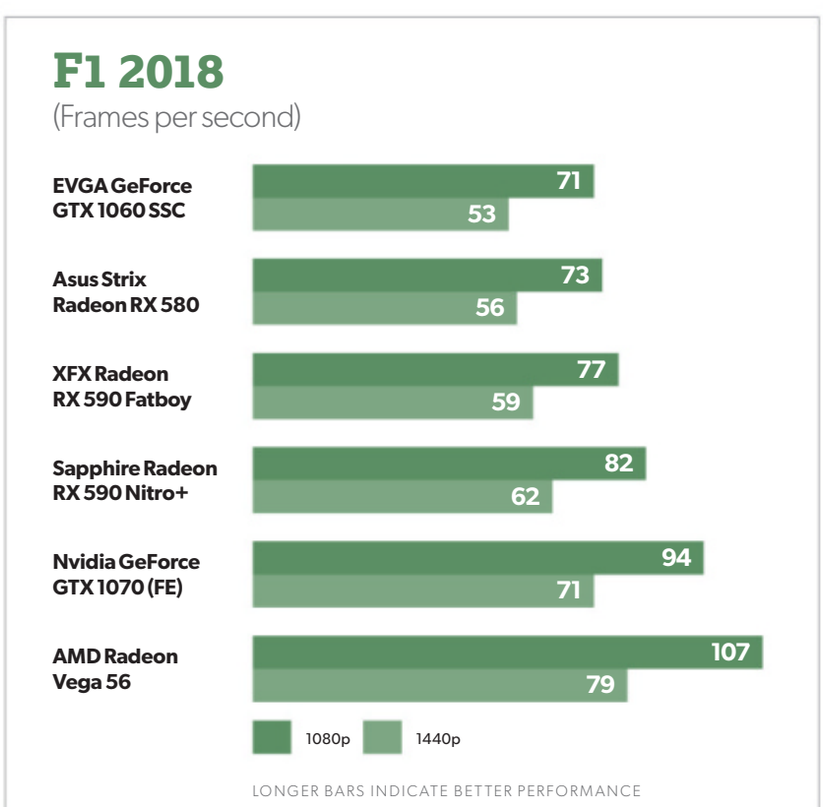
F1 2018

The latest in a long line of successful games, F1 2018 ($60 on Humble at go.pcworld.com/f118) is a benchmarking gem,









supplying a wide array of both graphical and benchmarking options—making it a much more reliable option that the Forza series. It's built on the fourth version of Codemasters' buttery-smooth Ego game engine. We test two laps on the Australia course, with clear skies.

Ashes of the Singularity: Escalation

Ashes of the Singularity ($40 on Humble at go.pcworld.com/sing) was one of the very first DX12 games, and it remains a flagbearer for the technology to this day thanks to the extreme scalability of Oxide Games' next-gen Nitrous engine. With hundreds of units onscreen simultaneously and some serious graphics effects in play, the Crazy preset can make graphics cards sweat. *Ashes* runs in both DX11 and DX12, but we only test in DX12, as it delivers the best results for both Nvidia and AMD GPUs.

GTA V

We're going to wrap things up with a couple of older games that aren't really visual barnburners, but still top the Steam charts

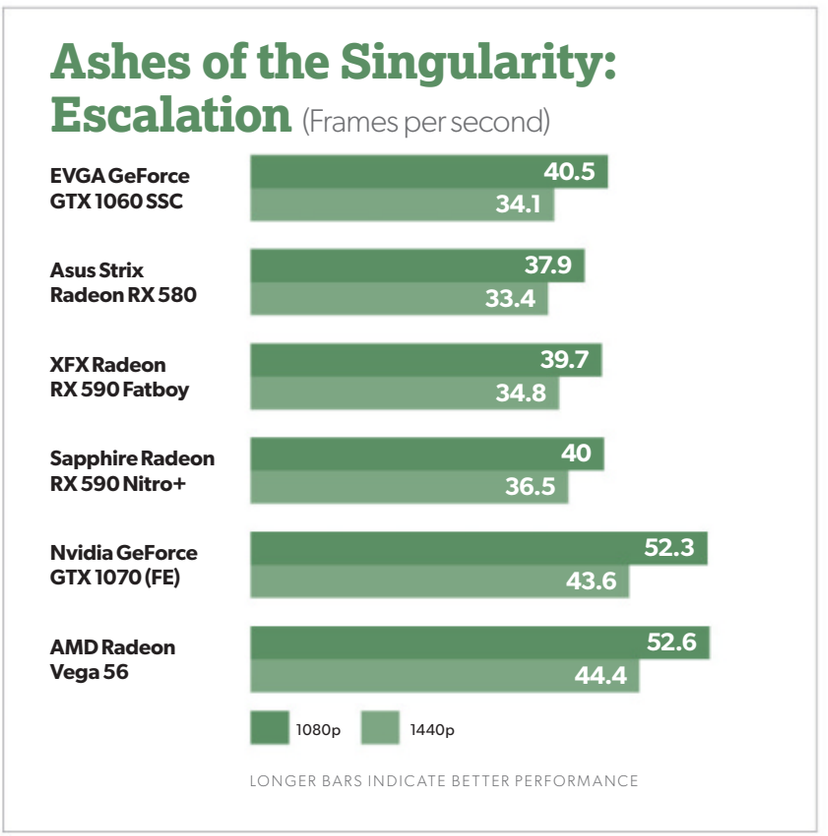
day-in and day-out. These are games that a lot of people play. First up: Grand Theft Auto V ($30 on Humble at go.pcworld.com/gta5) with all options turned to Very High, all Advanced Graphics options except extended shadows enabled, and FXAA. GTA V runs on the RAGE engine and has received substantial updates since its initial launch.

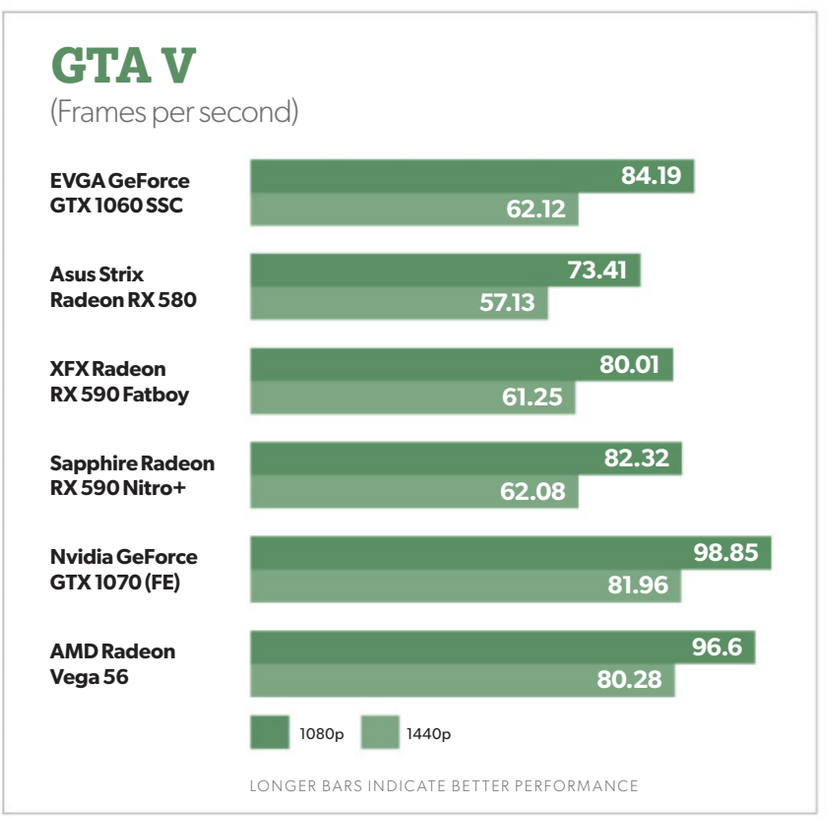
Rainbow Six Siege

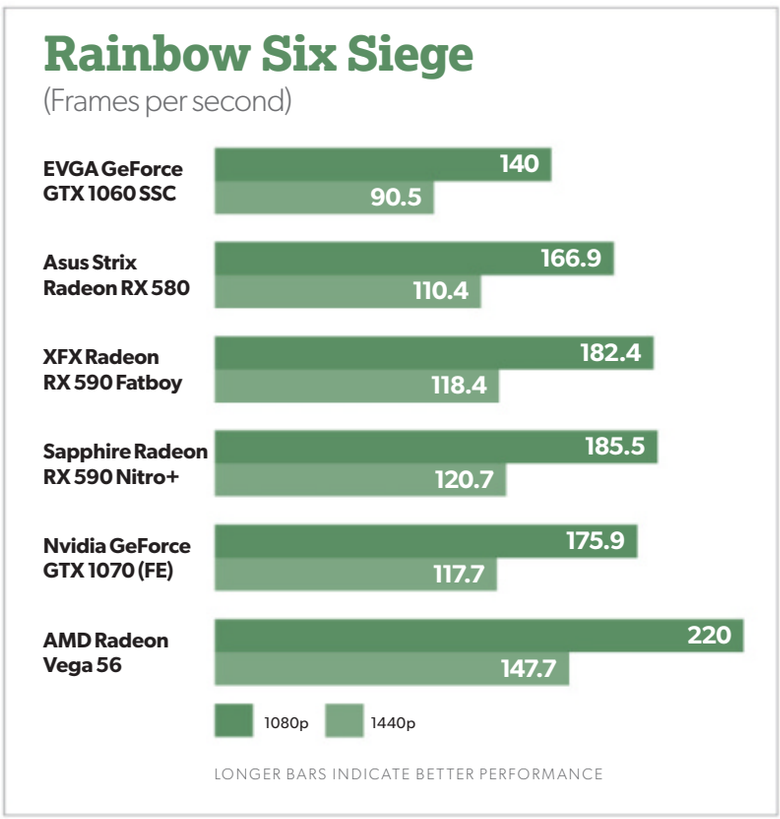
Finally, let's take a peek at Rainbow Six Siege ($40 on Humble at go.pcworld.com/rnss), a game whose audience just keeps on growing, and one that still feels like the only truly next-gen shooter (go.pcworld.com/rain) after all these years. Like Ghost Recon Wildlands, this game runs on Ubisoft's AnvilNext 2.0 engine, but Rainbow Six Siege responds especially well to games that lean on async compute features.

POWER DRAW, THERMALS, AND NOISE

We also tested the Sapphire Radeon RX 590+ using 3DMark's highly respected Fire Strike







synthetic benchmark. Fire Strike runs at 1080p, Fire Strike Extreme runs at 1440p, and Fire Strike Ultra runs at 4K resolution. All render the same scene, but with more intense graphical effects as you move up the scale, so that Extreme and Ultra flavors stress GPUs even more. We record the graphics score to eliminate variance from the CPU.

Yep, everything falls about where you'd expect after observing the gaming benchmarks, which is always the case with Fire Strike. The Sapphire card scores slightly higher than the XFX Fatboy despite its slightly lower clock speeds, which matches the performance difference we saw in actual games. Kudos to Sapphire's memory overclock and badass cooler.

We test power draw by looping the F1 2018 benchmark after we've benchmarked everything else with a card, and noting the highest reading on our Watts Up Pro meter. The initial part of the race, where all competing cars are onscreen simultaneously, tends to be the most demanding portion.

Even a move to the 12nm process and a highly effective cooler can't help here. The Radeon RX 580 already drew much more energy than the GTX 1060, and to consistently triumph over Nvidia's mainstream champion, AMD cranked the Radeon RX 590's power consumption to 11. The Sapphire Radeon RX 590 Nitro+ draws 100W more than the overclocked EVGA GTX 1060 SSC, and sucks down more juice than even the much more potent Vega 56 and GTX 1070.

We test thermals by leaving HWInfo's sensor monitoring tool open during the F1 2018 5-lap power draw test, noting the highest maximum temperature at the end.

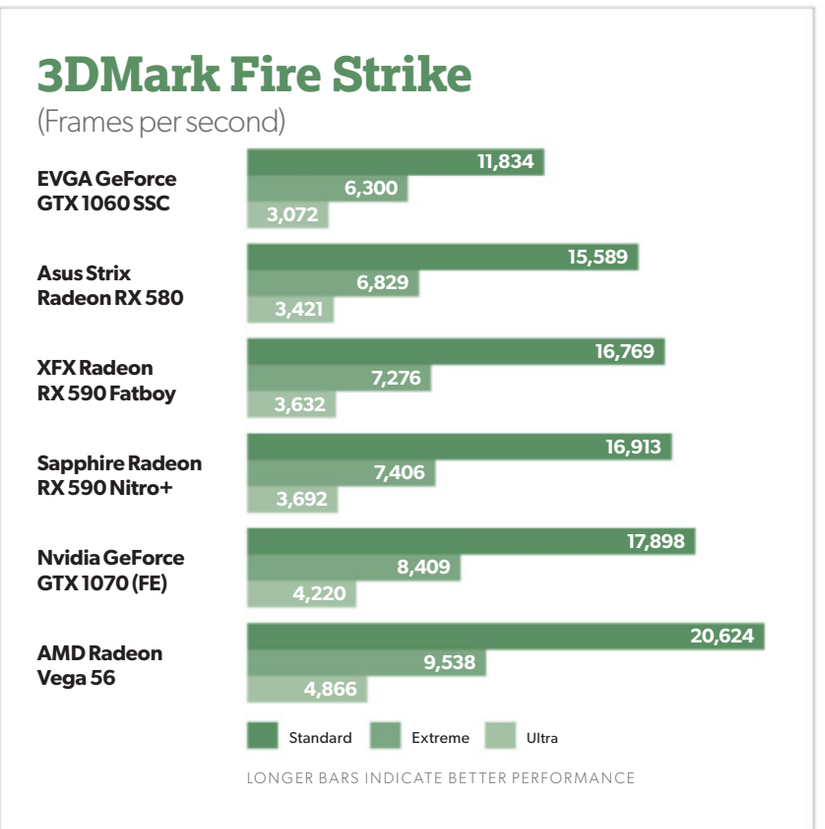
And here's where the Sapphire RX 590 Nitro+ gets more impressive. While the XFX Fatboy runs hot even with a much thicker triple-slot cooler, Sapphire's standard-sized dual-slot card never exceeds 75 degrees Celsius—a very respectable temperature for a mainstream graphics card. Sapphire's card makes slightly less noise than XFX's using the

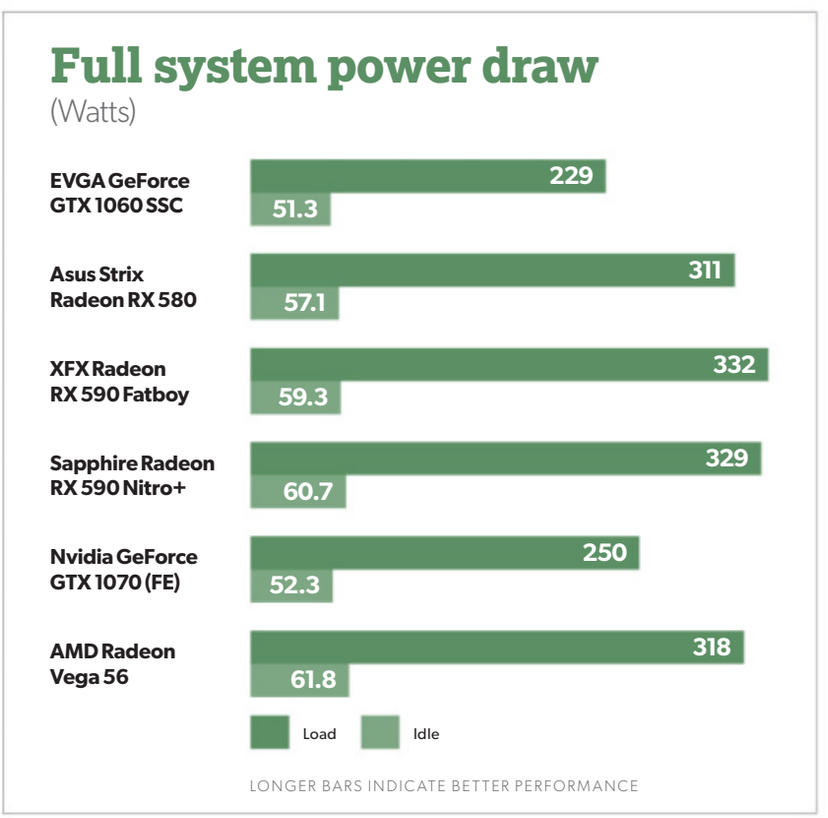
standard Performance BIOS, too, and its Silent BIOS is downright quiet. This graphics card doesn't make its presence known in any obnoxious ways.

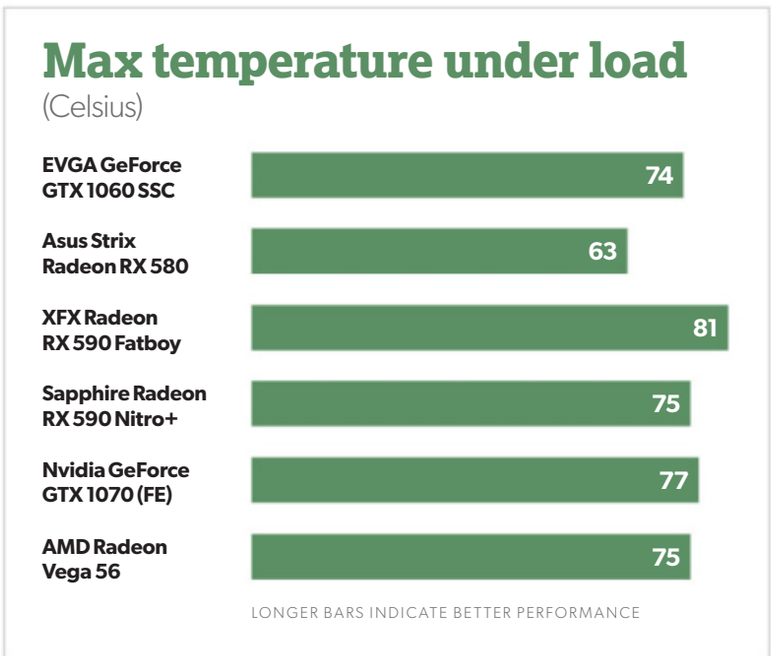
VERDICT

Definitely, if you're in the market for a Radeon RX 590. The Sapphire Radeon RX 590 Nitro+ ($280 on Newegg at go.pcworld.com/590r) is better than the XFX RX 590 Fatboy in every way, from performance to size to heat dissipation.

The question is whether you need a Radeon RX 590. It's the best mainstream (sub-$300) graphics card available for 1080p gaming. It puts in a fine showing at 1440p resolution, too, especially if you don't mind bumping some visual settings from Ultra to High or have a FreeSync monitor to smooth out any slight frame-rate hiccups. The Radeon RX 590 pounds on the GTX 1060 in every game but GTA V at roughly the same street price as Nvidia's cards, and AMD tosses in three free triple-A games from popular series, too. There's no reason to buy a GTX 1060 right now unless you need a mini-ITX GPU for a tiny







PC, or have limited power supply capability. The Radeon RX 590 blows it out of the water.

But AMD's other mainstream cards deliver outstanding value too. A huge number of gamers rock 1080p, 60Hz monitors. The Radeon RX 570 excels at high-fidelity gaming at those settings, and it can often be found for under $160 on sale. The Radeon RX 580 is a lot faster than the RX 570, but the custom Asus Strix model we tested is only 7 or 8 percent behind the Sapphire RX 590 Nitro+'s performance. You can usually find some 8GB Radeon RX 580s selling for around $200 on sale (go.pcworld.com/rdrg) these days, and you get your choice of two of the three free games that come bundled with the RX 590 with the lesser-powered cards. That's an absolutely stunning value that tarnishes the RX 590's allure, especially with performance being so close.

Highly overclocked RX 580 models with beefy custom coolers (a.k.a. something similar in quality to the Sapphire RX 590 Nitro+) still tend to cost $250 or more, though. If you want something swanky, or simply want as much future-proofing as possible under $300, opting for the Radeon RX 590's extra oomph makes a lot of sense. Sapphire's Nitro+ is easily the best Radeon RX 590 we've tested. The card delivers impressive all-around performance while staying quiet under load, and Sapphire loaded the card with luxurious features like fans that idle under light loads and a dual BIOS. It looks and feels luxurious, too.

Highly recommended. Just make sure it makes sense for you to snag a Radeon RX 590 rather than a discounted Radeon RX 580 before you pull the trigger.

Sapphire Radeon RX 590 Nitro+

★★★★☆

PROS

- Superb 1080p and good 1440p gaming performance
- Effective custom cooler
- Loaded with extra features

CONS

- Very high power draw
- Discounted RX 580 GPUs offer better value

BOTTOM LINE

The Sapphire Radeon RX 590 Nitro+ delivers superb 1080p gaming performance with few compromises, though the power draw is massive.

$279

Samsung 860 QVO SSD: Big capacity on the cheap, and fast the majority of the time

Samsung's new quad-level cell (4-bit) NAND SSD sets a new low in price per gigabyte in its 2TB and 4TB iterations. **BY JON L. JACOBI**

Samsung's 860 QVO SSD is an excellent everyday performer and an outstanding bargain in its 2TB and 4TB flavors. It's also the second quad-level cell (4-bit) SSD to pass our portals, the other being Intel's SSD 660P (go.pcworld.com/660p).

The reason I mention this competitive drive from Intel up-front is that it's becoming clear that 4-bit NAND, while allowing greater capacity, also extracts a performance hit that vendors must work around. How well a vendor does that affects which 4-bit drive you should buy, and whether you might be better off with an MLC or TLC drive.

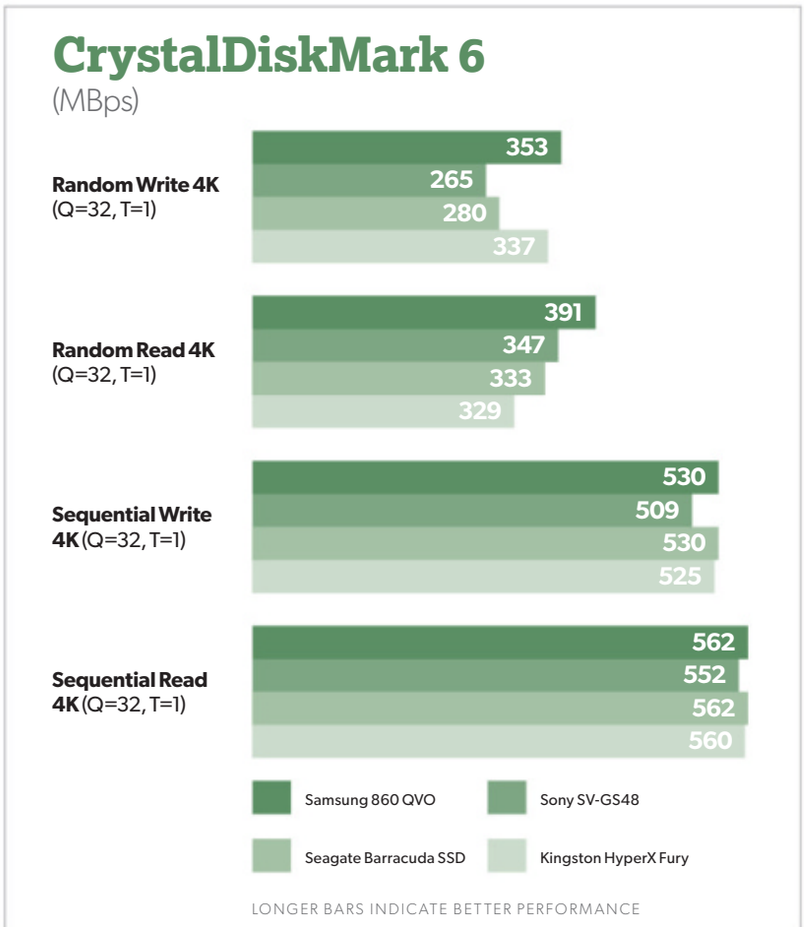
Note: Samsung refers to the 860 QVO as 4-bit MLC. As the acronym MLC stands for "Multi-Level Cell," this is technically correct. However, most refer to it as quad-level cell or QLC, which is what I assume the Q in QVO stands for.

IMAGE: SAMSUNG

DESIGN AND FEATURES

The 860 QVO is a 2.5-inch, 7mm thick, SATA 6Gbps SSD. It's a lighter shade of gray than most of Samsung's SSDs, and will be available in four capacities: 1TB, 2TB, and 4TB. That last is a boon of 4-bit NAND: greater data density than 3-bit TLC, so you can fit more data in the same number of chips.

The drive provides 1GB of DRAM cache for each 1TB of capacity. The TBW (TeraBytes Written) rating is 360TB for every 1TB of capacity. The 1TB version I tested has 42GB of available secondary cache (QLC, written as SLC or MLC). The 2TB and 4TB drives each get 78GB of cache. Pricing starts at $150 for the 1TB drive. The 2TB comes in at $300, and the 4TB model costs $600. A 4TB SSD for $500 is dirt-cheap compared to everything else on the market, as well as what you would've paid only last year.



The 860 QVO is more than competitive with other drives in CrystalDiskMark 6.

PERFORMANCE

The plain fact of the matter is that writing more bits to a NAND cell takes more time. It's not that SLC NAND cells are so much faster than TLC or QLC cells, it's that writing only one bit is faster. Write only one bit to TLC or QLC, and they're nearly as fast. Write three or four bits, and they're not even close. Hence a certain amount of the TLC (or QLC in this case) of any SSD is treated as SLC or MLC to form a secondary cache.

Using this secondary cache—again, approximately 42GB—the 860 QVO proved a very good performer in most circumstances, as you can tell from the benchmark results below. There were no performance slowdowns until our 48GB file copy tests, in which the last 4GB or so wrote at only 70MBps. This would not occur in the 2TB or 4TB drives, with their more bountiful Level 2 cache.

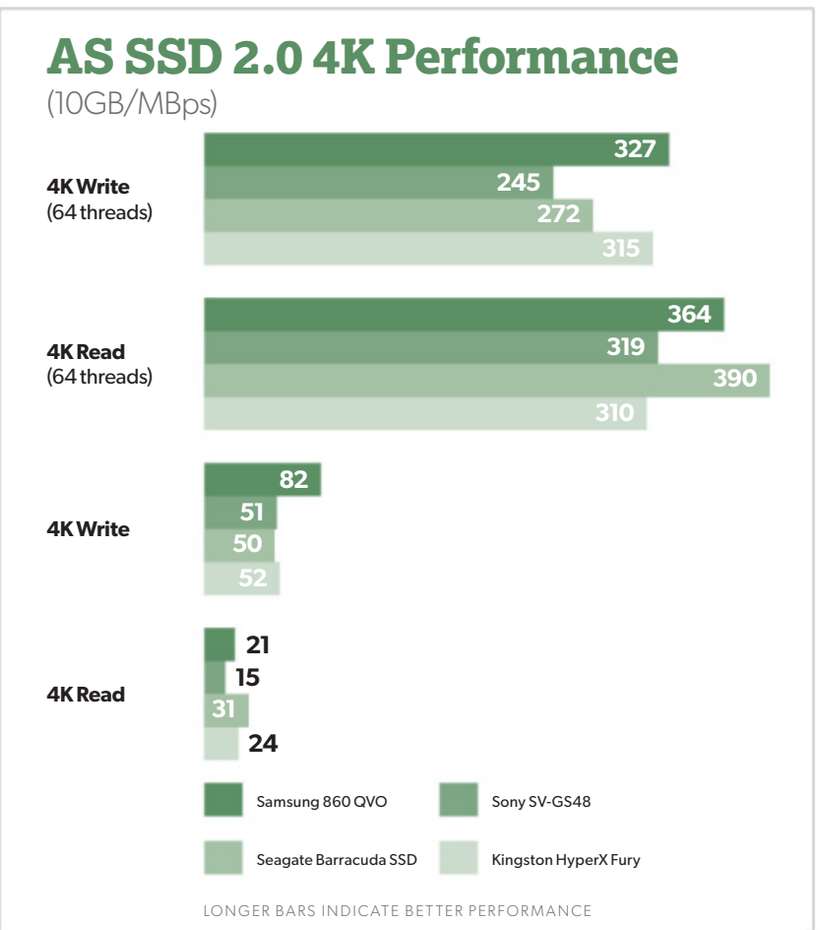
AS SSD 2.0 had roughly the same opinion as CrystalDisk-Mark about the 860 QVO's speediness. Note that this test isn't as optimistic about the throughput, erring slightly on the low side of what we see in our real-world, 48GB copy tests.

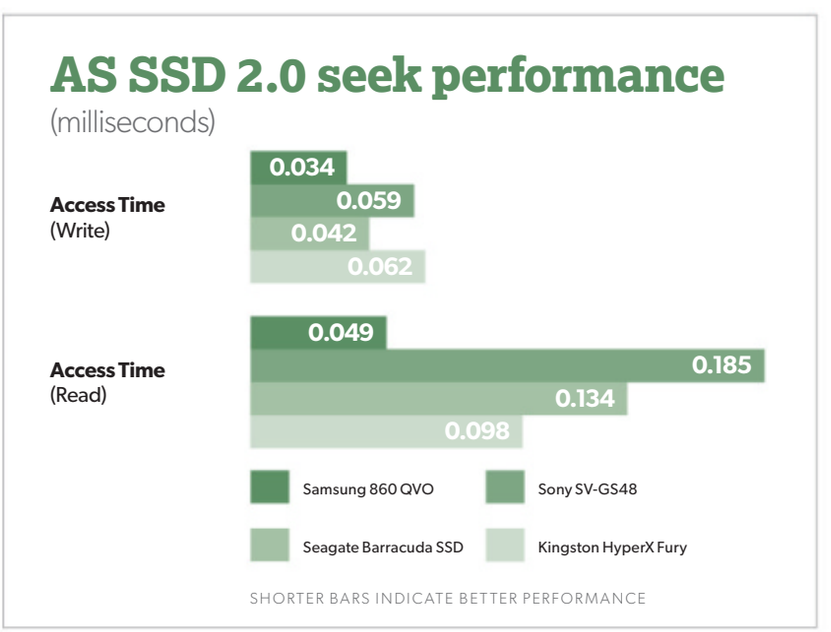
AS SSD largely agreed with CrystalDiskMark: The 860 QVO is fast under most circumstances

Seek times, as shown below, are actually quite quick compared to most SATA 6Gbps SSDs. This may have something to do with the previously described and generous allotment of DRAM cache.

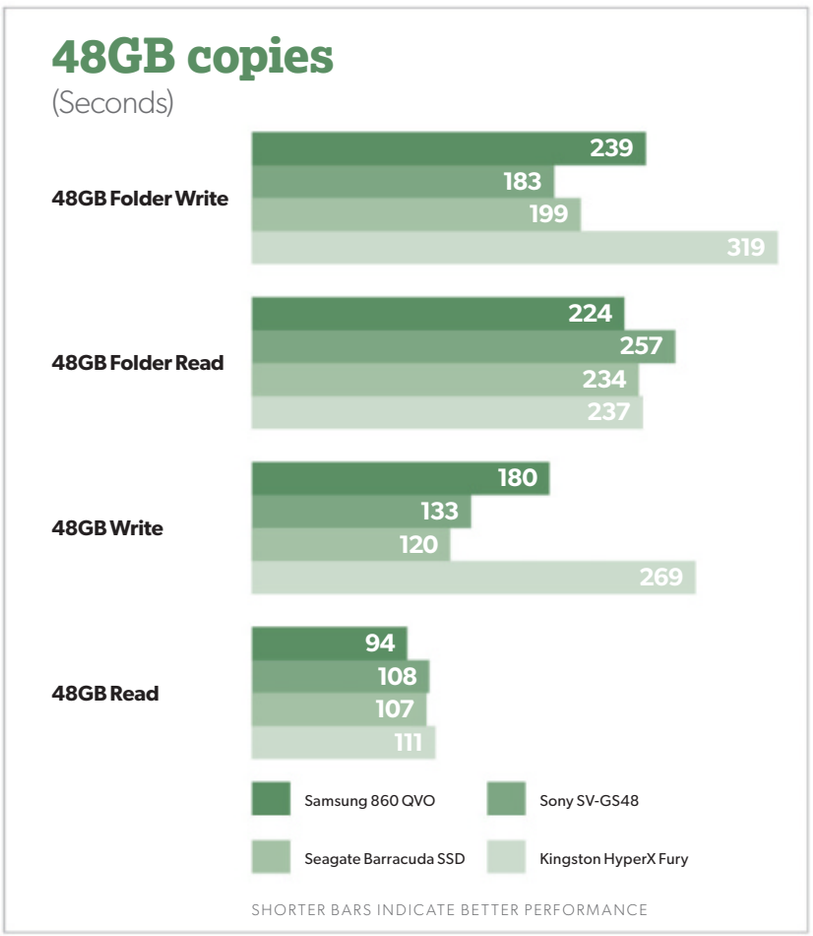
In the graph (right) you can see that the copy tests were only mildly affected by the 860 QVO's running out of cache, but that was only because such a small amount of data was written to the main body of QLC memory. Double this test size, and the 1TB 860 QVO and Kingston's bars would've been far longer than the Sony's or Seagate's. Even the 2TB and 4TB capacities would run dry in that scenario.

When the 860 QVO runs out of cache, it's pretty depressing. The drive will clear the cache by





The 860 QVO's seek times even faster than you'd expect from a SATA 6Gbps SSD.



The area where the 860 QVO falls short is in writing large amounts of data, a trait it shares with the HyperX Fury. The more data you write, the worse the times will be. The pace of the 860 QVO hovers around 70MBps once the cache is overwritten.

writing the data to the main body of 4-bit NAND, but that process takes a while. I waited a good ten minutes between tests. Below you can see what happened when I didn't wait that long to try copying 48GB one more time. The original 48GB copy didn't slow down until about the 90-percent mark.

Just by way of comparison, in terms of sustained throughput, we've seen hard drives clock 250MBps. But even when writing slowly, SSDs retain their super-fast seek times. Also note, this is strictly about writing. NAND read speeds in SATA SSDS remain quick no matter what the number of bits being read.

VERDICT

The 860 QVO is a great SSD most of the time, but there are many cheaper 1TB competitors that don't slow down. The 2TB and 4TB drives, on the other hand, are a couple of hundred dollars less than the competition and don't fall out of cache nearly as soon. That's a big-enough difference that I'd consider the trade-off, which will vary depending on your needs, worthwhile.

Bargain or not, know that you will see a massive drop-off in performance when the drive runs out of cache. It doesn't run out often, but it's ugly when it does.

Samsung 860 QVO SSD

★★★★☆

PROS

- Great cost per gigabyte in larger capacities
- Available in up to 4TB capacity

CONS

- Sustained write speed plummets to 70MBps after secondary cache is exhausted

BOTTOM LINE

In the 2TB and 4TB capacities, this SATAa 6Gbps SSD is a lot cheaper than the competition. It's also a very fast reader, and a fast writer. At the 1TB level however, there are cheaper drives that don't slow down even when writing large data sets.

Google Pixel Slate: So close, yet so far, from being a perfect Chrome-Android tablet hybrid

Frustrating limitations, flaws and glitches, and a tug-of-war between Android and Chrome prevent the Pixel Slate from being all it could be. **BY MICHAEL SIMON**

Reviewing the Pixel Slate was like reviewing two devices. Out of the box, it's something of a high-end Android tablet running full-screen Play Store apps and a touch-friendly interface. But when you attach it to the Pixel Slate Keyboard, it transforms into a premium Chromebook, with a large multitouch trackpad and PC-like multitasking.

The Pixel Slate appears to be a dream 2-in-1, the rare hybrid device that truly conforms to your immediate needs. Where the iPad Pro and various convertible PCs fail to consider the jarring interface changes

IMAGE: MICHAEL SIMON

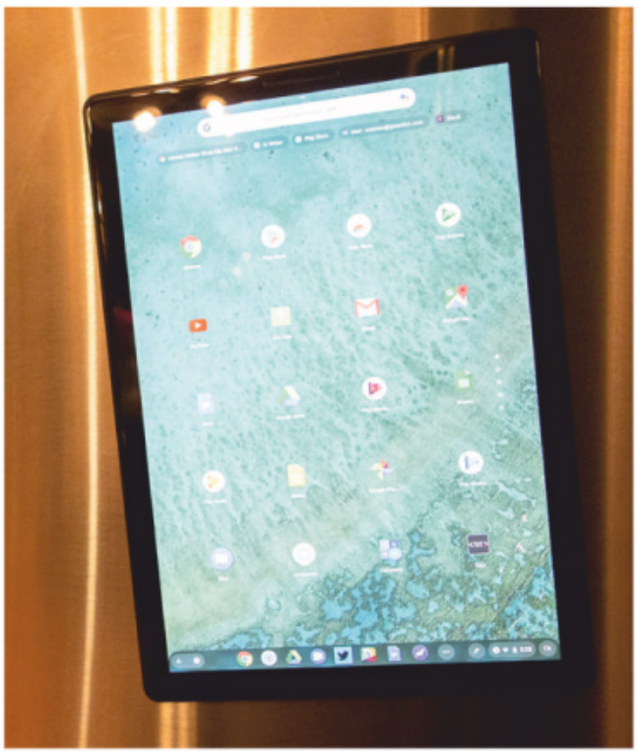
when switching from a touch-based UI to a keyboard-based UI, Google has designed Chrome OS's new hybrid interface specifically with the Pixel Slate in mind. Google understands that you'll use your Chromebook differently as a tablet than you would as a laptop.

So the Pixel Slate deserves to be taken seriously as the next generation of both Chromebooks and Android tablets. It's the culmination of a three-year evolution from the Chromebook Pixel to the Pixel C and Pixelbook. At once a tablet that wants to be a laptop and a laptop that wants to be a tablet, it's better at doing both than anything else out there.

But it's also a work-in-progress saddled with frustrating limitations, flaws, glitches, and a bit of tug-of-war between the Android and Chrome sides of its personality. All these issues conspire to prevent the Pixel Slate from being all it could be.

PIXEL SLATE PRICING AND FEATURES

The Pixel Slate comes in several configurations, ranging from an Intel Celeron and topping off at an 8th-gen Core i7 processor. That's a wide performance spread, with the low end delivering less horsepower than the $399 Surface Go and the high end competing with the Dell XPS 13.



The Pixel Slate has enough magnets to stick it to the front of a refrigerator.

I tested the $999 Core i5 model with 8GB of RAM and 128GB of storage, which represents the mid-point between the $599 entry-level model and the $1,599 top-of-the-line model. Unfortunately, LTE isn't an option on any of configs, which makes the Pixel Slate less of a road warrior than the iPad Pro or Surface Pro (go.pcworld.com/sfpr).

It's impossible to look at the Google Pixel Slate and not see shades of the iPad Pro. They both have a flat back and slim, uniform bezels, so orientation isn't an issue. They both have gorgeous 12-inch-plus screens that feel somewhat smaller than they are. And they

VIDEO: **GOOGLE PIXEL SLATE: JUST AN OK ANDROID TABLET**
Watch now at go.pcworld.com/oka

both have enough embedded magnets to stick to a refrigerator door.

The Pixel Slate is also very much a Google device. It looks a little like a giant Pixel 2, right down to the dust-trapping speaker grilles flanking either end of the screen and the missing headphone jack. The only cosmetic similarity the Pixel Slate lacks is a two-tone back, which would have been a classy addition to the otherwise plain aesthetic.

Still, the Pixel Slate's single color is undeniably a cool one. Google calls it midnight blue, and it switches from deep blue to rich black to iridescent depending on the reflection off of your fingerprints, which are quite visible on the back despite a matte finish.

The Pixel Slate has a 12.3-inch "molecular" display, a bit of Apple-style marketing to play up its 6 million pixels. With a 3000x2000 resolution, it's sharper than the 2400x1600 PixelBook and the 2732x2048 iPad Pro, with an impressive 293 pixels per inch (though your eyes won't really notice). Google says the LCD display covers 72 percent of NTSC, a pretty useless spec in an sRGB and DCI-P3 world, but the Pixel Slate won't offend critical eyes. It's very bright (over 500 nits maximum in my testing), and its colors are vibrant. While the square display corners feel a bit antiquated in an age of rounded corners, you certainly won't mind

It's not glass, but fingerprints are still a thing on the Pixel Slate.

The Pixel Slate has a camera on the back, but you probably won't be using it much.

looking at it for hours on end, especially if you're filling some of that time with movie-watching.

Holding it is another issue. At 11.4 x 8.7 x 0.4 inches, it's actually a bit larger than the 12.9-inch iPad Pro, and the extra tenths of an inch matter when you're already pushing the limits of comfort. At 1.6 pounds, the Pixel Slate is also a little heavier than Apple's biggest tablet (which weighs 1.4 pounds), all of which makes the Slate uncomfortable to hold for more than short stints. That means you won't be using it to take many pictures, which is probably why Google didn't bother to include any of the Pixel 3's cool camera tricks (though the Slate does have portrait mode).

The keys on the Pixel Slate Keyboard are circular, which looks good but feels weird.

Because of the Pixel Slate's limitations as a tablet, a keyboard is an essential accessory. You can connect a third-party model via Bluetooth 4.2, or purchase Google's own. To that end, Google charges $199 for its Pixel Slate Keyboard—as much as Apple's Smart Keyboard Folio—but it's put a good deal of thought into the design. The beautiful midnight-blue chassis perfectly matches the tablet, and it looks as great attached as it does folded up.

On a table, the Pixel Slate and the Keyboard cut a striking figure, looking like a slender Chromebook. When the Pixel Slate is in this position, its two USB-C ports are positioned on the bottom of either side of the tablet rather than the center, so you won't have to raise the power cord above desk height to plug in the device (as you're forced to on the iPad Pro). The Pixel Imprint fingerprint sensor/power button is awkwardly placed when holding the Slate with two hands, but it's easy to reach on its top edge when docked.

The multitouch trackpad is as responsive as it is on the Pixelbook. The backlit keys (called Hush Keys in the United States) are pleasantly quiet. They also have a decent 1.2mm of travel despite a low-profile design. Unfortunately, their circular shape and wide spacing gave me less margin of error in hitting the right key, resulting in more

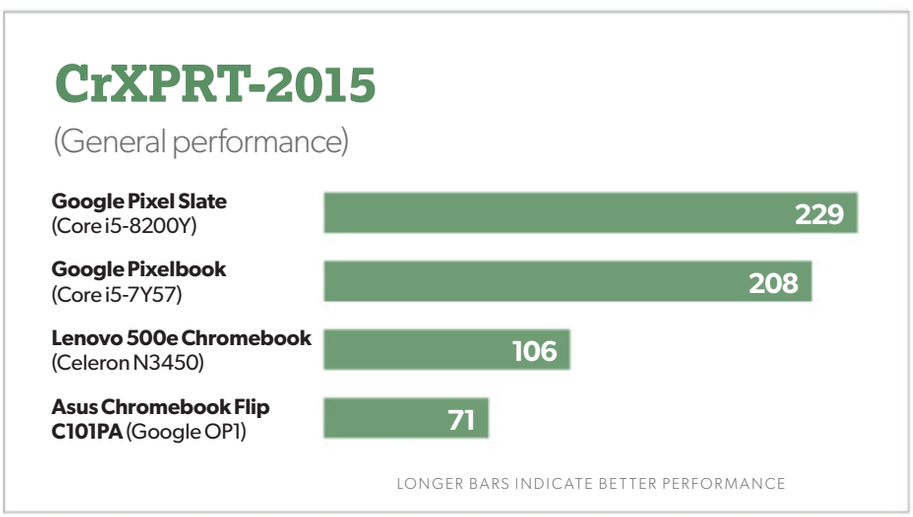
mistyping than usual.

The Pixel Slate Keyboard provides an "infinitely adjustable" design that lets you customize the angle of the attached Pixel Slate tablet far more than you can with an iPad or Surface Pro keyboard. It's impressive how the Pixel Slate's magnets allow for slight angular adjustments. However, you can't lay it completely flat without first detaching it from the Pixel Slate Keyboard, making "infinite" seem like an overstatement.

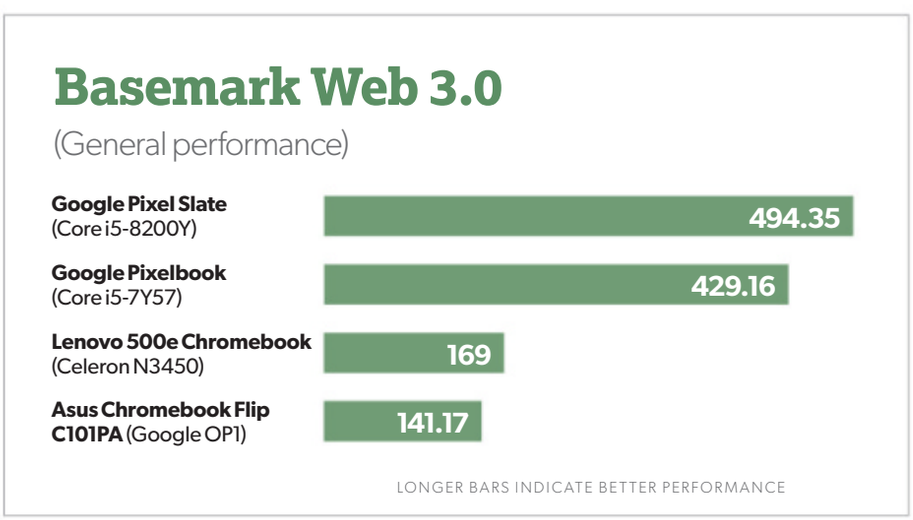
Unfortunately, the magnets aren't strong enough to prevent slight movements when you're tapping with a bit of force on the screen. I also would have appreciated a place in the keyboard design or on the tablet itself for that matter to rest the PixelBook Pen, which Google offers in Midnight Blue to match. (Otherwise the stylus is exactly the same as last year's silver model.) Overall, the keyboard's lightweight, somewhat flimsy design, coupled with the weight of the screen, makes it tough to use the Pixel Slate on your lap.

PERFORMANCE: MORE THAN ENOUGH

When benchmarking Chromebooks, you always have to deal with Google's relentless OS rhythm. Every six weeks, Google updated



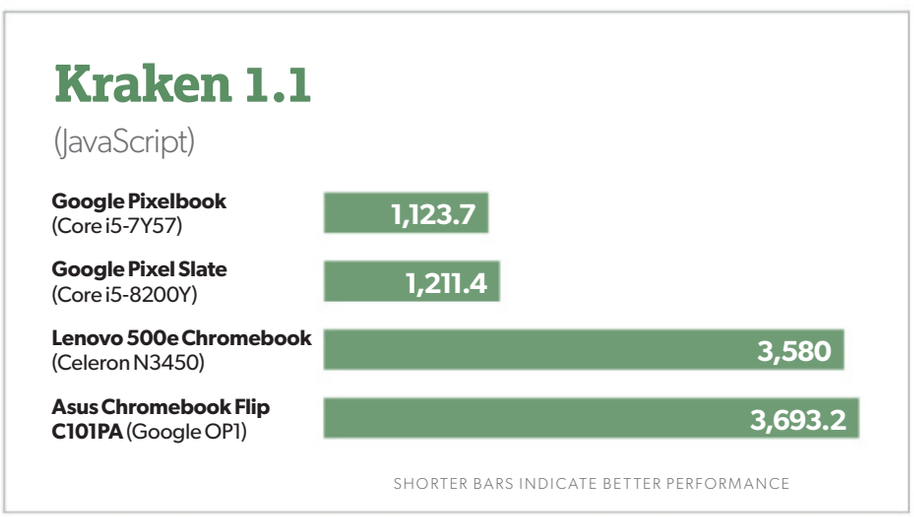
The Google Pixel Slate's Core i5 processor is a screamer, as the Cr-XPRT general benchmark shows.



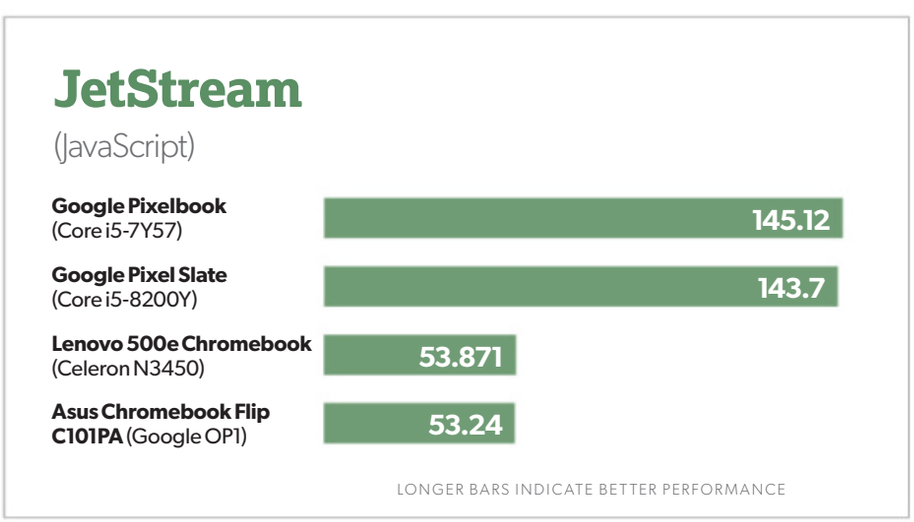
The Pixel Slate performed extremely well using the Basemark benchmark test, which combines WebGL and JavaScript performance.

Chrome OS, and our past results lose perfect apples-to-apples comparability. That said, we were still curious to see how the Pixel Slate performed against other recent Chromebooks, including its year-old Pixelbook cousin.

The Pixel Slate carries a brand-new Intel Core mobile processor, the Core i5-8500Y, from the 8th-gen Amber Lake Y family. This dual-core, four-thread, 14nm CPU is an ultra-low-power chip designed specifically for slender, light devices like the Pixel Slate. Paired with Intel's UHD 615 integrated graphics, it's made for mainstream productivity rather than high-end (CPU-/graphics-intensive) applications or gaming. The other Chromebooks on the chart include the Asus Chromebook Flip, with Google's own low-end OP1 chip, and the sturdy, student-oriented Lenovo 500e Chromebook.



The Pixel Slate is pretty equal to last year's Pixelbook when testing JavaScript.



With straight JavaScript using the JetStream benchmark, the Pixel Slate was slightly outpaced by the Pixelbook.

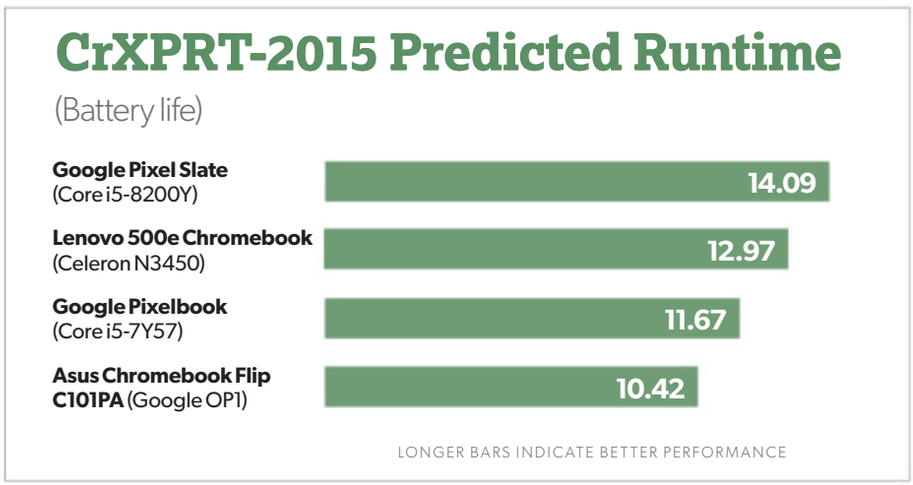
So how does the Slate perform? The short answer is the Pixel Slate ran neck-and-neck with its category-leading cousin the Pixelbook, until it pulled way ahead in battery life. Here's a look at the details.

Using the Cr-XPRT benchmark, which measures common tasks like browsing and movie playback, the Pixel Slate stays a bit ahead of the Pixelbook and leagues ahead of the lower-end 500e and Chromebook Flip.

Another general

performance benchmark, Basemark 2.0, combines WebGL and Javascript performance. The results echo what we see in Cr-XPRT: The Pixel Slate is they a little better.

In the Kraken and JetStream JavaScript benchmarks, the Pixel Slate and the Pixelbook stage a close competition.



The Pixel Slate has fantastic battery life.

As expected, the Pixel Slate performs somewhat similarly to the Pixelbook when testing straight JavaScript. It also runs circles around cheaper Chromebooks, as well it should.

More important than charts, however, is real-world performance. I didn't experience any slowdowns, freezes, or general issues during my day-to-day use, which included liberally bouncing between Chrome and Android.

As with the iPad Pro, however, there's a question of whether you need the power of an 8th-gen Core i5 or i7 in a Chromebook. Don't get me wrong—the Pixel Slate's zippy animations and buttery-smooth scrolling feel as powerful as a MacBook's. Still, a Core i5-8500Y is a little pricey for a Chromebook, let alone a Chrome OS tablet. I suspect the $799 Core m3 model will be plenty for most people, if not the $599 Celeron-based one. A thousand bucks is a lot to drop on a tablet, especially when you add $300 for a keyboard and pen.

Battery life is a big highlight. All five Pixel Slate models have the same 48Wh battery, and Google says each Pixel Slate will last for 12 hours of standby, web browsing, and other use. That's a conservative estimate according to my benchmarks, which clocked the Pixel Slate at over 14 hours (set to 200 nits brightness and medium volume), more than an hour longer than the Pixelbook.

Only after hours of testing, along with a great deal of work, did I have to plug in the Slate before I was ready to put it down for the night. Even then, it needed only a 15-minute charge to keep it going for a couple more hours. In short, the battery life is as impressive as the display, and it makes the Pixel Slate an excellent travel companion.

A BLEEDING-EDGE ANDROID TABLET THAT FEELS LIKE IT

The Pixel Slate's bleeding-edge OS is an inspiration and a challenge. It ships with

The back of the Pixel Slate is clean except for a camera and a small "G" logo in the corner.

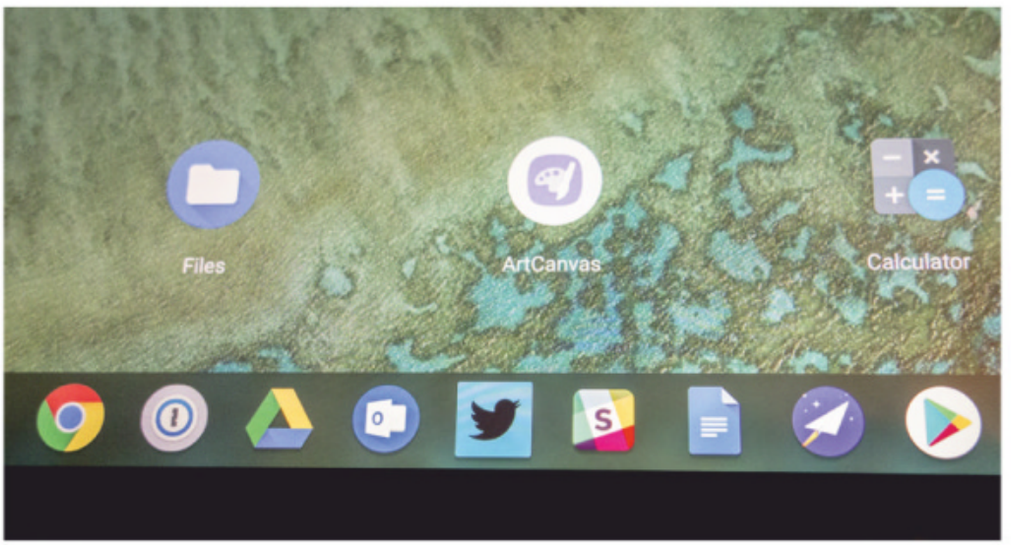
Chrome 71 on board, several updates beyond the radical revamp that arrived with version 70. For the first time, the new interface has a chance to spread its wings, and it truly gives the Pixel Slate a hybrid, modern vibe.

The Pixel Slate is one of Google's best-designed hardware products.

In tablet mode, the Pixel Slate has the feel of an Android tablet, with speedy navigation, full- and split-screen apps, picture-in-picture, and an awesome floating GBoard keyboard that is as comfortable as it is practical. An ever-present, OS X-style dock at the bottom of the screen show apps that are open and pinned, while Google's Material Design aesthetic gives the system a refined, sophisticated feel.

Google Assistant integration is as strong as ever, with Android Pie App Action-style shortcuts in the app drawer and an inconspicuous home button in the bottom left corner that summons Assistant when undocked. ("OK, Google" works too, of course.)

However, while Android 9's visual influence is undeniable, the Pixel Slate has its own personality, and it's not always agreeable. Google's Chrome-Android confluence is still very much a work in progress, and anyone who wants to use the Pixel Slate to run Play Store apps will be frustrated. For example, multitasking is



Chrome OS's new dock is very PC-like.

limited to side-by-side windows unlike Chrome OS proper, but I'd like some kind of middle ground, like the ability to run apps and YouTube videos in Picture-In-Picture mode (which Chrome's secret flags site suggests is on the way, at least for video).

Because many Android apps haven't been properly optimized for tablets, the experience is pretty hit-or-miss. But even beyond the state of the app ecosystem, there are loads of niggling issues when using the Pixel Slate as an Android-first tablet. The biggest by far is the lack of spellcheck, an annoyance that makes writing in anything other than Google Docs a major pain. I also experienced an occasional bug in IA Writer that froze the app and forced me to sign out of my Google account when using the text selection zoom tool. Other times I couldn't bring up the window at all.

That's not the only bug I encountered. Here is a sampling of others: When logged into multiple users, I completely lost Play Store access on the main account (and consequently all of my Android apps) and was able to restore it only by logging out. The backspace button turned into a space bar on several occasions. Tapping an icon in the dock didn't actually open the app. The app drawer put new app downloads on their own page, with no way to organize them other than physically dragging each icon and dropping it onto the prior page. And on three separate occasions, my Pixel Slate just spontaneously rebooted.

There are far fewer issues when you stick to the Chrome browser and Google apps, but because Google is installing the Play Store on Pixel Slate and clearly wants people to use the Pixel Slate as a tablet, these are bugs that will need to be squashed quickly. Google responded to my queries by saying some bugs would be fixed in updates available soon after launch.

BETTER AS A TRADITIONAL CHROMEBOOK

Curiously, these problems all but disappear when the Slate is attached to Google's keyboard. The familiar Chromebook interface returns, with

PC-style multitasking, resizable windows, and full keyboard shortcuts. Even when using Android apps, the bugs I experienced in tablet mode were nearly all gone.

My only real complaint with the Slate as a Chromebook is that the Pixel Imprint fingerprint sensor doesn't work as a biometric authenticator in any other capacity than unlocking. Also, smart unlocking with the Pixel 3—which is supposed to log you in automatically when your phone is within Bluetooth range—rarely worked. Oh, and a couple of times I lost my Bluetooth connection altogether and needed a full restart to get it back.

But my biggest gripe with the Pixel Slate is how jarring the transition is from tablet to Chromebook. When you undock it from the keyboard, whatever app you're using expands to full-screen. This requires a second or two of visual and mental adjustment, and not just because you're moving from type to touch. You're also switching from multitasking to duo-tasking. Floating to snapped. Desktop to app drawer. This awkwardness isn't unique to the Pixel Slate in a post-Chrome 70 world, but it's the first consumer Chrome device that sets itself up as a versatile 2-in-1. And ultimately it's still just way better when tethered to a keyboard that's sold separately.

Worst of all, the tablet mode—which is how the Pixel is sold, sans keyboard—is an inferior UI. The no-desktop concept is a good one, but I'd rather the tablet mode kept a little more of the Chromebook functionality rather than merely its design cues. Or simply expanded on Android's picture-in-picture feature, so apps like Calculator or Files didn't need to take up the whole screen. Chrome's tablet UI has tremendous potential, and the Pixel Slate feels like a classic Google move to iterate in public.

When attached to the Pixel Slate Keyboard, the Pixel Slate looks like an ordinary Chromebook.

VERDICT

There are a lot of things to like about the Pixel Slate. It has a gorgeous design, it comes in a range of prices

The Pixel Slate Keyboard has a very low profile.

and options, and it has a thoughtful two-way interface that plays to the strengths of each format. The companion Pixel Slate Keyboard fits the Slate like a dream, and the battery lasts long enough to leave a charger behind.

But in its current state, it's hard to recommend the Pixel Slate without a few caveats. You need the Pixel Slate Keyboard. Android apps are more of a bonus than a selling point. And there are enough little bugs to make it feel more like a $200 Chromebook than a $1,000 model.

But while I probably wouldn't recommend the Pixel Slate to anyone looking for a full-time tablet or Chromebook, I also wouldn't talk someone out of buying one. For all of the annoyances, I enjoyed using the Pixel Slate, and it's definitely one of Google's best-designed products. I'll certainly keep using and report back as things improve. The Pixel Slate is very much the future, but for now, if you have $1,000 to spend on a Chromebook, you're probably better off getting the year-old Pixelbook (go.pcworld.com/pxlb).

Google Pixel Slate

★★★½☆

PROS

- Bright, beautiful display with incredible resolution.
- Gorgeous hardware that rivals Apple's iPad Pro.

CONS

- A little too heavy and big to use for very long as a tablet.
- Adding a obligatory Pixel Keyboard makes it a very expensive.
- Bugs and growing pains make it tough to use as a tablet.

BOTTOM LINE

The Google Pixel Slate is a gorgeous tablet, but its software doesn't quite live up to its good looks.

$999

OnePlus 6T: Android's rebel phone goes mainstream—with a punkish purple streak

The 6T probably won't kill any flagships, but it'll definitely land some punches.

BY MICHAEL SIMON

OnePlus sure knows how to make an entrance. Arriving at the tail end of a jam-packed Android season that included nothing less than the Samsung Galaxy Note 9 (go.pcworld.com/not9), LG V40 ThinQ (go.pcworld.com/40th), Google Pixel 3 (go.pcworld.com/p3xl), and the Huawei Mate 20 Pro (go.pcworld.com/m20p), the OnePlus 6T could have easily been a victim of flagship fatigue.

But OnePlus took a different tack with the 6T. Rather than try to garner attention with over-the-top features or specs, it elevated the

IMAGE: CHRISTOPHER HERBERT

phone by delivering the one thing fans have been hoping for since the OnePlus One: U.S. carrier support. The 6T marks the first OnePlus phone to be sold at T-Mobile stores, so the 6T actually has a chance to steal sales from its premium peers.

And it probably will. The 6T continues OnePlus's breakneck pace of refreshes, coming just six months after the 6, and bringing a gorgeous design, higher-end specs, and a price that exposes just how much of a premium we're paying for other high-end smartphones.

PRETTY IN PURPLE

The past four OnePlus phones have each significantly increased screen real estate, from 5.5 inches on the 5, to 6 inches on the 5T, 6.28 inches on the 6, and now 6.4 inches on the 6T. But while the display has increased by nearly a full inch since the 5, the footprint has barely budged:

OnePlus 5: 154.2 x 74.1 x 7.25 mm

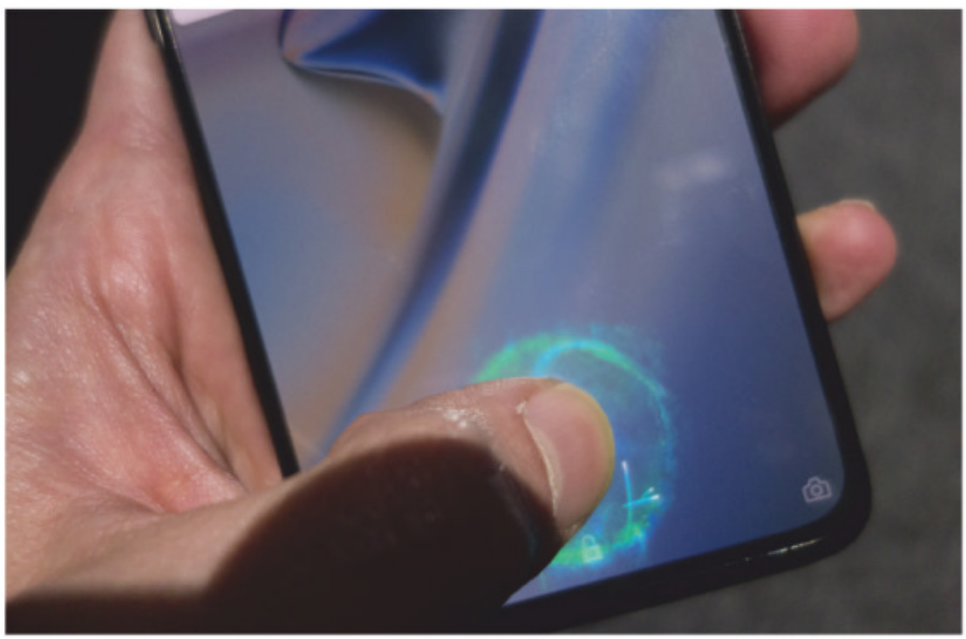
OnePlus 6T: 157.5 x 74.8 x 8.2 mm

Like the 6, the OnePlus 6T includes a display notch, but it's one of the smallest you're going to find—a tiny teardrop cutout that's barely big enough to contain the camera. The bezels have shrunk as well, giving the 6T one of the highest screen-to-body ratios and a truly immersive design that rivals the iPhone XS in aesthetics.

OnePlus did a fantastic job designing the 6T.

The side of the purple OnePlus 6T has a cool gradient to match the back.

Around the back, the 6T looks pretty much the same as the 6, with a vertically aligned camera array set against a clean piece of glossy or matte glass. The midnight and mirror-black color schemes have returned, and OnePlus is also offering a brand new color, which it calls Thunder Purple. It's darker than Samsung's Lilac Purple and fades into total darkness at the top, somewhat reminiscent of the glow around a lightning strike (hence the name). The sides of the phone follow the same gradient, so the power button is purple but the alert slider is black. There's also a subtle "S" curve down the middle when it hits the right light. In a strong season of smartphone colors, the purple 6T is one of the best, and anyone who rushed to buy a black one will likely be a little miffed.



The in-display fingerprint sensor on the 6T looks all futuristic when it works.

BLOWING OUT BIOMETRICS

One thing you won't find on the back of the OnePlus 6T is a fingerprint sensor. That's because it's returned to the front, under the display—but not like it was on the OnePlus 5. Instead, it's literally underneath the display on the 6T, making it one of the highest-profile phones to adopt this new technology.

The sensor tech is still optical, so it needs a burst of light to work. Activating this burst can be jarring in a dark room (as it's unrelated to screen brightness), but there's no denying the coolness of the animation. Setting it up for the first time is downright exciting, as the system prompts you to turn your finger on the display as it learns the contours of your fingerprint. You'll want to show it off to your friends with Pixels and Galaxy phones, and it definitely gives the 6T bragging rights over other premium phones.

But it also feels very much like a first-gen sensor, which is a bit of a step backward. Without a defined area to place my finger, I often missed the sensor on my first try. Other times I simply placed my finger at the wrong angle. Even when it worked on the first

try—I'd say 7 times out of 10, on average—it took a few milliseconds longer than a traditional sensor would. OnePlus offers face unlocking too, but it's nowhere near as secure. So if the fingerprint sensor frustrates you like it did on the Galaxy S8, your only option is a PIN or passcode, which is decidedly low-tech.

POWER AND PERFORMANCE ON DISPLAY

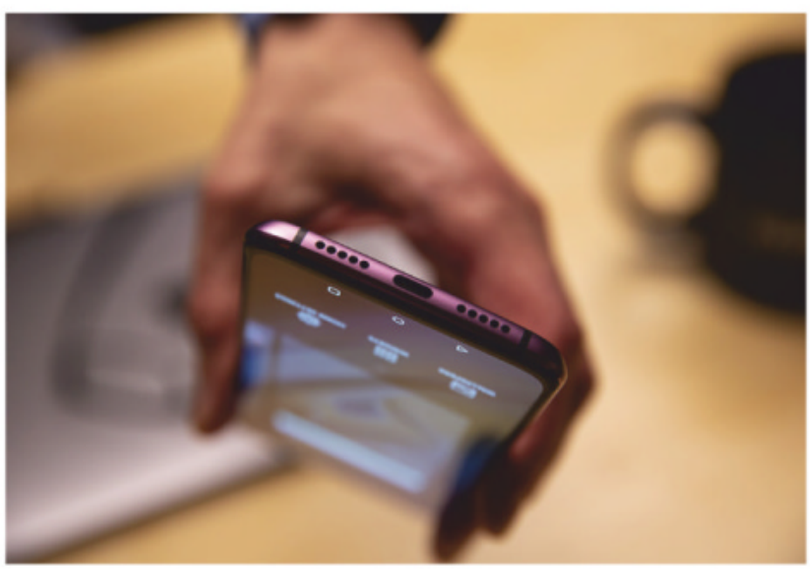
Once you get the screen unlocked, the OnePlus 6T is a delight. The 6.4-inch OLED screen is still 1080p, but it's every bit as crisp and vibrant as the 1440p displays on the Pixel 3 XL and Galaxy Note 9. The 6T is loaded with the top-level specs we've learned to expect from OnePlus:

Processor: Snapdragon 845
RAM: 6GB/8GB
Storage: 128GB/256GB
Battery: 3,700mAh
Rear camera: Dual 16MP, OIS, f/1.7 + 20MP, f/1.7
Front camera: 20MP, f/1.7

It's not without its downsides, though. You still don't get wireless charging or water resistance, and this time around OnePlus removed the headphone jack (though it does include a USB-C to 3.5mm adapter in the box). On the flipside, OnePlus has added a few extra milliamp-hours to the battery, and just like the 6, it's more than capable of powering through most days.

You also still get a great power-to-price value. While the entry-level 6T is $20 more than the 6, it gives you twice as much storage, which carries a $50 premium on the S9 and costs $100 extra on the Pixel 3 XL. You can increase RAM to 8GB for just $30 more. That $579 configuration is the only one being offered in the Thunder Purple color, but it's the best possible combination of storage and RAM. If you really need 256GB of storage, you can get that in either of the black varieties, but 128GB should be plenty for most people.

The model I tested was spec'd 8GB/128GB, and it's a screamer. I'm well accustomed to the Snapdragon 845 chip by this point, and OnePlus' OxygenOS makes it feel nearly as fast as it does on the Pixel 3 XL, along with a minimal interface, gesture



Sorry y'all, there's no more headphone jack on the 6T.

navigation, and full Android 9 Pie support.

OnePlus does things a little differently than Google, and I found the 6T's home button-less gesture navigation a little confusing. But the fact that the OnePlus 6T is one of the only phones to support the latest version of Android out of the box bodes well for future updates. OnePlus has rarely been at the front of the line when it comes to the latest software, so perhaps this is a sign that it's turning a new leaf.

If you hate notches, you still might like the OnePlus 6T.

Now would be a good time to do so. The 6T will be sold in T-Mobile stores, marking the first time that a OnePlus phone will be sold in any U.S. retail store, which will surely do wonders for its visibility. It works with Verizon SIMs as well, but that takes a little more doing. Out of the box, my OnePlus was able to make and receive calls, connect to LTE, and send texts but not receive them. After lengthy correspondence with customer service, it's still not resolved a few days later. However, Verizon did concede that it's "a known issue about the device not having the CDMA-less feature." So even though I didn't get it fully working for this review, Verizon is on board with the OnePlus 6T, and that's a big deal, if not for the 6T then certainly for the 7.

A GOOD, BUT NOT GREAT, CAMERA

Cameras have always been OnePlus's weakest link, and that hasn't really changed with the 6T. The hardware is identical—right down to the Sony IMX sensors—but OnePlus has enhanced its image processing to compensate.

Most notably, there's a new Night mode that boosts brightness in ultra-dark scenes. It's kind of like Night Sight on the Pixel 3 XL, though not nearly as successful. Where there was available light, the OnePlus tended to blow out details with too much exposure, and it struggled to pull out recognizable images when shooting in intense darkness. Still, it's a definite improvement over the standard auto mode.

Elsewhere, the OnePlus 6T still behaves like a mid-range camera. The pictures I took

The OnePlus 6T (right) handled the various shades of green slightly better than the OnePlus 6 (center), but neither were a match for the Pixel 3's superb detail.

weren't bad by any stretch, but they also didn't stand up to the output of the Pixel 3 XL or Note 9. You can argue that those phones cost way more—and many people will—but that's a hard pill to swallow when OnePlus is positioning itself as a premium phone at an affordable price. It tells us to "never settle," but consistently asks us to compromise when it comes to the camera. That said, OnePlus has made measurable advancements in computational photography with the 6T, and it's also bringing it to earlier models, which gives hope that the 6T will only get better.

With Night Mode on (right), the OnePlus 6T blows out the light, which can be problematic at times.

The OnePlus 6T in Thunder Purple.

VERDICT

There's a lot to like about the OnePlus 6T. It has the core silicon best specs you can get in an Android phone, an excellent screen, fantastic design, and a super-cool, next-gen unlocking method. It costs hundreds of dollars less than its Snapdragon 845 peers do. And the new purple color is straight-up gorgeous.

But while the OnePlus 6T punches above its weight when it comes to raw power, it still comes up short in the things the make premium Android phones premium. It doesn't have wireless charging or rated water resistance, its camera is an also-ran, and it's even lost the headphone jack. These are all things someone buying a $550 phone might overlook, but OnePlus wants to be known as an affordable premium phone, not a powerful budget phone, so these things matter.

Now OnePlus will literally be side-by-side with its rivals in T-Mobile stores. For many people, the 6T will be their introduction to OnePlus, and it definitely makes a strong first impression. But when competing against the likes of Google, Samsung, and Apple, it's more about the second, third, and fourth impressions. Still, if OnePlus can address those shortcomings, it might truly become the flagship killer it wants to be.

OnePlus 6T

★★★★☆

PROS

- Gorgeous design with a fantastic purple gradient option.
- Excellent specs, battery, and display.
- Low price as always.

CONS

- Camera is still unremarkable.
- No wireless charging, headphone jack, or water resistance.

BOTTOM LINE

The 6T is the perfect phone for OnePlus's first carrier partnership, with great specs, a gorgeous design, and the same low price.

$579

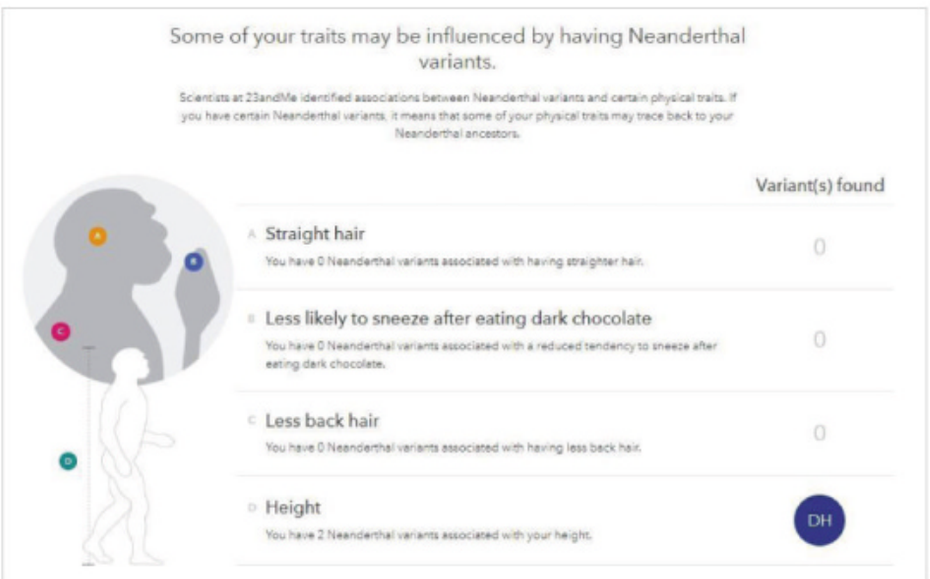
23ANDME VS. ANCESTRYDNA

WHAT'S THE DIFFERENCE?

IT DEPENDS ON WHAT YOU'RE AFTER. **BY DIETER HOLGER**

IMAGE: PESHKOV/GETTY IMAGES

AncestryDNA and 23andMe are the world's most popular DNA tests. Combined, the companies have tested the DNA of more than 15 million people, according to the International Society of Genetic Genealogy (go.pcworld.com/isgg).



Here are all the Neanderthal traits 23andMe can identify

They also both cost $99, unless you elect for 23andMe's $199 Ancestry + Health service to get info on potential health risks and genetic traits in addition to ancestry. So what's the difference? We took both tests to find out. You can read our full reviews of AncestryDNA (go.pcworld.com/adna) and 23andMe (go.pcworld.com/23me), but below we break down the primary differences between the two kits.

THEY TEST DIFFERENT PARTS OF YOUR DNA

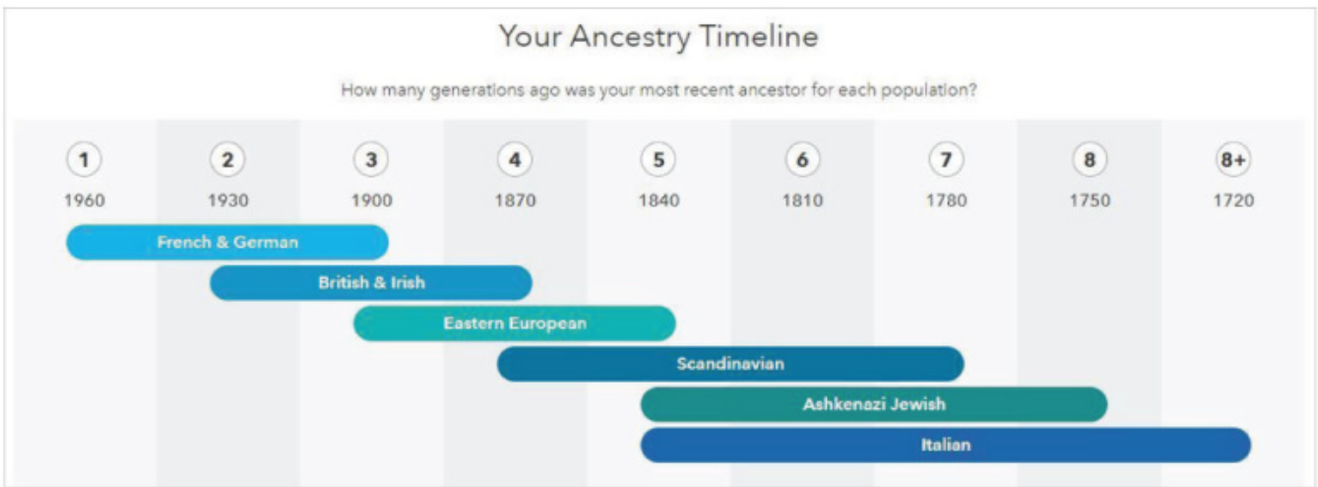
For one, AncestryDNA only tests your autosomal DNA, while 23andMe tests your autosomal DNA, your mtDNA, and your yDNA (if you're male).

Autosomal tests are the most common DNA tests. They look at DNA inherited from both sides of your family and compare it to other samples to determine your ethnicity. Autosomal DNA tests also reveal family relations up to seven generations—or 210 years—with up to 95 percent accuracy.

On the other hand, mtDNA comes from your mother and yDNA from your father—however, only men can have their yDNA tested. These types of DNA reveal the lineage, known as a haplogroup, that you descend from on your mother's or father's side. 23andMe uses this information to tell you about your ancestors tens of thousands of years ago and their migration patterns.

THEY GIVE DIFFERENT RESULTS

Because of the aforementioned different kinds of DNA the tests examine, the results you get also differ. AncestryDNA just provides an ethnic breakdown of your DNA through an interactive map, while 23andMe



23andMe's fascinating ancestry time-line visualization.

does this and much more.

The results from 23andMe are more varied and informative than AncestryDNA. For instance, I learned that I was descended from "Ötzi the Ice Man," who was apparently killed by an arrow 5,300 years ago in the Alps. You also see your ancestors' migration patterns and even how many Neanderthal variants you carry in your DNA.

Visualizations from 23andMe were also far more interesting. While AncestryDNA just provides you with a map, 23andMe goes above and beyond with unique offerings like Your Ancestry Timeline and Your Chromosome Painting. In short, you get a lot more with 23andMe.

THEY REPRESENT A DIFFERENT NUMBER OF ETHNIC REGIONS

Both tests offer hundreds of ethnic regions to match your DNA against. But as of this writing, AncestryDNA provides 499 regions compared to 23andMe's 171. That's 328 more regions.

This is partly thanks to the 169 regions AncestryDNA offers on European migrations into the Americas, Africa, and elsewhere. 23andMe doesn't trace the DNA of European settlers yet.

People of European descent also have a disproportionately high number of regions in both tests compared to other ethnic groups. Seventy-four percent of AncestryDNA's regions are European compared to 23andMe's 30 percent.

Read our in-depth feature on why DNA tests are more detailed for white people to learn more (go.pcworld.com/dtst). In short, it's because most of their customers are of European descent.

The companies are regularly updating their ethnic breakdowns as new data come in, so expect more regions to appear with time.

THEY HAVE DIFFERENT-SIZED DNA MATCHMAKING DATABASES

Both AncestryDNA and 23andMe have a DNA matchmaking service, where you can learn about, and make contact with, genetic relatives. But AncestryDNA has tested the DNA of more than 10 million people, compared to 23andMe's more than 5 million tests.

That means you have a far higher chance of matching with a relative on AncestryDNA than 23andMe. You can also enhance your search even further by signing up for access to Ancestry.com's extensive genealogical records, starting at $19.99 a month. Ancestry.com has amassed more than 11 billion records to create millions of family trees, based on marriage and death certificates, immigration dates, and military records.

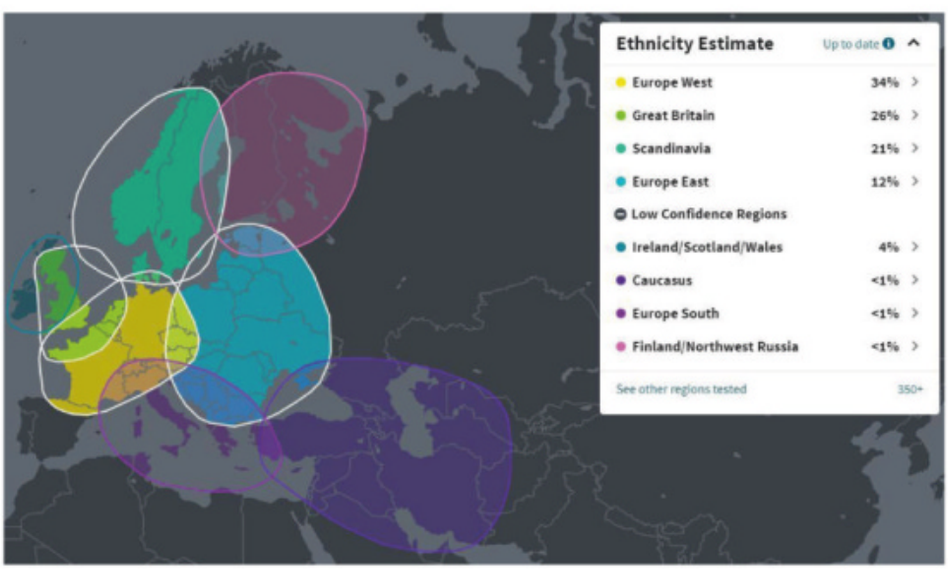
It should also be noted that the more people in a DNA database, the more accurate the test results become. More DNA data allows these companies to perfect the algorithms used in creating ethnicity estimates.

WHICH ONE IS RIGHT FOR ME?

Like most things in life, it depends on what you want to get out of the experience. If you're looking for genealogical information and want to find relatives, then AncestryDNA is the way to go, just by virtue of it having a much larger database.

Still, 23andMe's 5 million users is substantial, and the service excels by providing a lot more detail about your DNA than just your ethnicity estimate since it tests more of your DNA. It's also far more educational than AncestryDNA, which basically just shows you an ethnicity map and matches you with people. For those reasons it seems like a better value.

Both tests are regularly refining their data and algorithms to improve the results. Over time, you can expect to receive notifications when either service has improved its ethnicity estimate.



The map of my ethnicity breakdown from AncestryDNA.

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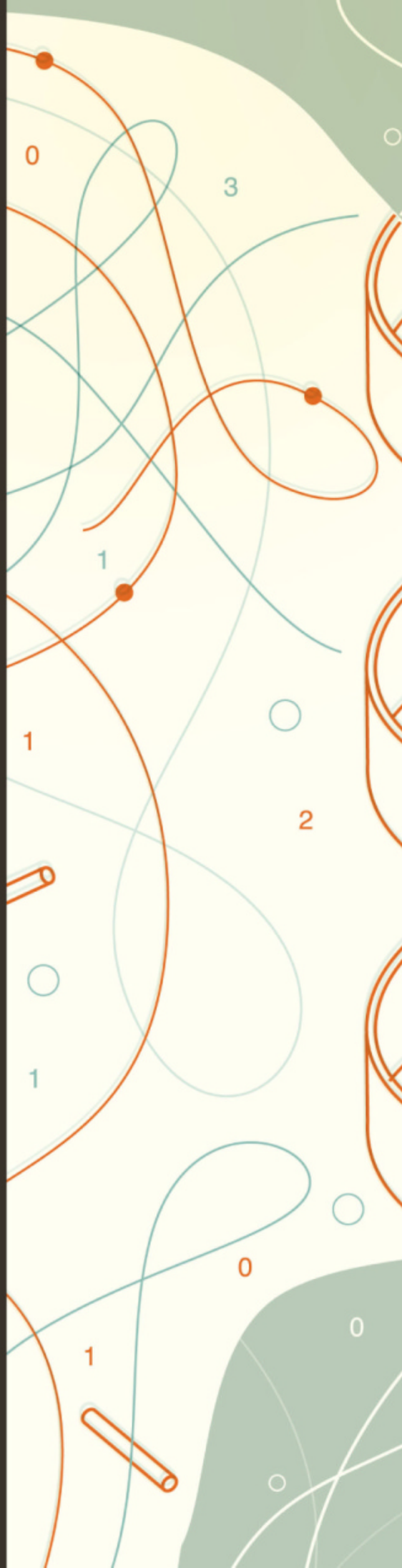
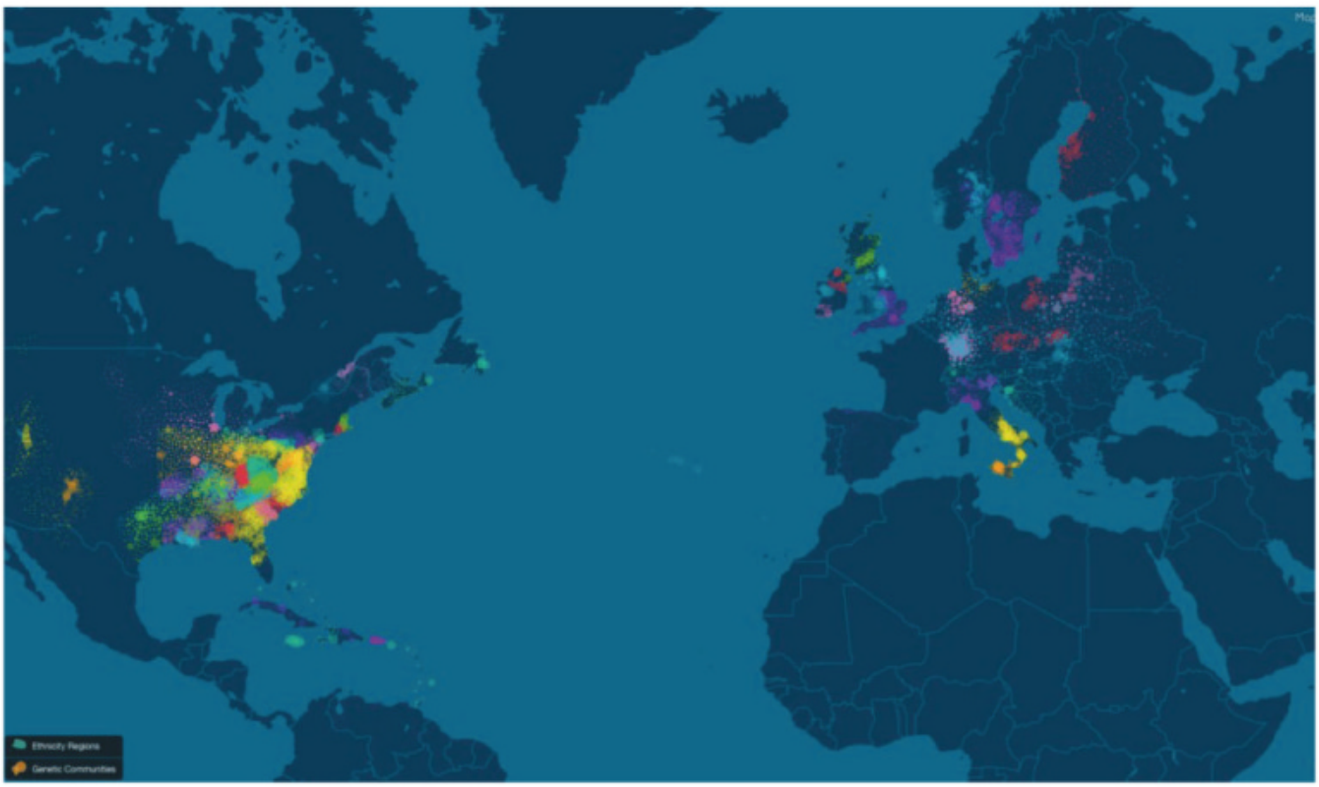
IT'S ALL IN THE DATA. **BY DIETER HOLGER**

ILLUSTRATION BY HARRY CAMPBELL

DNA TESTING FOR ANCESTRY IS MORE DETAILED FOR WHITE PEOPLE.

HERE'S WHY, AND HOW IT'S CHANGING.





As DNA tests for ancestry explode in popularity, a fundamental problem remains: The tests deliver more detailed results for people of European descent, as evidenced by the ethnicities and data that major DNA testing companies represent. While this bias should recede as more people take the tests and add their genetic data to the mix, the companies have some work to do before their kits can work reasonably well on a worldwide population.

In 2017, more people took DNA tests than in all the previous years combined (go.pcworld.com/mitr), according to the MIT Technology Review, and that number keeps climbing. According to the International Society of Genetic Genealogy (go.pcworld.com/isgg; ISOGG), more than 18 million people have tested their DNA to learn about their ethnic identity or to find relatives. DNA testing companies like AncestryDNA (go.pcworld.com/adna) and 23andMe (go.pcworld.com/23me) have become household names as a result, while new tests (go.pcworld.com/ldna) claiming more specialized results crop up every few years.

It's easy to see the appeal. For $99, 23andMe and AncestryDNA simply require that you spit in a cup, send it off to a lab for testing, and then wait a matter of weeks to learn the ethnic breakdown of your genes by region. (See our comparison of these two popular kits starting on page 90.)

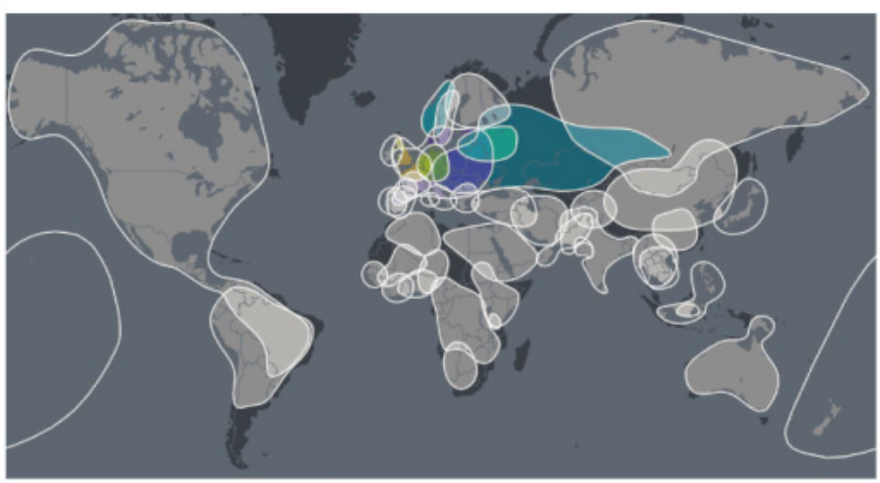
THE DATA PROBLEM

The risk for racial bias starts with the data used by DNA tests. AncestryDNA, for instance, bases its ethnicity estimate on a reference panel (go.pcworld.com/rfpn) sourced from the DNA of 16,638 people representing 43 different populations. The people in the reference panel are screened to ensure they represent a certain ethnicity strongly—"people with a long family history in one place or within one group," the company explains. The screening involves controls, such as removing close relatives, to avoid skewing the ethnicity profile.

While this pre-screened data can identify ethnicity on a broad level, more detail comes only with more data. Every DNA test kit sent in adds to the company's database. That's why leading contenders AncestryDNA and 23andMe have some of the best estimates available—they have more customers, and therefore more data.

Because DNA tests like AncestryDNA and 23andMe were at first available only in the United States and have expanded mostly to European countries or former colonies, the customer base continues to be fairly uniform. ISOGG estimates that four-fifths of the people who have taken DNA tests are U.S. citizens, meaning their data reflects a population with majority European ancestry.

Challenges in funding and poor infrastructure make it more difficult to gather genetic data on underrepresented DNA groups like Africans, Asians, and indigenous peoples. Sarah Tishkoff (go.pcworld.com/stlb), a professor at the University of Pennsylvania who has studied African genomics for 18 years, told *PCWorld,* "Right now, it's not possible to infer the exact sources of ancestry of African Americans, and it would be unfortunate if they have the expectation that they will be able to get that information." Tishkoff said that gathering a more diverse set of DNA data brings its own challenges, both financial and ethical. "There needs to be better funding and resources for generating that data. It's also important to do the research in an ethical manner. I personally think there should be caution about using information from indigenous populations for commercial purposes such as ancestry testing."



AncestryDNA's ethnic regions. Colored areas represent locations that came up in *PCWorld*'s review (go.pcworld.com/anrv).

REGIONAL REPRESENTATION: A BREAKDOWN

Now that you know how data for these DNA tests come in, the ethnicity breakdowns should be no surprise. Both AncestryDNA and 23andMe skew toward people of European descent.

AncestryDNA is the most popular DNA test in the world, having sampled more than 10 million people. Yet 296 of the 392 ethnic regions it represents are for people of European heritage. That's more than three-fourths European.

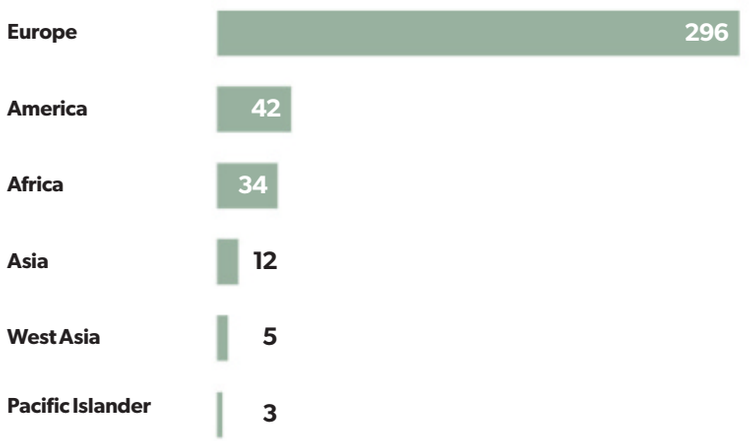
23andMe, the world's second-most popular DNA test, became more representative of non-European ethnicities earlier this year after it added regions for Asia (go.pcworld.com/xanc) and Africa (go.pcworld.com/nwaf). The company has tested the DNA of more than 5 million people.

Of the ethnicities it represents in the Ancestry Composition panel if you take the test, 52 of 171, or 30 percent, are European. That's nearly 50 percent more regions than East Asia, which has the second highest number.

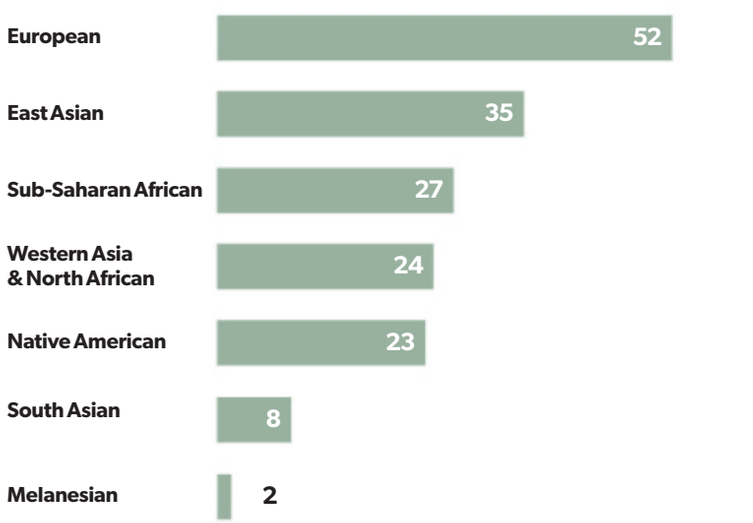
What's more, half of the DNA reference samples 23andMe uses to test a customer's genes and estimate ethnicity come from Europeans, suggesting it's better at evaluating people of European descent.

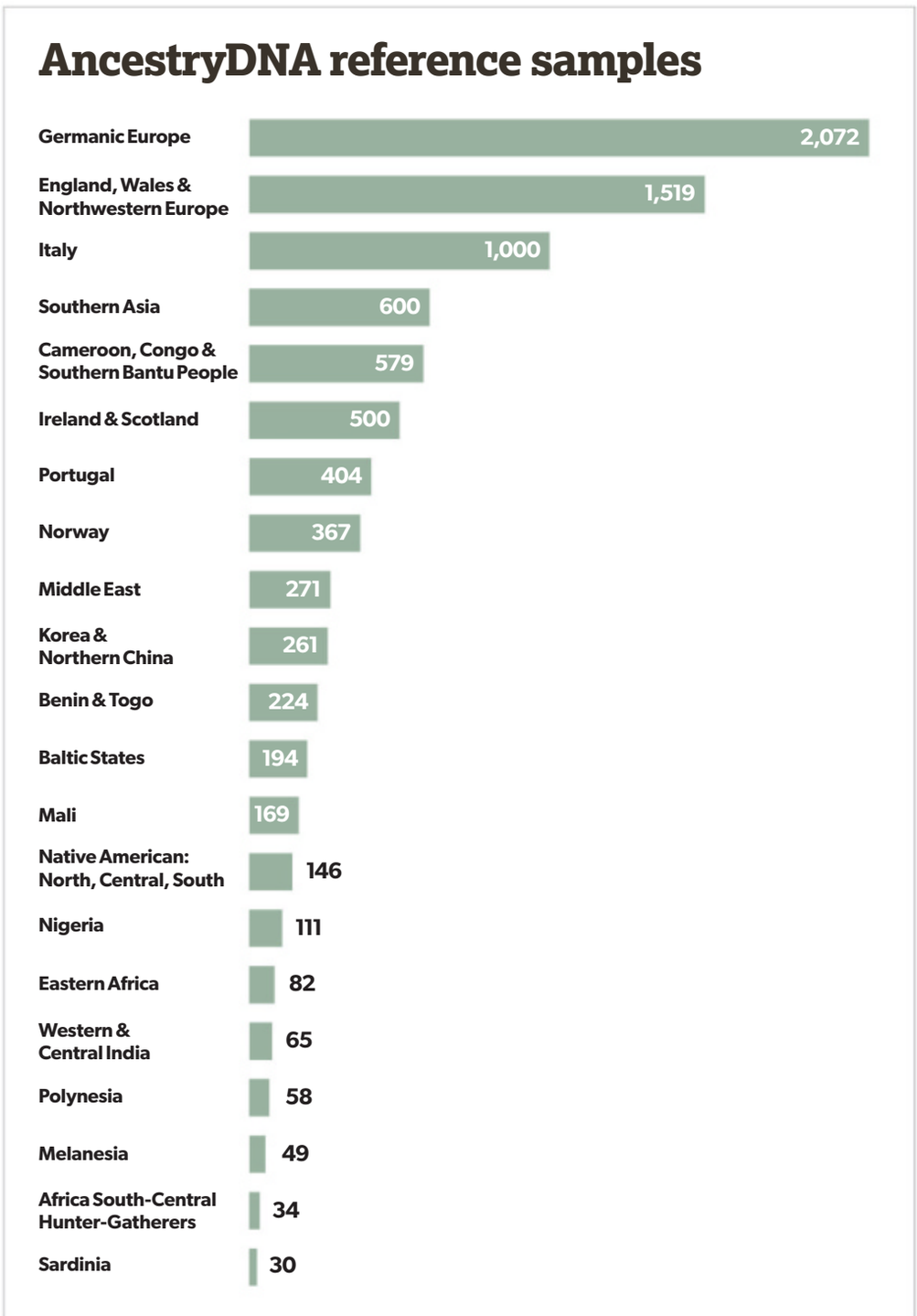
AncestryDNA also has a disproportionately higher amount of reference samples (go.pcworld.com/rfpn) from people of

AncestryDNA ethnic regions



23andMe ethnic regions

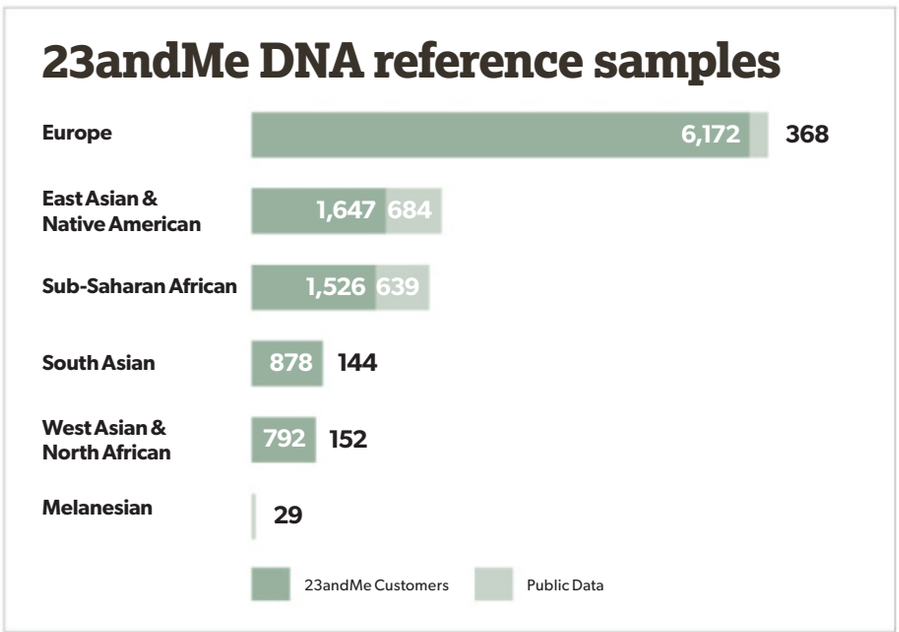




European heritage. Of the 16,636 samples AncestryDNA uses, more than 65 percent come from people of European ethnicity.

Even though Africa is geographically larger than Europe, China, and the U.S. combined, AncestryDNA offers only 33 ethnic regions for people of African descent, while 23andMe has 34 regions. Compare that to the 296 regions AncestryDNA offers for people of European descent, and 23andMe's 52 regions.

In the case of AncestryDNA, many of these regions include migrations out of Europe. The company lists 173 ethnic regions where Europeans settled in America, South Africa, and elsewhere. It does something similar for African Americans, but only 24 of the 33 regions in its Africa category track the lineage of Africans forced into slavery.



HOW DNA TESTERS ARE DIVERSIFYING THEIR DATA

In a statement to *PCWorld,* an AncestryDNA spokesperson said the company plans for its test to include more than 500 regions by early 2019, with a particular focus on African American and Hispanic communities. To improve its test, AncestryDNA is gathering more DNA reference samples from around the world, updating its algorithms, and adding and updating the genetic markers of diverse global populations.

"Our company's history is one of continued evolution and progress and our platform is constantly improving as more and more people participate through AncestryDNA and build family trees," the spokesperson said.

When 23andMe first offered its ethnicity estimate in 2008, the company included only three regions. Now, it represents 171.

The rapid growth is a testament to how algorithms and big data can quickly improve genetic science. But there's still more to be done.

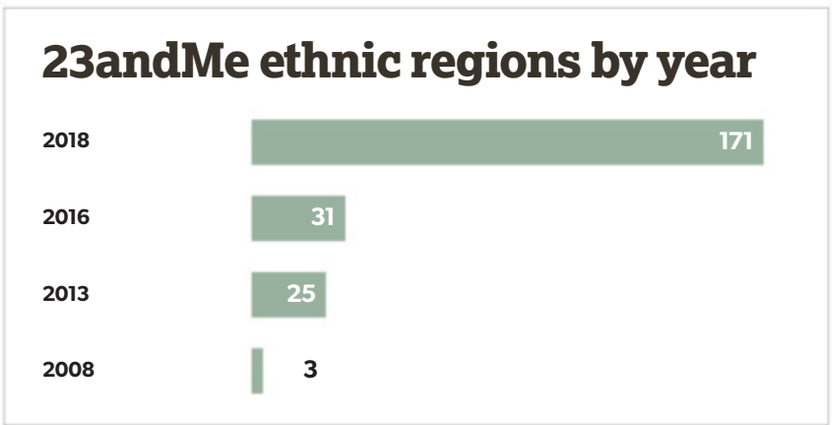
To better serve underrepresented DNA groups, 23andMe launched the Global Genetics Project (go.pcworld.com/glgn) in February of this year to gather more genetic data. If you have a grandparent from one of 59 underrepresented countries, 23andMe provides you with a free test and access to its more than 90 genetic reports.

Joanna Mountain, senior director of research at 23andMe, told *PCWorld* in an interview that the Global Genetics Project has already exceeded its original two-year goal of collecting 5,000 samples in less than a year.

"We really have captured the genetic diversity of the world in a way that I would never have imagined 20 years ago," she said.

Mountain said 23andMe is also collaborating with researchers and academics to gather more data and better educate the world about genetic science.

"Many people in this country and beyond have very little understanding of genetics and



concerns about privacy," Mountain said. "So there is a lot of education to be done."

Mountain said 23andMe noticed early on that there was a bias in its reference sample data because they had more U.S. customers. "We have more representatives of Italy than we have of Devon (go.pcworld.com/dvon), [South Africa], for instance, which is not surprising given our customer base."

But she said that doesn't always mean 23andMe is less detailed for people of non-European descent. Someone from Mexico could learn about both their indigenous and Spanish ancestry, for example.

"It varies so much from person to person depending on your family's history," Mountain said. "You could at a very crude level say that Europeans might get a bit more detail, but that's going to be very much variable."

The good news is that 23andMe and AncestryDNA are regularly updating their models to improve the accuracy and detail of their tests.

"We are going to be looking where people get less detail and working to fill those gaps and to provide more detail to as many people as we can," 23andMe's Mountain said. "So that's going to be something we continue to push on in the next five years."

23andMe's map of its ethnic populations.

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Marriott Starwood hotel data breach FAQ: What 500 million hacked guests need to know

Here's everything you need to know. **BY MICHAEL SIMON**

It's been a couple of months since a major company unveiled a data breach that affected millions of people (go.pcworld.com/tmdb), so it's time for a new one. The Marriott hotel chain has announced (go.pcworld.com/dbsc) a major database breach that could affect anyone who stayed at its 6,700 worldwide Starwood hotel properties since 2014—up to 500 million people in total.

That's a lot of people and a long stretch of time, so check out our FAQ:

IMAGE: MARRIOTT

WHAT HAPPENED?

Marriott says it received an alert from an internal security tool on September 8 warning of an attempt to access the Starwood guest reservation database in the United States. In its investigation of the incident, Marriott learned that an unauthorized party gained access to the company's customer database and "copied and encrypted information, and took steps toward removing it."

HOW DID THE HACKERS GET IN?

Marriott isn't being totally clear here, but it appears as though this wasn't the usual exploit of a vulnerability. Rather, someone without the proper credentials was able to access the Marriott reservation database to make a duplicate encrypted copy of customer information, which was then presumably taken outside the system.

HOW FAR BACK DOES THE BREACH GO?

Marriott says the unauthorized access goes back to 2014.

WHY WASN'T MARRIOTT ALERTED SOONER?

Also unclear, but perhaps the unauthorized party only recently started accessing the system. Or possibly Marriott recently installed new security software that was able to detect the access.

WHY ARE WE JUST HEARING ABOUT THIS NOW?

Marriott says it was only able to decrypt the files on November 19, and is still working to uncover the scope of the breach.

WHAT WAS STOLEN?

Marriott is still sorting through the data it was able to recover, but for most customers, the following data may have been stolen: name, mailing address, phone number, email address, passport number, Starwood Preferred Guest ("SPG") account information, date of birth, gender, and arrival and departure information, along with reservation dates and communication preferences.

SHOULD I CHANGE MY PASSWORD?

Marriott hasn't said whether any

accounts were accessed or passwords stolen, but it certainly can't hurt. But this was a breach of the company's internal database of hotel guests, not online accounts.

Password managers make it easy to create strong, unique passwords for every site you visit. If you aren't using one yet, our guide to the best password managers can help you pick a great one (go.pcworld.com/pwmn).

WHAT ABOUT CREDIT CARD INFORMATION?

For some users, Marriott says payment card numbers and payment card expiration dates were included in the stolen data, but card numbers were encrypted using Advanced Encryption Standard encryption (AES-128).

SO MY CREDIT CARD IS SAFE?

Possibly not. As Marriott explains: "There are two components needed to decrypt the payment card numbers, and at this point, Marriott has not been able to rule out the possibility that both were taken."

WHAT ABOUT MY SPG POINTS?

Marriott says there is no evidence that any loyalty points were obtained, but you should check your account for any suspicious activity.

HAS THE BREACH BEEN STOPPED?

Presumably, but Marriott doesn't explicitly say whether the unauthorized access has been shut down. However, the chain is working with law enforcement agencies and regulatory authorities, so the likelihood of a continued breach is extremely low.

WHAT IS MARRIOTT DOING TO STOP FUTURE BREACHES?

Again, it's not totally clear if the hacker exploited a vulnerability or merely used an unauthorized password, but Marriott says it is devoting the resources necessary to phase out Starwood systems and accelerate the ongoing security enhancements to our network.

HOW DO I KNOW IF MY DATA WAS ACCESSED?

Marriott began sending emails on a rolling basis on November 30 to affected guests, so be sure to check your email, particularly your spam folder, to see if you've received one.

WHAT CAN I DO IF I AM AFFECTED?

Marriott has set up a dedicated call center to answer any questions you may have. U.S. Customers can call 877-273-9481 seven days a week to reach a representative.

SHOULD I CANCEL MY CREDIT CARD?

That is not a bad idea. If you know the credit card or cards that are on file with Marriott or Starwood hotels, canceling them now is the best way prevent any future malfeasance.

WHAT ELSE CAN I DO?

Marriott is providing all guests in the U.S., Canada, and the UK with the opportunity to enroll in Kroll's Web Watcher Monitoring Service (go.pcworld.com/krll), which tracks sites where personal information is shared and alerts you if evidence of your personal information is found.

Our guide to what to do after a data breach (go.pcworld.com/5dtb) can help you minimize your exposure to any pilfered information. Good luck.

Quora data breach FAQ: What 100 million hacked users need to know

Answers to truly burning questions after the Quora hack. **BY BRAD CHACOS**

Another week, another massive hack. Recently it was Marriott Starwood hotels (page 105); now it's question-and-answer website Quora's turn. Late on a Monday night in early December, Quora revealed (go.pcworld.com/qura) that "a malicious third party" gained access to its systems and swiped the account data of approximately 100 million users. That includes personally identifiable information, like your name and email address, as well as details about the actions you've taken on Quora itself, and data from other sites you've linked to your Quora account.

It's bad, and the Quora hack affects a lot

IMAGE: THINKSTOCKK

of folks. Here's everything you need to know.

SO WHAT HAPPENED?

Quora is still investigating, but CEO Adam D'Angelo says that "On Friday [November 30] we discovered that some user data was compromised by a third party who gained unauthorized access to one of our systems." Further details weren't provided yet.

WHAT QUORA USER DATA WAS TAKEN?

Pretty much everything associated with your account. D'Angelo says that the hackers may have pilfered 100 million users' names, email addresses, and encrypted passwords. Any data imported from another social network, such as contacts and demographic information, could have been compromised as well. The hackers may also have records of every public and private action you've taken on Quora, including comments, upvotes and downvotes, questions, and direct messages.

Anything posted anonymously shouldn't have been included, as D'Angelo says Quora does "not store the identities of people who post anonymous content."

HOW DO I KNOW IF MY QUORA ACCOUNT WAS HACKED?

Quora says it's notifying everybody who was hacked, and logging out every account that may have been affected. If you use a password for authentication, your password will also be reset.

Any further information discovered during Quora's investigation will be shared with affected users via email.

WHAT SHOULD I DO TO STAY SAFE?

If you have a Quora account, and especially if Quora confirmed you've been hacked, you should change your password. And if you reuse your passwords across multiple sites, you'll want to change your password at those as well. Reusing passwords is an awful security practice, though; if you use a

password manager, it can help you create strong, unique passwords for every site and service you visit. *PCWorld*'s roundup of the best password managers can help you find a great one (go.pcworld.com/pwmn).

Since Quora doesn't collect deeply personal information, such as credit card or social security numbers, you probably don't have to worry about identity theft. Nonetheless, you might want to read our guide on what to do after a data breach for additional steps to consider taking (go.pcworld.com/5dtb).

Finally, this is also a reminder that you want to practice best security practices at all times, because you never know when or where breaches will happen. A password manager and unique logins keep your accounts firewalled from each other when events like this happen; a solid security suite can lock down your local data. *PCWorld*'s guide to the best Windows antivirus software (go.pcworld.com/avru) can help you find your best option.

Since Quora doesn't collect deeply personal information, such as credit card or social security numbers, you probably don't have to worry about identity theft.

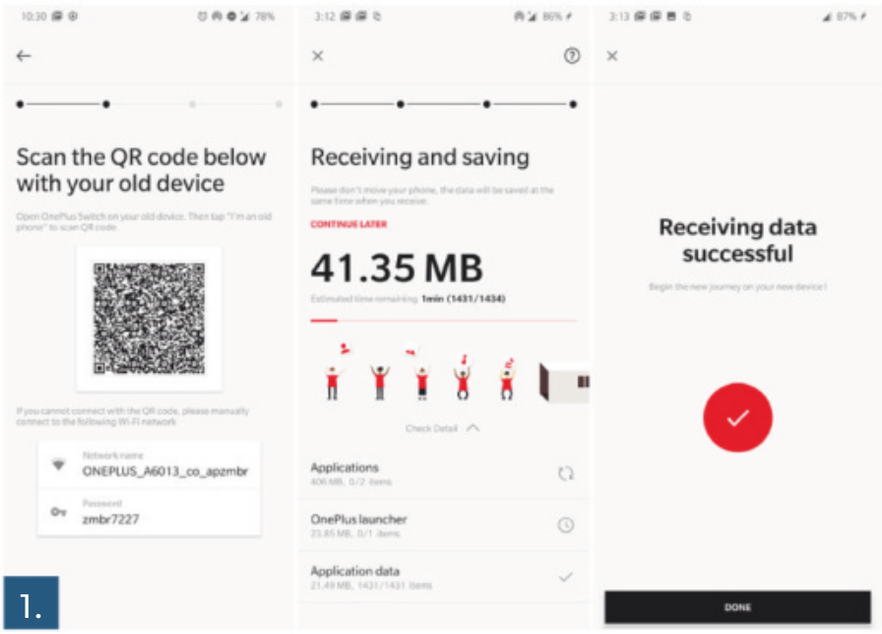
OnePlus 6T tips: The 10 features to check out first

OnePlus may not be a 'mainstream' phone manufacturer like Apple, Samsung, or Google, but its 6T is filled with innovation. Here are the features to check out first. **BY RYAN WHITWAM**

OnePlus doesn't subscribe to the once-yearly update cycle we see from most smartphone makers. Instead, it updates its hardware quickly, and adds new features with each iteration. The OnePlus 6T just launched around the world with one of the first in-display fingerprint sensors, and it's now being sold in the U.S. via T-Mobile—a first for OnePlus, which previously sold phones unlocked, direct-to-consumer.

So, you've got a shiny new OnePlus 6T, but how can you make the most of it? By taking advantage of the 10 features we describe here. And if you don't yet have a 6T, make sure to read Michael Simon's OnePlus 6T review (see page 83).

IMAGE: RYAN WHITWAM



The OnePlus Switch app makes it super easy to set up your new 6T.

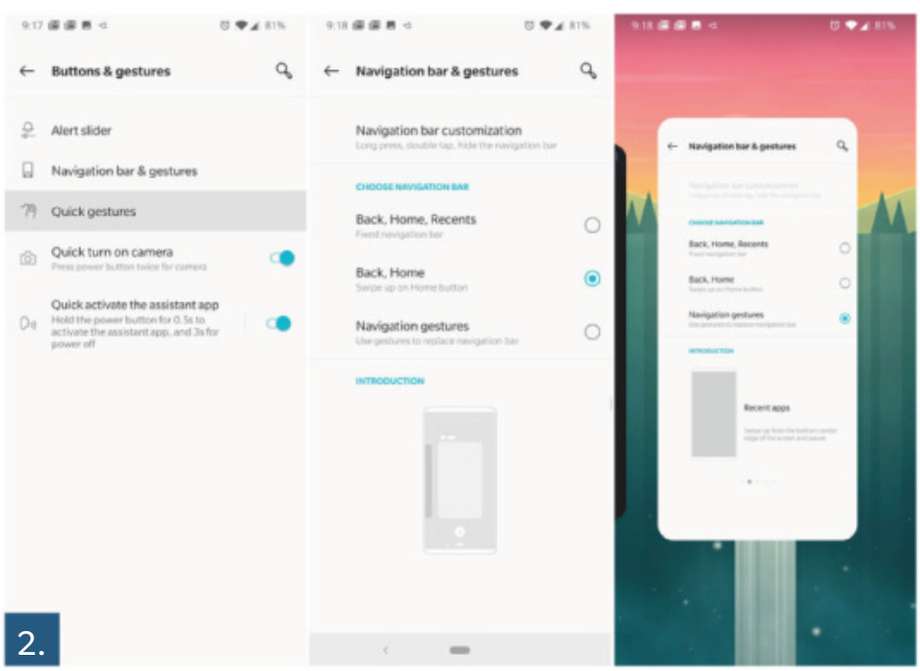
1. ONEPLUS SWITCH

The OnePlus 6T has a standard Android device restore feature as part of its setup process, but you might want to skip that and use the OnePlus Switch app (go.pcworld.com/opsw) instead. You can fire this up at any time from your app drawer, too. Install the app on your old phone if it's not already there, and then go through the pairing process.

The OnePlus Switch app can transfer images, SMS, call history, and apps. It works over Wi-Fi Direct, so the process is incredibly fast. If you're transferring from an older OnePlus phone, it can even bring over the app data so your apps will already be configured and working on the new phone.

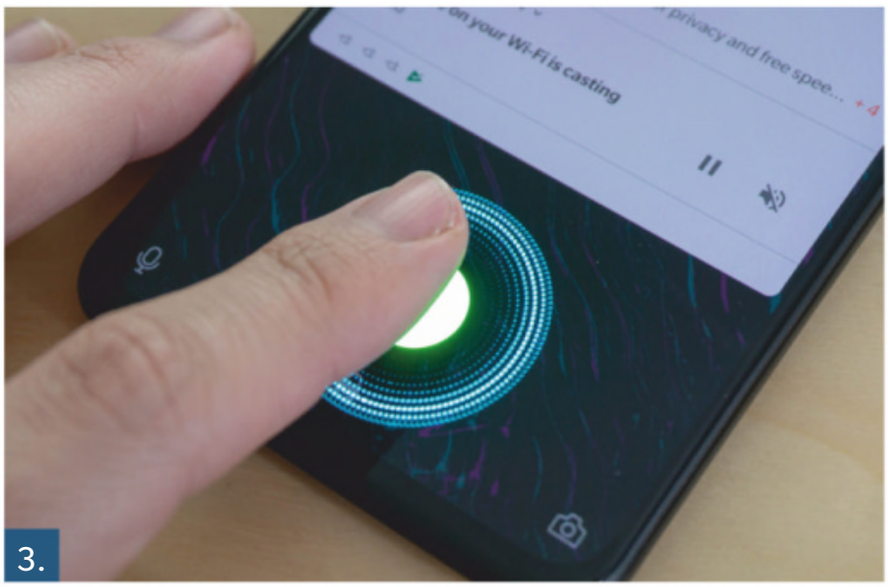
2. ONEPLUS GESTURE NAVIGATION

By default, your OnePlus 6T has navigation buttons. But if you want to fill the screen with as much content as possible, there's a fully gesture-based navigation option at your disposal. Go to Settings > Buttons & Gestures > Navigation Bar & Gestures. Change to the Navigation



Be sure to customize gesture navigation to your personal preferences.

Gestures option, which completely removes the navigation bar. Home is a swipe up from the bottom of the display; multitasking is swipe up and hold; and back is a swipe up on the bottom left or right.



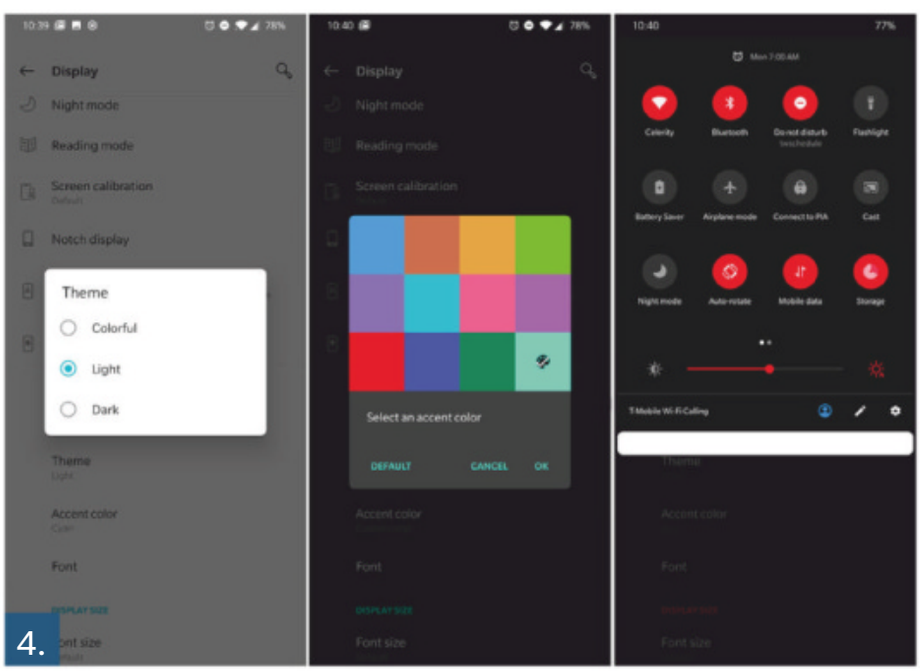
You can adjust the animation of the in-display fingerprint sensor.

3. FINGERPRINT UNLOCK ANIMATION

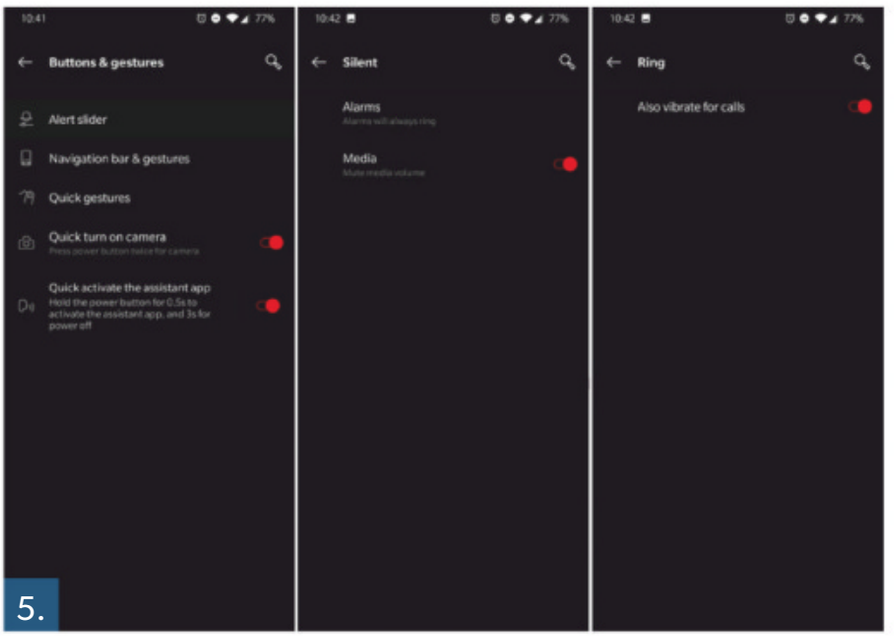
One of the 6T's new tricks is the in-display fingerprint sensor. OnePlus has a flashy animation when you press the sensor that looks like a little ball of lightning. If you want something a bit more understated, there are some alternatives in the settings. Go to Settings > Security & Lock Screen > Fingerprints > Fingerprint Animation Effect. From there, you can change to Wave or Stripe.

4. CHANGE THE THEME

OnePlus sticks close to stock Android, but its theme options are much more extensive. It defaults to an all-white UI, which uses more power than a dark UI, and it'll blind you at night. You can, however, make some tweaks in Settings > Display > Theme. From there, you can stick with a light theme, or change to a dark one. In addition, there's a customizable accent



You don't have to live with a bright, white theme.



You can customize the alert slider to fine-tune notifications.

color. You have a few default choices, but there's also a color picker to set any other color in the rainbow.

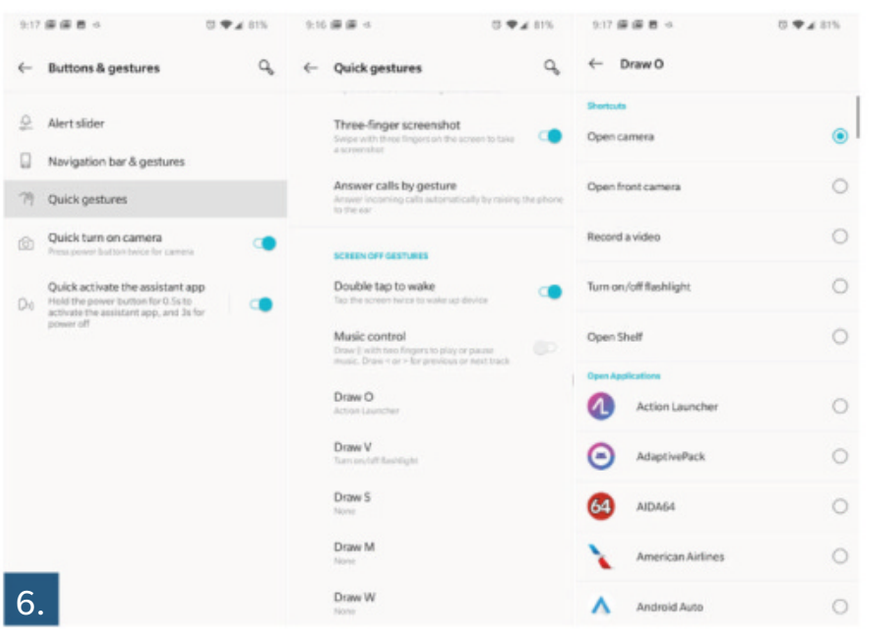
5. CUSTOMIZE ALERT SLIDER

OnePlus is the only Android device maker with a three-position alert slider on the side. It toggles between ring, vibrate, and silent, and there are a few useful tweaks available under Settings > Buttons & Gestures > Alert Slider. In silent mode, you can also have the phone mute all media, which is handy when using your phone at night. In ring mode, you can also configure the 6T to vibrate for calls.

6. SAVE TIME WITH QUICK GESTURES

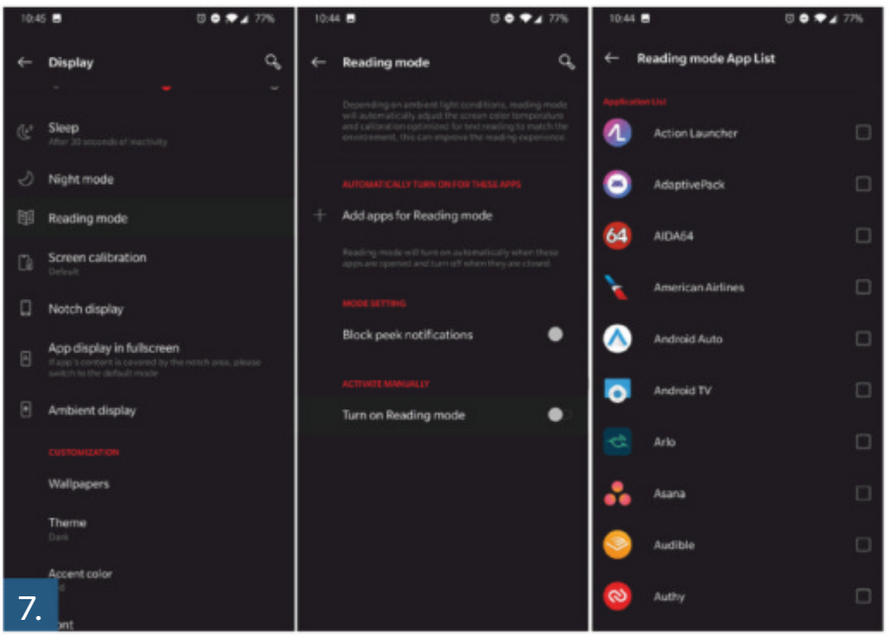
The OnePlus 6T, like other smartphones, is a wellspring of features and information when you turn it on. However, you don't even need to wake the phone to get things done. The 6T has several Quick Gestures, but not all of them are on by default. Head to Settings > Buttons & Gestures > Quick Gestures to get started.

The screen-off gestures can toggle features or open apps while the phone is



Quick Gestures let you perform actions while the phone is asleep, and you can customize them to your liking.

asleep. For example, drawing a "V" will turn the flashlight on and off. There are some other shapes and letters available to configure as well. You can assign preset functions like the flashlight, opening the camera, or recording a video.



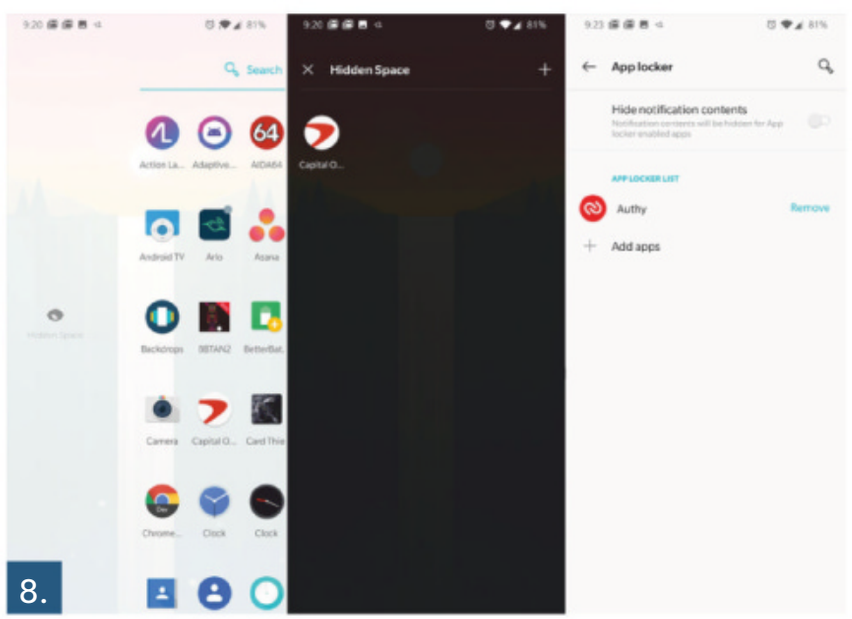
Reading Mode takes the sting out of reading long-form text on a phone.

7. READING MODE

Reading on a smartphone screen can be uncomfortable, but many of us do it anyway. The OnePlus 6T, however, can make it a bit easier on your eyes with its custom reading mode. You'll find this feature under Settings > Display > Reading Mode. This feature applies a filter that makes your vibrant OLED screen look more like the monochrome display on an eReader by sampling the ambient light. You can turn this feature on manually, or add apps to a watch list that automatically enables reading mode.

8. PROTECT YOUR APPS

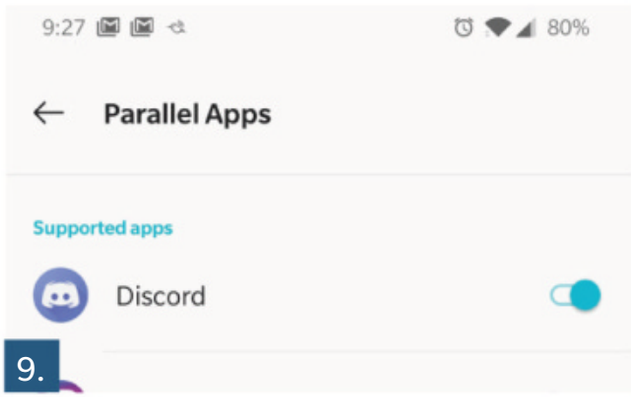
If you've got apps you don't want readily visible in your app list, you can keep them out of the way in the Hidden Space. This is a separate app drawer accessible by swiping to the left from your regular app drawer. Tap the plus icon at the top to choose apps to add to the hidden



Hiding apps in Hidden Space will keep them out of your main list.

space. Once they're added, they no longer appear in the main list. To remove an app, long-press and tap Unhide.

Hiding an app is fine, but you can take it a step further for maximum protection. The OnePlus 6T also has app encryption under Settings> Utilities > App Locker. Apps you've added to the list will open only after you verify your identity with your fingerprint or secure unlock code.



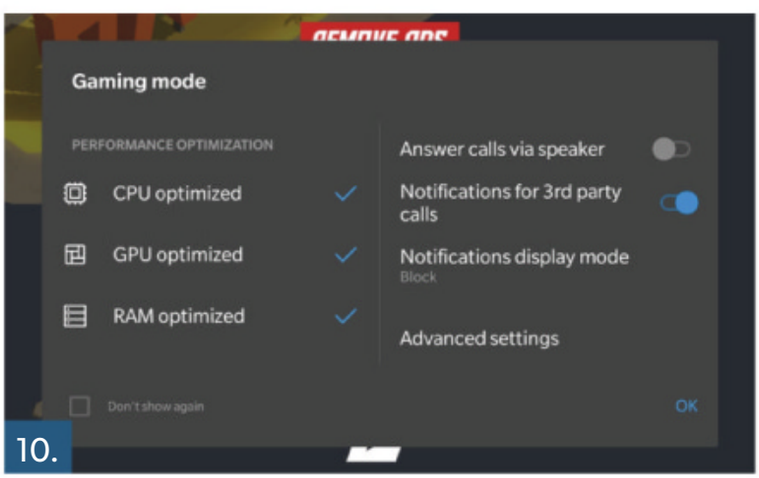
With Parallel apps, you can log in to multiple accounts via a single app.

9. PARALLEL APPS

Sometimes you end up with different accounts for some services, but drat, the app only supports a single account. Luckily, the OnePlus 6T has Parallel Apps. You'll find the settings for this feature under Settings > Utilities > Parallel Apps. It only works with select apps, but that includes most of the popular messaging clients like Telegram, WhatsApp, and Discord. Enabling a Parallel App creates a copy of it, available in your app drawer with a separate icon. Then, you can log in to the copy with your second account.

10. GAMING MODE

The OnePlus 6T has the hardware chops to tear through any mobile game in the world, and there's a custom Gaming Mode to make your experience just a bit better. Gaming Mode is accessible via Settings > Utilities > Gaming Mode. While in Gaming Mode, the phone won't show regular notifications on top of what you're doing. You can also set the phone to answer calls via speaker mode, disable automatic brightness, and limit other apps' use of the network interface. That last feature is handy if you're playing an online game on a weak connection. Gaming Mode activates automatically when it recognizes a game, but you can also add additional games to the list manually.



Gaming Mode suppresses notifications and provides other gamer-friendly features.

How to create Excel macros and automate your spreadsheets

Use macros to combine multiple tasks into a single, one-second transaction. **BY JD SARTAIN**

Excel macros are like mini-programs that perform repetitive tasks, saving you a lot of time and typing. For example, it takes Excel less than one-tenth of a second to calculate an entire, massive spreadsheet. Manual operations slow you down, so instead use macros to combine all of these chores into a single one-second transaction.

EXCEL MACROS: TIPS FOR GETTING STARTED

We're going to show you how to write your first macro. Once you see how easy it is to automate tasks using macros, you'll never go back. First, some tips on how to prepare your data for macros:

- Always begin your macro at the Home position (use the key combination

Ctrl+Home to get there quickly).

• Use the directional keys to navigate: Up, Down, Right, Left, End, Home, etc., and shortcut keys to expedite movement.

• Keep your macros small and focused on specific tasks. This is best for testing and editing (if needed). You can always combine these mini-macros into one BIG macro later once they're perfected.

• Macros require "relative" cell addresses, which means you "point" to the cells rather than hard-code the actual (or "absolute") cell address (such as A1, B19, C20, etc.) in the macro. Spreadsheets are dynamic, which means they constantly change, which means the cell addresses change.

• Fixed values and static information such as names, addresses, ID numbers, etc., are generally entered in advance and not really part of your macro. Because this data rarely changes (and if it does, it's just to add or remove a new record), it's almost impossible to include this function in a macro.

• Manage your data first: Add, edit, or delete records, then enter the updated values. Then you can execute your macro.

WHY STARTING WITH MINI-MACROS IS EASIER

For this example, we have a store owner who has expanded her territory from a single store to a dozen in 12 different major cities. Now the CEO, she's been managing her own books for years, which wasn't an easy task for a single store, and now she has 12. She has to collect data from each store and merge it to monitor the health of her entire company.

We created a few mini-macros to perform the following tasks:

1. Collect and combine the data from her 12 stores into one workbook in a Master three-dimensional spreadsheet.

2. Organize and sort the data.

3. Enter the formulas that calculate the combined data.

Once the mini-macros are recorded, tested, and perfected, we can merge them into one big macro or leave them as mini-macros. Either way, keep the mini-macros, because it's much easier and more efficient to edit the smaller macros and re-combine them than it is to step through a long, detailed macro to find errors.

We've provided a sample workbook for the above scenario so you can follow along with our how-to. Feel free to create your own spreadsheet too, of course (go.pcworld.com/mcwb).

PREP WORK: THE MASTER SPREADSHEET

If you're building your spreadsheets from the ground up, start with the Master spreadsheet. Enter the date formula in A1 and the store location in B1. See the screen shot on the following page.

1. Enter this date formula in cell A1: **=Today()**. Now this cell always displays today's date. Be sure; however, that your store location (branch name and number) are entered in B1.

2. Leave row 2 blank. Once the static data and initial dynamic data are entered, we'll use row 2 for the totals. This might seem like a strange custom, but for macro spreadsheets, it's the best way because this row is stationary and always visible.

3. Next, enter the field names (and/or any other field-specific information) in row 3 (e.g., from A3 through J3, or however many fields your spreadsheet requires).

Tip: You can text-wrap the information in the individual cells if the data is lengthy. For example, you can put the store contact information all in one cell and wrap the lines. Press Alt+Enter to insert extra lines in the cells.

4. Next, enter the static data in column A. That is the record information in your spreadsheet that rarely changes. If your business uses product numbers or ID codes, which are unique because there is only one code per product, enter those in column A beginning on row 4 (don't skip to row 5). Other static data fields might include the Product Description, the Product Price, sales tax percentage, etc.

Do not skip rows or leave any rows blank for column A. Every row must contain the unique field's data—if not a product code, then some other unique identifier. We do this for two reasons:

- Column A is the main navigational column. The macro moves and navigates through the spreadsheet based on the Home (A1) position and column A. The macro will fail if you ignore this rule, because blank rows disrupt the actions of the directional keys.
- If you decide to create multiple/relational tables later for Pivot Reports, you must have a unique, key field to connect the related tables. Check out our Excel pivot tables tutorial for more information (go.

	A	B	C	D	E	F	G	H
1	Sep 30, 2018	Boston Store 1100 555 Commonwealth Avenue Boston, MA 02215 617-555-9720 Nana1100@ComputersUSA.com	Enter formula for column totals in cell C2; C4:C500 for ttl units sold	Enter current product price in column D	Enter formula for column totals in cell E2 & row formulas in range E4:E500	Enter formula for column totals in cell F2 & row formulas in range F4:F500	Enter formula for column totals in cell G2 & row formulas in range G4:G500	Enter formula for column totals in cell H2 & row totals in range H4:H500
2		GRAND TOTALS						
3	Model Number	Description	Quantity	Price	Ext Cost	Discounts	Sales Tax	Totals
4	AS84040	Asus Slim						
5	AS84105	Asus Laptop						
6	AS84106	Asus All-In-One						
7	AS84215	Asus Tablet						
8	AS84414	Asus Tower						
9	D1718	Dell Tower						
10	D2112	Dell All-In-One						
11	D2654	Dell Laptop						
12	D8180	Dell Tablet						
13	HP2758254	HP Laptop						
14	HP5250121	HP All-In-One						
15	HP6011815	HP Slim						
16	HP6568889	HP Tablet						
17	HP7872533	HP Tower						
18	LE32507	Lenovo Tablet						
19	LE35216	Lenovo Tower						
20	LE45412	Lenovo All-In-One						
21	LE70125	Lenovo Slim						
22	LE90120	Lenovo Laptop						
23	SP3300	Surface Studio Desktop						
24	SP7400	Surface Pro Tablet						
25	SP9200	Surface Pro Laptop						

Build the Master spreadsheet first.

pcworld.com/xlrp).

5. Normally, the Product Description resides in column B, the Quantity Sold in column C, Product Price in column D, Extended Cost in E, Discounts in F, Sales Tax in G, and Totals in H. The column totals are across the top on row 2, remember? Format the column widths based on the length of the field names, and adjust the row height to 20 on all rows. Change the Top/Bottom alignment to Center, select the justification you prefer (left, right, center), and then format the spreadsheet "styles" to your preference.

6. Once the master database is set up, do not move anything. If you need to add fields, use the Insert Column command. For example, if you wanted to add a second sales tax, position your cursor anywhere on column H (Totals) and click the tab: Home > Insert > Insert Sheet Columns. The new column drops in to become the new H column, and the Totals column moves over to I. This process does not affect the macro.

7. The same process applies to rows. Normally I would caution you to insert rows "inside" the active database area. For example, if the formula says =SUM(B3:B20) and you insert or use a row outside of the formula's range like B21, the new record's data is not included in the formula and therefore, does not calculate.

8. Now we'll set up that formula range. Enter the following formulas on row 2 (this is a one-time task):

C2: **=SUM(C4:C500)**

E2: **=SUM(E4:E500)**

F2: **=SUM(F4:F500)**

G2: **=SUM(G4:G500)**

H2: **=SUM(H4:H500)**

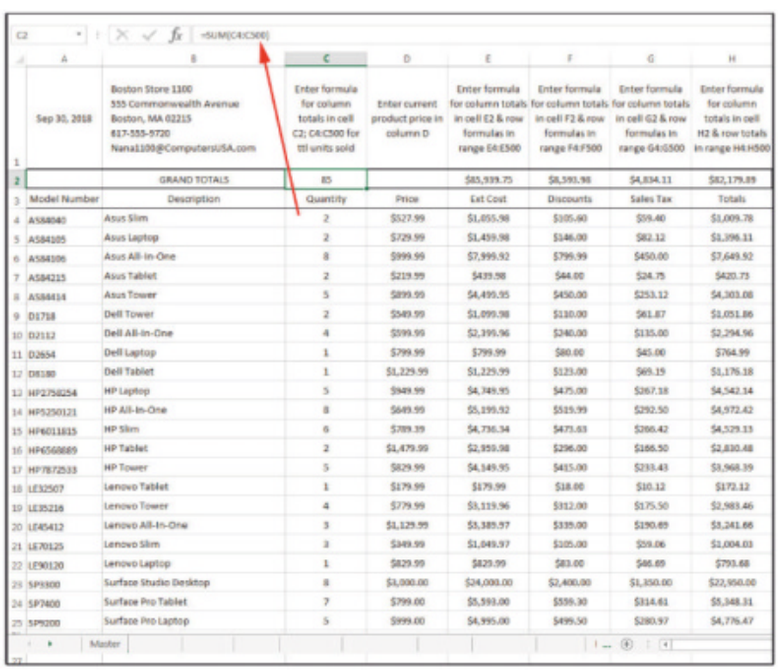
Next, enter the following formulas in these columns (also a one-time event):

E4: **=SUM(C4*D4)**, then copy from E4 down to E5:E500

F4: **=SUM(E4*10%)**, the current discount percentage in your store, then copy from F4 down to F5:E500

G4: **=SUM(E4-F4)*6.25**, where 6.25 is the sales tax in your area, then copy from G4 down to G5:G500

H4: **=SUM(E4-F4+G4)**, then copy from



	A	B	C	D	E	F	G	H
1	Sep 30, 2018	Boston Store 1100 555 Commonwealth Avenue Boston, MA 02215 617-555-5720 Nana1100@ComputersUSA.com	Enter formula for column totals in cell C2; C4:C500 for ttl units sold	Enter current product price in column D	Enter formula for column totals in cell E2 & row formulas in range E4:E500	Enter formula for column totals in cell F2 & row formulas in range F4:F500	Enter formula for column totals in cell G2 & row formulas in range G4:G500	Enter formula for column totals in cell H2 & row totals in range H4:H500
2		GRAND TOTALS	85		$85,939.75	$8,593.98	$4,834.11	$82,179.89
3	Model Number	Description	Quantity	Price	Ext Cost	Discounts	Sales Tax	Totals
4	AS8040	Asus Slim	2	$527.99	$1,055.98	$105.60	$59.40	$1,009.78
5	AS8105	Asus Laptop	2	$729.99	$1,459.98	$146.00	$82.12	$1,396.11
6	AS8106	Asus All-In-One	8	$999.99	$7,999.92	$799.99	$450.00	$7,649.92
7	AS8215	Asus Tablet	2	$219.99	$439.98	$44.00	$24.75	$420.73
8	AS8414	Asus Tower	5	$899.99	$4,499.95	$450.00	$253.12	$4,303.08
9	D1718	Dell Tower	2	$549.99	$1,099.98	$110.00	$61.87	$1,051.86
10	D2112	Dell All-In-One	4	$599.99	$2,399.96	$240.00	$135.00	$2,294.96
11	D2654	Dell Laptop	1	$799.99	$799.99	$80.00	$45.00	$764.99
12	D8180	Dell Tablet	1	$1,229.99	$1,229.99	$123.00	$69.19	$1,176.18
13	HP2758254	HP Laptop	5	$949.99	$4,749.95	$475.00	$267.18	$4,542.14
14	HP5250121	HP All-In-One	8	$649.99	$5,199.92	$519.99	$292.50	$4,972.42
15	HP6011815	HP Slim	6	$789.39	$4,736.34	$473.63	$266.42	$4,529.13
16	HP6560889	HP Tablet	2	$1,479.99	$2,959.98	$296.00	$166.50	$2,830.48
17	HP7872533	HP Tower	5	$829.99	$4,149.95	$415.00	$233.43	$3,968.39
18	LE32507	Lenovo Tablet	1	$179.99	$179.99	$18.00	$10.12	$172.12
19	LE35216	Lenovo Tower	4	$779.99	$3,119.96	$312.00	$175.50	$2,983.46
20	LE45412	Lenovo All-In-One	3	$1,129.99	$3,389.97	$339.00	$190.69	$3,241.66
21	LE70125	Lenovo Slim	3	$349.99	$1,049.97	$105.00	$59.06	$1,004.03
22	LE90120	Lenovo Laptop	1	$829.99	$829.99	$83.00	$46.69	$793.68
23	SP3300	Surface Studio Desktop	8	$3,000.00	$24,000.00	$2,400.00	$1,350.00	$22,950.00
24	SP7400	Surface Pro Tablet	7	$799.00	$5,593.00	$559.30	$314.61	$5,348.31
25	SP9200	Surface Pro Laptop	5	$999.00	$4,995.00	$499.50	$280.97	$4,776.47

Enter the formulas to calculate the columns and rows.

H4 down to H5:E500

Now that you have all the spreadsheet formulas in place, all you have to do is enter the quantity (column C) for each computer sold (daily, weekly, or monthly). If the prices change, enter the new prices in column D. The rest of this database is all formulas or static information.

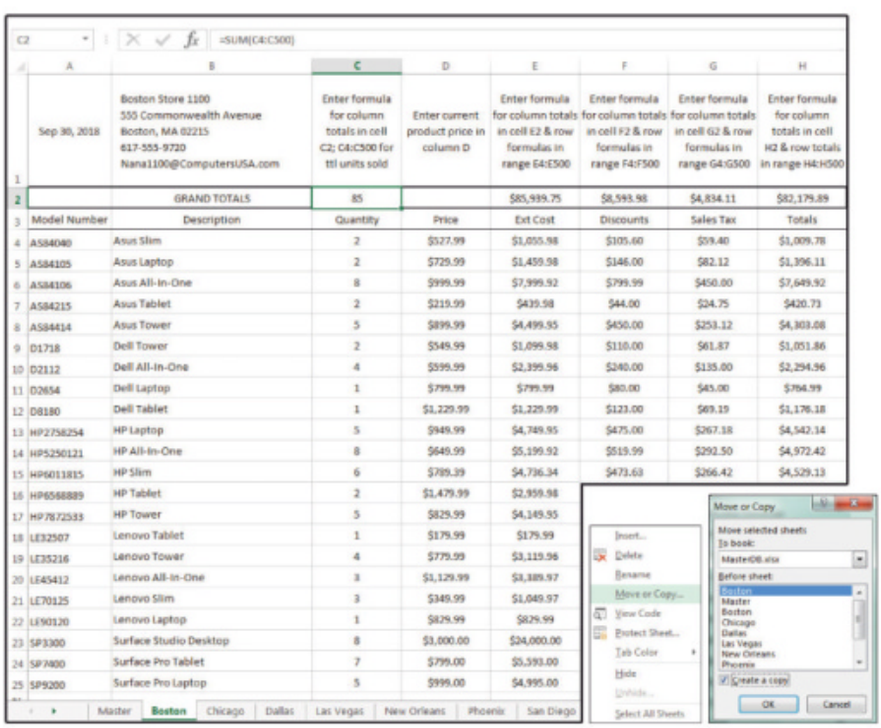
9. As seen above, with "macro" spreadsheets, you set the formula range to be many rows beyond the last record, so you can just add new records at the end and not worry about adjusting the range. Because the macro sorts the database, the new records are relocated to the proper position. The spreadsheet data in our example ends on row 210. The formula range extends out to row 500, so it's safe to add the next new record on row 211.

10. Once the spreadsheet is defined and set up with the structure, static data in place, and correct formulas, make 12 copies in worksheets 2 through 13. Edit the tabs on the bottom to identify the individual stores. Change the name of the sheet1 tab to Master, because this is your master database file.

11. Change the location data on row 1 to identify the store information (that matches the store on the tab) on all 12 spreadsheets. Next, email an electronic copy of each branches' spreadsheet to each of the store managers; for example, send the Boston sheet to Boston, the Dallas sheet to Dallas, etc.

Their copies include the spreadsheet formulas that work on their individual spreadsheets (but not the formulas of the combined spreadsheets in the workbook).

12. The macro provides the formulas for the Master. The Master is the spreadsheet for the combined totals of all stores. If you are the one who collates all the data and executes the Master macros *and* you also manage an individual store, you must use one of the 12 sheets you copied for your store. The Master is for the grand totals only.



Copy the Master spreadsheet 12 times, then name the tabs.

13. Once the branches email their individual spreadsheets, it's safer to just copy the individual sheets from the 12 stores' workbooks manually.

PROGRAMMING MACROS

Macro1: Collect and combine data

1. Access your database folder and open your spreadsheet titled MasterDB.xlsx

2. Open one of the new store spreadsheets, such as the one titled BostonDB.xlsx

3. Move your cursor back to the MasterDB so it's the active sheet.

4. Select the Developer tab and click Record Macro or press ALT+L+R. The Macro Name field says Macro1, and that's a good name.

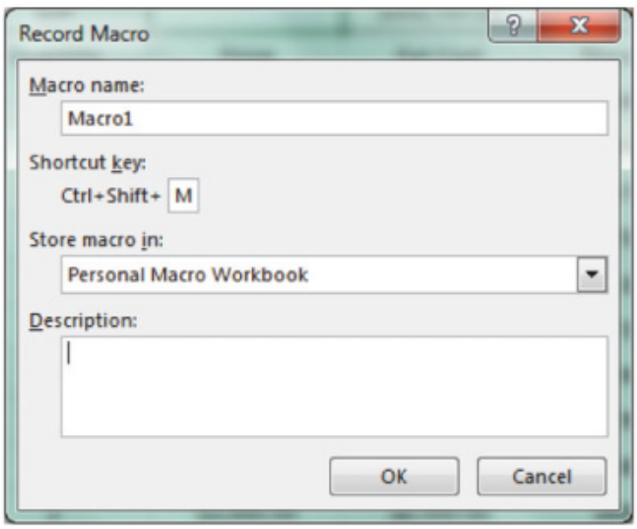
5. Enter a shortcut key (if you like) in the Shortcut key field box (enter the letter M; you can create a button on the Ribbon menu later).

6. In the Store Macro In field box, click the down arrow and select Personal Macro Workbook from the list, then click OK.

Now you are recording the macro.

Follow the instructions below, exactly, and use your mouse to navigate around the spreadsheet. Please note that phrases inside square brackets are tips, notes, and explanations of the instructions. Do not include these phrases or anything they say in your macro.

1. Move back to the BostonDB



Record macro dialog box.

spreadsheet, then right-click the Boston tab. In the pop-up menu, select Move Or Copy.

2. In the Move Or Copy dialog, check the box that says Copy.

3. In the Move Selected Sheets dialog, click the down arrow beside the To Books field box.

4. Select "MasterDB.xlsx" from the list.

5. In the second dialog: Before the Sheet, select the first spreadsheet on the list called "Master," then click OK.

6. Excel copies the sheet and relocates your cursor to the MasterDB. Notice the new tab that says "Boston2." Verify that the info in cell A1 shows the store number followed by a recent date (9/29/18 in this example). If yes, you're good to go.

7. Right-click the tab of the original Boston spreadsheet and select Delete from the pop-up menu.

8. Excel warns in a dialog box that you can't undo deleting sheets. If you're certain you want to remove it, click Delete. Why? Because you want to replace it with the *new* Boston sheet that the Boston manager sent to you.

9. Move the Boston2 tab between the Master and Chicago tabs. If you keep the "2" from Boston2, it will be easier to quickly recognize which sheets have been updated each month.

10. Click Ctrl+Home to relocate the cursor to cell A1 and re-enter this date formula: **=TODAY()** (if this formula is missing), then press the Enter key.

Execute the Macro

1. Select the Developer tab again and click Stop Recording or press ALT+T+M+R.

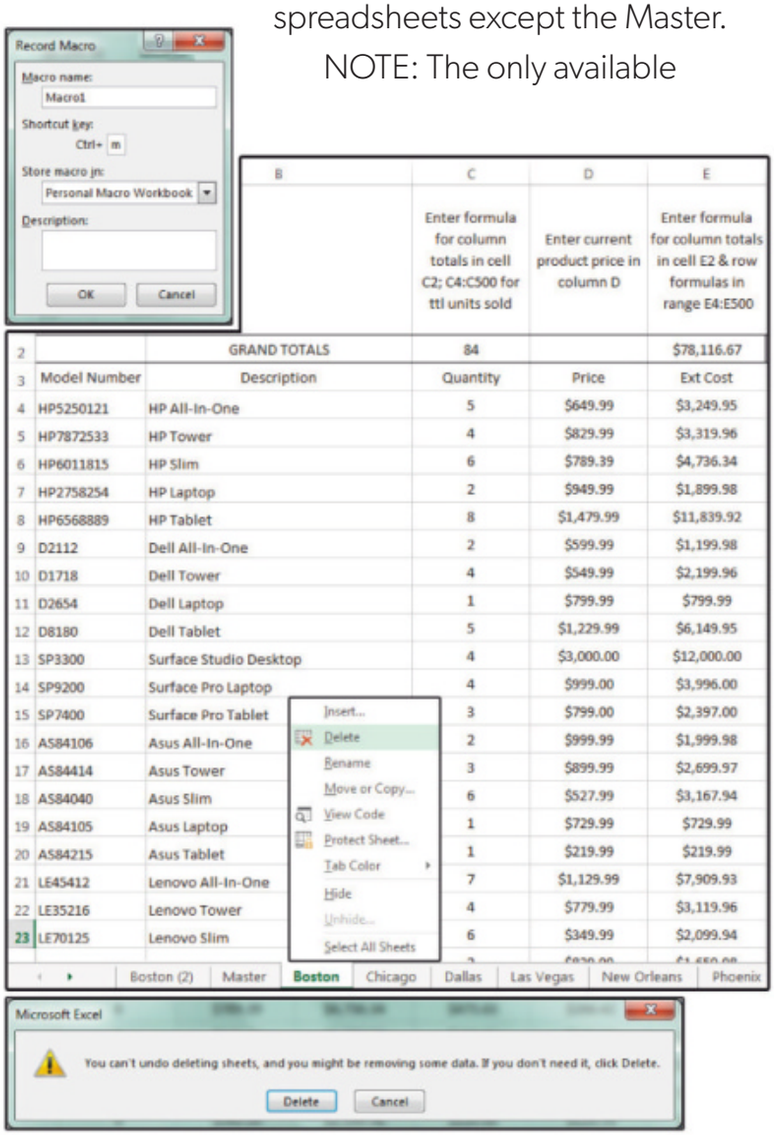
2. Save the Master file, then save the BostonDB file.

3. Go back to the MasterDB spreadsheet and run the macro: Press Ctrl+M.

NOTE: Remember that the plus sign (+) means a "simultaneous" combination keystroke; that is, Ctrl+Shift-J means: Press and hold down the Ctrl and Shift keys with your left hand, then press the J key with your right hand, then release all three keys simultaneously. The dash (or hyphen) means a "consecutive" combination keystroke, such as End-Down, which means press the End key and release, then press the Down arrow and release. These are *not* interchangeable, so watch the signs.

4. If the macro works as expected, repeat this process again for each of the remaining 11 spreadsheets, then run the macros, save the files, and exit all spreadsheets except the Master.

NOTE: The only available



Record the macro, combine the data, delete duplicate sheets

shortcut keys are Ctrl+M (which you have already used), Ctrl+Shift-M, Ctrl+J, and Ctrl+Shift-J. Because shortcut keys are in short supply and the character combinations don't make any logical sense anyway, the best solution for your mini-macros are macro buttons on the Ribbon menu with names that make sense, such as Boston for the Boston macro and Dallas for the Dallas macro. Check out this other Excel macros how-to, where there's a section with detailed instructions on how to create, name, and use macros (go.pcworld.com/num).

Macro2: Organize and sort data

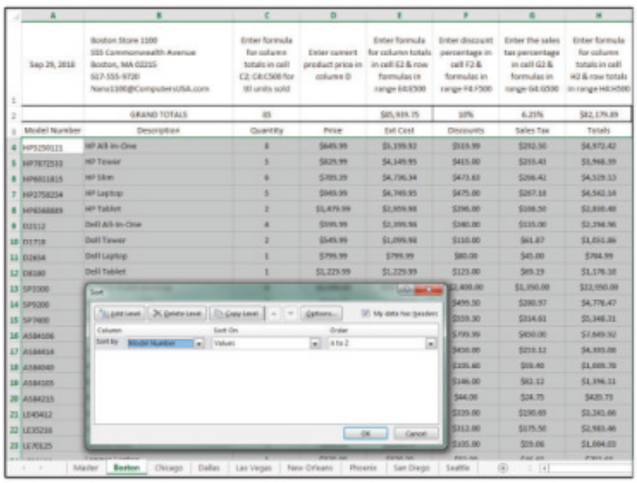
This one is easy, but with so many spreadsheets, it can be a daunting task if you do it manually. Excel actually provides a way to modify all your spreadsheets at once, but this task is unreliable when sorting.

Follow the Record Macro instructions (4, 5, 6 under Macro1 above) to create this next macro. Name the macro Macro2 and use Ctrl+Shift-M for the shortcut (you can create a button on the Ribbon menu later). This macro affects all the spreadsheets in the MasterDB, so ensure this file is open and active.

1. Press Ctrl+Home [to move cursor to A1].

2. Press the Down arrow key three times.

3. Press Shift-End-Down-End-Right [Hold down the Shift key, press the End key and release, press the Down Arrow and release, press the End key and release, press the Right arrow and release all].



Macro sorts the spreadsheet by Model Number.

4. Select Data > Sort. In the Sort dialog, choose Model Number from the drop-down list in the Sort By field box, then choose Values from the Sort On field box, and then choose A-Z from the Sort Order field box, and click OK.

5. Press Ctrl+Home.

6. Click the next tab at the bottom to access the next spreadsheet (i.e., Chicago after Boston), and repeat all steps above: 1–6, and then continue with the following instructions below. Remember, the macro is recording through all these steps.

7. Click the Master spreadsheet tab, press Ctrl+Home.

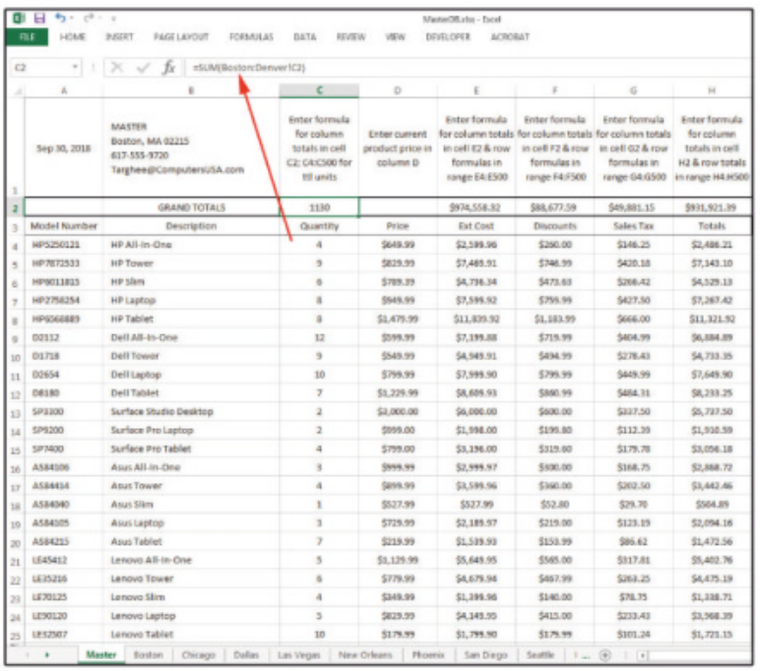
8. Select the Developer tab (from Ribbon menu) and click Stop Recording or press ALT+T+M+R.

9. Save the Master file, MasterDB.

10. With cursor still in MasterDB spreadsheet, run the macro: Press Ctrl+Shift-M.

Macro3: Enter formulas

The formulas for the individual stores' spreadsheets are already in place. You entered those back in step 9 of the Prep Work section above. These formulas are for the Master spreadsheet, which calculates all the others and combines the grand totals into one "master" sheet. We use a macro for this process rather than doing it manually 12 times.



Enter+ calculate formulas in Master for multiple sheets.

Follow the Record Macro instructions (4, 5, 6 under Macro1 above) to create this next macro. Name the macro Macro3 and use Ctrl+J for the shortcut (you can create a button on the Ribbon menu later). This macro affects all the spreadsheets in the MasterDB, so ensure this file is open and active.

1. Press Ctrl+Home [to move cursor to A1].

2. Press Down-Right-Right

3. **`=SUM(Boston:Denver!C2) Enter`**

(Enter this formula in cell C2, where the tabs named Boston and Denver represent the first and last spreadsheet tab names in your workbook. This is excluding the Master, of course, because you are calculating all the values in cell C2 from the first tab Boston through the last tab Denver and entering the totals in cell C2 of the Master. Then the Enter key is pressed.)

4. Up-arrow, Ctrl+C (Moves cursor back up to cell C2 and copies this formula.)

5. Right-Right-Shift-Right-Right-Right Enter (moves cursor to the right twice and stops on cell E2, press the Shift key and hold down while moving to the right three times, which highlights cells E2 thru H2, then press the Enter key).

6. (While these cells are still highlighted, press) Shift-Ctrl+4

7. ALT+T+M+R (Press these keys simultaneously or select the Developer tab and click Stop Recording.]

Save, copy, and distribute

1. Ctrl+Home

2. Save the Master file, MasterDB.

3. Send copies of the MasterDB to all store managers.


Smokey Says...
DON'T KEEP IT
LIT,
EXTINGUISH
IT
SMOKEY
FOLLOW THE RULE, STAY
ONLY YOU CAN
SMOKEY
PREVENT WILDFIRES
UNTIL ASHES ARE COOL
SMOKEYBEAR.COM
Ad Council